LCAMP
Learner Centric Advanced Manufacturing Platform

IDENTIFICATION OF INDUSTRY 4.0-SPECIFIC QUALIFICATIONS AND JOB PROFILES IN DIFFERENT INDUSTRY SECTORS

Authors: Lea Schmitt, Jan Stenzel (DHBW)

Contributors: Iñigo Ariztegui, Unai Ziarsolo (TKNIKA), Chiara Bonelli (MADE), Richard Gale (Camosun College), Liher Errasti Gonzalez, Irati Zabaleta Miguel Altuna), Alicia Leonor Sauli Miklavčič, Natalija Klepej Gržanič (Skupnost VSS), Audrey Lebras (CMQE), GEBKIM VET

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LCAMP partners:
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Glossary and acronyms

Acronyms

AI - Artificial Intelligence

Cedefop - European Centre for the Development of Vocational Training

CoVE - Centres of Vocational Excellence

EAfA European Alliance for Apprenticeships

EC European Commission

ECVET European Credit System for Vocational Education and Training

EntreComp The Entrepreneurship Competence Framework

EQAVET European Quality Assurance in Vocational Education and Training

EQF European Qualifications Framework

ESCO European Skills, Competences and Occupations

ETF European Training Foundation

EU European Union

HE Higher Education

HVET Higher Vocational Education and Training

I4.0 Industry 4.0

KET Key Enabling Technology

OECD Organisation for Economic Cooperation and Development

SWOT Strengths, Weaknesses, Opportunities, Threats

TVET Technical and Vocational Education and Training

VET Vocational Education and Training

WBL Work Based Learning

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1. EXECUTIVE SUMMARY

By providing, a sector-specific overview of I4.0 qualifications at EQF 3-6 correlated to the I4.0 technology and skills framework in different industry sectors, LCAMP's D5.1 report at hand aims to identify future-proof vocational Advanced Manufacturing qualifications available among the LCAMP consortium and their regional industry associations and clusters.

This report is not limited to listing relevant I4.0 VET qualifications within our consortium. It provides the reader with detailed insights into how exactly these future-proof I4.0 qualifications in both VET and higher VET are designed, described, accredited and undergoing change both within and outside Europe. Relevant Advanced Manufacturing qualifications and occupations from Spain, France, Germany, Italy, Slovenia, Turkey and Canada are presented below. The data shows how ongoing transformational processes in Advanced Manufactuirng are already being addressed at national level and how disruptive changes have already been captured through national and regional qualification and retraining approaches.

After introducing the targets, main activities and special objectives (SO) of the Human-Centric Training approach for LCAMP in Work Package 5 (WP5) and how we are planning to meet our ambitious goals, chapter 2 outlines the state of play working with the ESCO database. In this section we present our preliminary findings what we've learnt about the specifics of the ESCO classification and how we best could tackle some major and minor challenges coming along with a straightforward linkage and harmonization between ESCO and our growing database of international up- and reskilling offers.

The table below gives an overview of D5.1's main findings presented in chapter 3. The reader will find vocational Advanced Manufacturing qualifications gathered and sorted by country. Each section further provides the necessary definitions and a short introductory description of the learning provider contributing to D5.1's desk-research. The table below summarizes the number, EQF-Level and the international distribution of vocational qualifications for Advanced Manufacturing included in this report. The sampler lists relevant qualifications offered by LCAMP's partners and organizations or their national associations and networks.

COUNTRIES	NUMBER OF FUTURE-PROOF QUALIFICATIONS INCLUDED IN THE REPORT			Number of Upskilling courses included in the report
	EQF 4	EQF 5	EQF 6-8	
France		2		
Germany		4	13	
Italy				2 (EQF 4)
Slovenia	5	10		2 (EQF 5)
Spain		7		8 (EQF 5)
Türkiye		2		2
Canada		2		2
TOTAL	**5**	**27**	**13**	**16**

Finally, in our conclusion of this report, we are giving an outlook on how we will use the data at hand to develop our future learning pathways in LCAMP according to both national and international education requirements.

1. INTRODUCTION

1.1. Overview of the Human Centric Learning for Advanced Manufacturing

This section outlines the specific objectives and tasks undertaken in Work Package 5 (WP5) of the LCAMP project. WP5, titled "Human-Centric Learning for Advanced Manufacturing", aims to meet the needs of LCAMP by identifying future learning pathways, developing a learning model and competency approach for learners and workers in Advanced Manufacturing, and creating micro-credentials for platform users covering the educational scope according to the EQF-Levels 3-6.

WP5 focuses on providing personalized re- and upskilling opportunities to LCAMP platform users based on their educational and training backgrounds. It seeks to identify future-proof occupations and essential competencies, as well as develop industry-aligned micro-credentials. By equipping users with the necessary skills and knowledge, WP5 ensures their success in the rapidly evolving landscape of Advanced Manufacturing.

The human-centric training approach in WP5 plays a crucial role in the LCAMP project by creating innovative learning environments for Advanced Manufacturing and linking it to a hybrid transnational hands-on training solution provided by our innovative Collaborative Learning Factories accessible via the platform (CLF, WP6). By identifying future-proof occupational profiles, developing a tailored LCAMP learning model for Advanced Manufacturing, and developing a learning pathway tool, our work ensures that users of the LCAMP platform are equipped with the necessary skills to succeed in the rapidly evolving industry. Through the outputs and deliverables of WP5, workers and lifelong learners in VET can access personalized learning opportunities to stay ahead of industry demands, fostering a culture of continuous learning and professional growth in the manufacturing sector.

The human-centric learning and training approach in LCAMP is designated to cater to the needs of end users, particularly learners like students and employees but also teachers and trainers in VET. These individuals will have the ability to easily search for personalized re- and upskilling opportunities within the platform. An individual user-centric search function will allow users to find specific services and educational offers that match best their educational prerequisites,

including the necessary courses, micro-credentials, and institutions for up- and reskilling opportunities. By providing a comprehensive Skills Profiler, LCAMP ensures that learners can quickly identify and access the learning opportunities that best suit their individual career pathways to equip them with new future-proof skills and competencies to adapt and thrive in a fast-evolving working environment like Advanced Manufacturing.

1.2. Overview on the specific objectives in WP5, Human-Centric Learning for Advanced Manufacturing

- Identification of Industry 4.0 (I4.0)-specific qualifications and job profiles in different industry sectors. I4.0 related qualifications (EQF3-6) with description according and aligned to the EQF framework and skills database.
- Develop skills assessment toolkit.
- Provide sector-specific datasets of trainings, courses and Micro-Credentials for different career pathways.
- Establish a clearing house for Micro Credentials and training based on Micro-Credential EU-Standards.
- Develop and provide micro-credentials for new and existing I4.0 specific qualifications in Advanced Manufacturing.

2. ESCO IN LCAMP

The European Multilingual Classification of Skills, Competences and Occupations, also known as ESCO, describes, identifies and classifies relevant skills and competences as well as occupations in the EU labour market. The platform therefore comprises three main pillars, on the one hand an Occupational Pillar with a total of 3,008 occupation descriptions, as well as a pillar with descriptions of 13,890 skills and competences linked to the occupations and a pillar on qualifications, with information from the respective awarding countries. The service of descriptions of occupations and related skills, competences and qualifications on ESCO is intended to support the labour market mobility of employees by providing relevant information for employees in and from Europe (vgl., European Commission 2020).

Due to the links between the qualifications and skills & competencies with the respective occupational profiles, the ESCO service platform could be beneficial and starting point for the

LCAMP platform. On ESCO, the information relevant to the European labor market is presented in an understandable way across the board at European level (vgl., European Commission 2020). The descriptions of the national qualifications are currently presented on the other Europass website. Here, European qualifications of European education providers are described with the relevant information in a mask that shows both the national and European level of education and description of the learning outcomes. ESCO obtains the information required for this from national data sets. The occupational profiles on ESCO list both essential and optional skills, competencies, and knowledge that is required in the respective occupational field. There is no distinction made between skills and competences, only knowledge is listed separately. The optional skills, competencies and knowledge usually include sector- and industry-specific characteristics and related relevant skills. When comparing the occupational profile of a mechanical engineer with the curriculum of the DHBW Heidenheim, it is noticeable that the curricula of the university currently show the learning outcomes associated with the technical, methodological, social and personal competences (vgl., DHBW Heidenheim 2020a, S. 20). A direct comparison with the occupational profiles is therefore difficult, as they do not distinguish between competence and related skills. The occupational profile of the mechanical engineer in ESCO includes skills and competencies that are often very specific (vgl., European Commission 2018). Thus, the occupational profile regarding engineering and technical design skills includes: *adjust engineering design*, *approve engineering designs*, *design a solar absorption cooling system* as well as *heating system*, *designing of heating and cooling emission systems*, *usage of technical drawing software* and *knowledge about technical drawing* (vgl., DHBW Heidenheim 2020a, 20 ff.). These skills would be included in the curriculum of the DHBW Heidenheim in the field of mechanical engineering and listed under the competencies *create and interpret technical designs*, *knowledge of technical drawings* as well as further the competence to be *able to solve problems on the basis of technical drawings*. The competencies of each occupational profile listed in the essential skills and competences can be fully mapped with the competencies specified in the four categories of the curriculum, with the latter summarizing the specific skills from ESCO in larger competencies. In addition, some optional skills such as handling CAD/CAE software, teamwork and communication skills, and simulation of mechanic design concepts can be found in the learning outcomes of the mechanical engineer of the DHBW Heidenheim. The skills and competencies specified in ESCO also differ in terminology from those in the curriculum. Furthermore, compared to the curriculum, many competencies are not listed in the occupational profile, such as structural, systematic & methodological mode of operations, problem-solving or conflict management. However, competency terminologies vary in curricula, which is why it would be helpful to have a uniform

indication of competencies in ESCO, as at the European level. A link to ESCO within the qualifications and courses on the LCAMP platform would also be beneficial in terms of transparency and support for employment and learning mobility. Accordingly, the further procedure of this work package includes describing learning outcomes of future-proof qualifications as well as courses that are to be presented on the platform with both competencies and skills and establishing a link between the information in the descriptions in ESCO on occupational profiles, skills and competences. In addition, additional competency terms, which are currently not found in ESCO in individual occupational profiles, can be supplemented and reported back to ESCO.

3. FUTURE PROOF QUALIFICATIONS FOR ADVANCED MANUFACTURING WORKING ENVIRONMENT

3.1. What is considered a Qualification – the EU definition

Our focus in LCAMP's Human-centric Training is on accurate alignment with educational concepts and terminologies across Europe. Therefore, the terminology used in this report is in line with the recommendations of the European Council of May 22, 2017. In the context of this report, which aims to provide an overview of the EQF (3-6) aligned Advanced Manufacturing qualifications within the LCAMP consortium, the term "qualification" is defined as follows:

"the formal outcome of an assessment and validation process by a competent authority and typically take the form of documents such as certificates or diplomas. They determine that an individual has achieved learning outcomes to given standards. […] Information on learning outcomes should be easily accessible and transparent. They signal to employers what their holders in principle know and are able to do ('learning outcomes'). They may be a prerequisite for accessing certain regulated professions. They help education and training authorities and providers to determine the level and content of learning acquired by an individual. They are also important for an individual as an expression of personal achievement. Therefore, qualifications play an important role in raising employability, easing mobility and access to further education."

(cf., European Commission) (See: C189/15)

3.2. “Future-proof” Advanced Manufacturing Qualifications in LCAMP

In Europe, the trend towards increased demand for highly skilled workers is translating into a greater need for advanced and continuing training. Demand for higher formal qualifications is expected to increase, stimulated by industrial change and the associated changes in employment. In addition, the average qualification level for new job roles is likely to rise due to an influx of overqualified applicants for jobs that do not require advanced qualifications, a phenomenon known as "qualifications inflation" (cf., Brugia, 2018, p. 41).

Important sectoral and professional developments are having a direct impact on the qualifications of current and potential workers. Ubiquitous megatrends, including digitization and ecological transition, are perpetually transforming the landscape of "new" skills, competencies, professional profiles, and corresponding qualifications. Technological change is having a major impact on job opportunities in all sectors.

As a result, it is essential that current employees adopt an open attitude to retraining and skills enhancement. Learners and workers need to obtain additional qualifications to take up new occupations and adapt to changing tasks and requirements. A Cedefop study suggests a growing demand for qualifications corresponding to EQF levels 3 to 8, implying professionals, technicians and intermediate occupations (cf., p.Mara Brugia 2018, S. 60)

Consequently, by 2030, the EU is expected to see an increase of 26 million highly qualified employees. At the same time, demand for lower qualifications is set to decline, while intermediate qualifications will see a moderate increase (cf., Mara Brugia 2018, S. 43)

Megatrends, particularly in the Advanced Manufacturing and the automotive sector, are driving significant structural impacts and changes. For example, the automotive industry is moving towards the production of environmentally-friendly vehicles (cf., Brugia, 2018, p. 35). As a further result, there will be an *increased demand for professionals specializing in materials science, computer analysis, chemical, electrical, industrial, materials, and mechanical engineering.* This increased demand is likely to lead to job growth in areas essential to Advanced Manufacturing, requiring employees to acquire advanced qualifications in programs such as mechatronics, mechanical engineering, computer science, and industrial engineering.

In mechanical engineering programs, students receive a comprehensive engineering education, including a solid theoretical foundation in areas such as engineering mathematics, technical mechanics, and strength of materials, design, production engineering, thermodynamics, electrical engineering, physics, materials, computer science, CAD/CAM laboratory training and business management. Learners acquire communication and presentation skills through complementary courses. The programme , which leads to an engineering degree (B.Eng.), extends over six semesters. From the third semester onwards, students can choose from a variety of specialized study programs.

In mechanical engineering, students receive a solid basic engineering education. During the basic studies, solid theoretical foundations are taught in the areas of engineering mathematics, technical mechanics, strength of materials, design, production engineering, thermodynamics, electrical engineering, physics, materials, computer science, training in the CAD/CAM laboratory and business management content. In addition, communication and presentation skills are predominantly promoted through additional courses. The mechanical engineering programme lasts six semesters and concludes with a Bachelor of Engineering (B. Eng.). From the 3rd semester onwards, students choose one of the in-depth study programme specializations:

- Design & Development
- Mechatronics
- Production Engineering
- Virtual engineering

Given the changes in the field of Advanced Manufacturing and the ongoing shifts in industry trends as outlined above***, a future-proof qualification in Advanced Manufacturing*** would imply an in-depth education in fields that are at the forefront of technological, digital, and green transitions. In concrete terms, a generic future-proof qualification in Advanced Manufacturing could be outlined as follows:

A future-proof qualification in Advanced Manufacturing is referring to skills that not only encompass a deep understanding of traditional manufacturing processes, but also integrate knowledge in areas such as mechatronics, material science, computer science, and industrial engineering. This includes mastery of current and emerging technologies, such as digitization, automation, artificial intelligence, additive manufacturing, and green technologies. It further incorporates 'soft skills' like adaptability, problem-solving, communication, and a lifelong learning mentality, to enable the individual to evolve alongside the industry. Moreover, this qualification embodies a commitment to ongoing education in response to the continuous industry

developments, facilitating resilience and relevance in the face of future transformations in the field.

Such a generic, broad, and responsive concept of a continually evolving Advanced Manufacturing qualification ensures the human ability to contribute significantly to industry advancements while remaining adaptable to future technological shifts and the associated changes in skills and occupational profiles.

3.3. Advanced Manufacturing Qualifications in European VET

Against this background of both economic and social transformations and their potential impact on the labor market, the following overview of I4.0 Qualifications, provided by our consortiums's (H-)VET schools, aims to provide a forward-looking benchmark comprising international VET qualifications (EQF3-5) within the relevant fields of interest. Throughout the project and beyond, we will continuously enlarge and assess the soundness of this foundation, seeking evidence and comparing it with ongoing developments in the economy and the diverse landscape of European, Canadian and Turkish education systems.

3.3.1 Vocational Advanced Manufacturing Qualifications in France

Regarding Advanced Manufacturing the most common vocational degrees are the certificate of vocational aptitude (CAP; EQF 3) which lasts 2 years, the professional baccalaureate (EQF 4) which lasts 3 years, the advanced technician certificate (BTS) (EQF 5) which lasts 2 years and grants 120 ECTS, and the professional degrees (EQF 6) which lasts 3 years and grants 180 ECTS. To better understand the Italian VET system reader should refer to the CEDEFOP's publication "Vocational education and training in Europe, Detailed description of VET systems in Europe: France" (CEDEFOP, 2021).

The following are the qualifications by CMQE's Network listed as examples of "future proof qualifications for advanced manufacturing (EQF4).

CMQE If brings together networks of secondary and higher education establishments, initial training centres (schools and apprenticeships), and continuing vocational training centres from the Lot and Aveyron (France) working in the field of activity linked to Industry 4.0. The mission of the Campus is to provide solutions to the recruitment issues faced by the mechanical industries in the area, in terms of human resources and skills.

CMQE If's VET network is currently made up of 17 centers among which there are 8 high schools, 2 apprentice training centers (CFA), 2 Chambers of Commerce and Industry (CCI), a GRETA-CFA (an association of local public educational institutions that gather their skills and resources to offer a range of training courses for adults), 2 University Institutes of Technology (IUT), and 2 other centers for tertiary education (IN&MA and INU). These centers cater to various types of students (high school students, adults, and employees) and offer various vocational degrees as follows.

1) **Maintenance of connected production systems** training programme is a professional baccalaureate (EQF 4) aimed at training students to do maintenance work on multi-technology systems in areas such as hydraulics, electronics, mechanics, etc. This 3-year programme includes 22 weeks of training in a professional setting. Through this training, students learn to manufacture welded parts, repair mechanical subassemblies, perform preventive maintenance operations, wire electrical, and pneumatic and hydraulic circuits. Once this training is completed, students can enrol in a BTS dedicated for instance to system maintenance, electrical engineering, industrial product design, or public works machinery maintenance. This training leads to jobs in manufacturing or product transformation companies in sectors such as the agri-food business, metallurgy, aeronautics, etc. (cf., ENT Lycée Alexis Monteil 2012)

2) **Mechanical engineering technician-training programme** is a professional baccalaureate (EQF 4) aimed at training students in manufacturing for 3 years. This training is offered throughout France one of these two specializations: tooling design and maintenance or production and manufacturing monitoring. The second specialization is the one taught at the Champollion high school in Figeac.
   The curriculum includes 22 weeks of internships in manufacturing companies. It also offers the possibility for students to do their training through an apprenticeship in a partner company. The learning approach of this training programme focuses on system and manufacturing study, 3D designing and printing, virtual machining through CAD, and CNC machining. This training can be followed by a BTS in process design for product manufacturing or in industrial product design. The mechanical engineering technician training programme leads to jobs such as CNC machine tool set-up operator in areas such as the automotive, spatial, and military sectors. (cf., Padlet; cf., Padlet)

3.3.2 Vocational and Higher Vocational Qualifications in Germany

A vocational education and training qualification refers to the acquisition of the knowledge, skills and competences required to practice a particular occupation or professional activity. These qualifications are usually acquired through formal education programmes, continuing education courses or degrees.

The Chamber of Industry and Commerce (CIC/IHK) is a German institution responsible for promoting and regulating vocational training. It plays an important role in defining qualifications in different occupational fields and setting the requirements for obtaining these qualifications. The CIC defines qualifications in close co-operation with relevant sectors and employers. It develops training regulations that define the content and requirements for different training professions, which serve as the basis for the implementation of training and examinations in the respective professions. In addition, CIC (IHK) also offers further training programmes to enable already qualified professionals to develop their knowledge and skills and obtain higher qualifications (up- and reskilling). The exact definitions and requirements for individual qualifications can be found in the relevant CIC/IHK training and examination regulations. . To better understand the German VET system reader should refer to the CEDEFOP's publication "Vocational education and training in Europe, Detailed description of VET systems in Europe: Germany" (CEDEFOP, 2021)

In the following paragraphs the reader finds future proof qualifications and upskilling programs offered by DHBW (EQF 6-7) listed as examples of "future proof qualifications for advanced manufacturing".

DHBW is a Cooperative State University, a higher education institution. Throughout its nine locations and three campuses, the university offers a broad range of undergraduate study programmes (EQF 5-7) in the field of Business, Engineering, and Social Work. With around 34,000 enrolled students, over 9,000 partner companies and more than 125,000 graduates, the DHBW counts as one of the largest HE institutions in the German Federal State of Baden-Wuerttemberg. DHBW has a vast amount of knowledge and experience in dual studies, and higher education policy and management more generally. Given that DHBW is a University, the levels of the Advanced Manufacturing qualifications provided hereafter are all Bachelor Degrees.

1) **General Mechanical engineering** focuses on competences referring to drive technology, quality management, control engineering, fluid mechanics, electronics and

microcomputer technology, simulation technology, as well as mechatronic systems. Moreover, the study programme implies electives such as measurement technology, sensors and actuators, business administration courses or robotics and automotive technology (vgl., DHBW Heidenheim 2023a).

2) **Mechanical Engineering Design and Development** study programme offers drive and control technology and quality management as part of the basic degree programme , as well as product development, design and development technology, simulation technology, machine dynamics and vibration theory, mechanical drive technology. The study programme with focus on design and development also includes three electives for students. Within the study programme , students can choose between elective one implying measurement technology, sensors and actuators, piston machines, transmission technology, fluid machinery and aircraft propulsion systems, elective two including material science, plant engineering, industry 4.0 and business law, patent law, cost accounting and controlling, and elective 3 – robotics, fibre composite structures and automotive engineering (vgl., DHBW Heidenheim 2023a).

3) The study programme **Mechanical Engineering - Production Engineering** presents a great consistency with the specialization design and development. In contrast to design and development, this study programme specialization shows a focus on production concerning technologies, planning, cost accounting as well as marketing and communication (vgl., DHBW Heidenheim 2020b).

4) **Mechanical Engineering** - **Virtual Engineering** The increasing implementation of new technologies, especially regarding simulation, this programme leads to changes and new opportunities for specialization of mechanical engineering and occupations in this field. presents a recent addition to the study field of mechanical engineering. This focuses on competences in the use of modern simulation and visualization methods to create the strength of components, the calculation of flows or the design of entire factory plants (vgl., DHBW Heidenheim 2023b).

5) **Integrated Engineering** is a new degree programme at theDHBW. Due to the increasing influence of Industry 4.0 on technical and organizational processes and globalization, companies need interdisciplinary qualified project engineers who organise and manage technical projects. The **Integrated Engineering - Project Engineering**

field of study in the Integrated Engineering degree programme has a strong interdisciplinary orientation. The fundamentals are formed by content from mechanical engineering, electrical engineering, automation, digitalization and business studies on the one hand, but also project and conflict management, negotiation skills, law, business games and an introduction to modern media technology on the other hand. Furthermore, company problem-based projects are important for developing and increasing the employability of graduates. An example of this is the business management game in which a study course is transformed into a complete company with different hierarchical levels and responsibilities: Project management, a technical team, marketing, controlling - all roles are represented. They learn how to organize themselves and others, to recognize the strengths of their different characters and personalities among the team as well as how to use their individual strength efficiently and how to bring a task to its goal with a good combination of professional knowledge, social skills and leadership. During the six semesters of the Bachelor's programme with a final 210 ECTS credits, international competences are also promoted through visits abroad (cf., DHBW Mannheim).

6) The **Service Engineering** study programme in Integrated Engineering focuses on service and maintenance. The increasing implementation of new technical systems in production processes requires reliable functioning, as these form the basis of production cycles in companies. The curriculum of the degree programme is based on sound technical knowledge of the systems and machines to be serviced. This includes the classic engineering subjects such as mechanical engineering, electrical engineering, information technology, mechatronics and electronics. - Due to the growing relevance of safety and reliability with increasing technology integration, students receive skills such as reliability engineering, functional safety and IT security. - In addition, maintenance and service engineers are expected to have comprehensive knowledge of business administration. The curriculum also includes business administration, law, marketing, sales and project management. Like Integrated Engineering – Project Engineering, this study programme also designed for sic semesters and 210 ECTS-Points (vgl., DHBW Mannheim 2023b).

7) **General Computer Science**. The programme focuses on the development of secure software. The programme teaches core computer science modules, the general basics of computer science and the state of the art in software development. A special feature

of general computer science is the varied didactic format. As far as possible, modern forms of teaching such as flipped classroom, e-learning and, above all, a continuous project are used in addition to classical lectures to promote the individual strengths and needs of the learners as much as possible and to develop the ability to work in small teams in a results-oriented manner. Students of general computer science receive in-depth competences in dealing with technologies such as the Internet of Things, client-server systems, distributed systems and cloud computing, mobile applications, artificial intelligence, big data and data protection. The aim of the programme is that at the end of the study programme, after six semesters and 210 ECTS credits, a holistic picture of the development of secure software emerges (cf., DHBW Heidenheim 2020a).

8) **Computer Science - Information Technology** focuses on the interaction of software and hardware and focuses on skills in handling data from technical processes. The broad spectrum of content of the Computer Science degree programme enables students to master all standard tasks in software development and information technology. In addition to the pure computer science subjects (fundamentals of computer science, programming, software engineering, computer construction, operating systems, digital technology, databases and networks), other subjects are added, such as physics, electrical engineering, microprocessor technology. In the final year of the six-semester programme, students can choose between two specializations: Industrial Automation or Information Management and Systems. The focus on industrial automation deals with the digitalization of manufacturing technology up to the smart factory, where many different types of networking, computer types and programming types meet technical/organisational challenges. The subjects offered accordingly include electrotechnical and engineering orientation. The focus on information management and systems deals with the management and acquisition of large amounts of data (Big Data) and how data is explored, analysed (data mining), managed and presented (data science) or what infrastructure and organization is necessary for this (cf.DHBW Heidenheim 2020a).
9) The **General Industrial Engineering** degree programme teaches both engineering and business fundamentals and thus offers a holistic view of decision-making contexts. The aim of the degree programme is to provide students with comprehensive technical, methodical and social competence. General industrial engineering includes mathematics, physics, computer science, business administration topics such as general business administration, finance and accounting, controlling, marketing and sales,

economics, quality management, social skills competences, economics, quality management, project management, law and corporate management. In addition, third-year learners can choose between five specializations. On the one hand, these include innovation and product management, which focuses on the design, implementation and marketing of new technical goods or services. Accordingly, learners in this specialization receive in-depth skills with regard to design/CAD, project management, innovation processes and product life cycles. As part of the specialization in International Technical Management, students complete at least one semester abroad in an international network, thus enabling participants to complete their studies at a partner university with a "double degree". In addition to the economic and technical course content, language skills and impulses for personal development are taught in depth. The specialization Production and Logistics is primarily concerned with internal logistics, production, external logistics and service. Above all, students receive technical skills related to supply chain management, value stream optimization and corporate management. The focus of technical sales is intended to enable students to convey the quality and functionality of products in a customer-oriented manner. With the help of project studies and case studies, students learn to build a relationship with the customer and to design and communicate the properties of technical products in a demand-oriented manner. The last selectable study focus presents Networked Digital Systems - Process Management. In this engineering specialization, the general course content is extended by the subject area "IoT" or "Industry 4.0". Knowledge is imparted for planning, controlling, analysing and optimising the corresponding systems and processes, such as quality management techniques, digitalisation, mechatronics and lean production methods. One focus is on the important topic of data science, with competence transfer in the generation and analysis of data streams in the company (cf., DHBW Heidenheim 2021).

10) Students of the field of study **Industrial Engineering and Management - Chemical and Process Engineering** can choose these specializations in the last year of study, like General Industrial Engineering. This field of study deals with the management of energies, chemicals, lubricants, paints and coatings. The focus of the study hereis on logistics processes, chemical technologies as well as hazard and environmental management. In-depth course content includes, for example, material analysis, energy technology and recycling processes (cf., DHBW Heidenheim 2021).

11) M**echatronics – Vehicle Technology and Electric Mobility** The automation industry faces several developments and changes regarding propulsion technology. These changes and developments have also impact on study programs in the field of mechatronics. Qualifications such as vehicle technology and electric mobility as well as energy management referring to mechatronic study programs have emerged in recent years. Mobility is a state of upheaval, as well as scarcity of resources and environmental compatibility evoke the need of innovative technologies for an environmental compatible future. To adequately prepare students in Mechatronics – Vehicle Technology and Electric Mobility for the future, this study programme implies courses in mechanical and electrical engineering, business administration, information technology and teaching management competences. Alumni of the six-semester study programme are able to assess infrastructural conditions and design mobility. Furthermore, graduates in vehicle technology and electric mobility can develop components, integrate them into sub- and overall systems of electric drives and supply them with energy (cf., DHBW Mannheim 2022).
12) **Mechatronics – Energy Management** The energy transition is becoming increasingly important throughout the world, which is why the mechatronics degree programme Mechatronics – Energy Management is very future-oriented in this area. The aim of the degree programme is for qualified graduates to contribute to innovation and sustainability in the energy industry and to play an active role in shaping it. The study content includes topics in supply and electrical engineering as well as energy management topics and business administration. Students acquire skills in the fundamentals of electrical and mechanical engineering, technical physics and mechanics, IT, programming and communication technologies, water and gas supply and technology, geoinformation systems and surveying, waste disposal, biomass, power plants, energy supply, price adjustment, concession contracts and procedures, network takeover and valuation, technical sales, trading and portfolio management, smart grid, smart meter, organisation, personnel and management, business administration, accounting, bookkeeping, special technical controlling, law, economics and project management (cf., DHBW Mannheim 2020).

13) **Embedded Systems – Automotive Engineering** Embedded systems are increasingly finding their way into everyday private and professional life with smart devices as well as vehicle and aircraft systems. The Embedded Systems – Automotive Engineering degree programme combines computer science with engineering. Students receive the

necessary technical knowledge in the area of system and software engineering, but also the competences in project management and soft skills to develop, produce, test and operate such systems. The Embedded Systems - Automotive Engineering degree programme therefore teaches not only the technical fundamentals of electrical engineering, electronics and computer science, but also extensive teaching content on system and software development, taking into account the legal regulations, approval requirements, norms and industry standards in the automotive sector. In practical teaching projects, students also gain experience in project management (cf., DHBW Ravensburg 2023).

Regarding qualifications in VET that refer to EQF-level 5 and the sector of Advanced Manufacturing, higher technicians present relevant future-proof qualifications. In the field of manufacturing and industry-sector, relevant qualifications imply:

1) **Higher Technicians in Production Programming in Mechanical Manufacturing**
2) **Higher Technicians in Design in Mechanical Manufacturing**
3) **Higher Technicians in Automation & Industrial Robotics**
4) **Higher Technician in Mechanical Production Scheduling**

3.3.3 Vocational Advanced Manufacturing Qualifications in Italy

Vocational qualifications in Italy are typically structured within the National Qualifications Framework (NQF). The NQF classifies qualifications based on learning outcomes and the level of knowledge, skills, and competencies acquired. This framework aims to promote transparency, comparability, and recognition of qualifications across different educational sectors. To better understand the Italian VET system reader should refer to the CEDEFOP's publication "Vocational education and training in Europe, Detailed description of VET systems in Europe: Italy" (CEDEFOP, 2021)

Advanced Manufacturing Qualifications offered by MADE Competence Center Industry 4.0

1) The course **Internet of things: applications, networks and platforms** is a vocational training course (EQF 4) aimed at training students to become familiar with the IoT practice, putting the theory immediately on the ground, deepening a single platform that well represents the iot ecosystem. The target audience of this course is composed of PMI - managers - function managers - automation engineer - R&D.

The structure of the course provides a division into modules: **Module 1: Theory on the IoT World:** Applications and business models enabled by iot technologies - IoT technologies - Hardware platforms - Software platforms **Module 2: practice with IoT Systems:** The Node-RED Platform - Guided development of a complete IoT platform.

The course offers both practical and theoretical knowledge in broad contexts, in a working environment. At the end of the course, students can manage themselves independently, within the framework of instructions in a context of work or study, usually predictable, but subject to change.

2) **Additive manufacturing** is a vocational training course (EQF 4) aimed at training students exploring the potential of 3D printing or additive manufacturing as enabling technology for the twin transition (digital and sustainable). Through an analysis of the current and expected scenarios, it offers an overview of the business opportunities that additive technologies open up in various industrial sectors. On the second part of the course, participants are involved in a training experience that starts from product design to additive manufacturing and final qualification of 3D printed products.

   The main topics herein addressed are:

   Additive technologies for the twin transition: evolutionary scenarios
   Overview of technologies, advantages and disadvantages
   Impact of additive technologies on product value
   Impact of additive technologies on costs and supply chain
   Customization, sustainability, increased product value, on-demand production: case studies and possible scenarios
   Design for Additive Manufacturing - **3D printing**: on-site experience - Non-destructive testing.

3.3.4 Vocational Advanced Manufacturing Qualifications in Slovenia

This section describes a sampler of future proof qualifications related to Advanced Manufacturing offered by VET colleges associated to Skupnost VSŠ (Association of Slovene Higher Vocational Colleges – Association HVC), founded in 2005 by the Slovene government.

The association holds under its umbrella 49 members (100% of HVC institutions) all providing EQF level 5 as private or public providers (Skupnost VSŠ, 2023). They offer their study programmes (35) in 28 locations across Slovenia. Our members provide education and training opportunities on EQF levels 3 – 7 (VET and HE). Our colleges provide various professional programmes in the field of short-cycle higher education (120 ECTS). In addition to the implementation of regular and specialized programmes, they provide various trainings for companies and adult learners. Each of our members has a broad local and regional network of employers, as 40% of curricula represents in-company work-based learning under the supervision of certified in-company mentors. To better understand the Slovenian VET system reader should refer to the CEDEFOP's publication "Vocational education and training in Europe, Detailed description of VET systems in Europe: Slovenia" (CEDEFOP, 2021)

SHORT VET PROGRAMMES (EQF 3; 120 credit points)

Short VET programmes are intended for students who have fulfilled primary school requirements and completed at least 7 grades of a nine-year primary school or have thus completed primary school according to an adapted educational programme. Education lasts two years. In the professional modules, the emphasis is on practical lessons, which are supported by professional theoretical content. At the end of the education, the students pass the final exam. After completing the education, the student is qualified to perform work at the level of a narrow professional profile, while at the same time maintaining the opportunity to continue education at upper secondary vocational education programmes. These programmes entail general education, WBL ranges from 35% to 40% of the programme, with four weeks in-company training (152 hours) and the rest in school workshops or ITCs.

Available short VET programmes in Slovenia are Woodworker, Assistant construction worker, Biotechnology and care assistant, Assistant in technological processes, Auxiliary administrator, and Textile worker. **There is no specific implication to advanced manufacturing in these programmes**. (Ministry of Education, 2021; and CPI, 2020)

VET PROGRAMMES (EQF 4; 120 to 240 credit points)

VET programmes are offered at upper secondary for young (full-time) and adult (part-time) learners. The VET offer in Slovenia is diversified into different programme types and delivery modes (school- based and apprenticeships), leading to different types of qualifications and consequently offering different progression possibilities and obtain qualifications for a specific occupation to enter the labour market. These programmes entail general education, technical modules, over half of this time is dedicated to school based practical lessons; some modules are compulsory, others are optional, employer based practical training with an employer, and open curriculum (20 %) - part of the programme determined by the school in cooperation with companies. (cf., Cedefop, 2021).

1) **Mechatronics Operator** (EQF 4; 180 credit points) The training programme was created at the initiative of industry and crafts due to the need for professionals capable of maintaining machines and devices in modern computer-controlled manufacturing technologies. The profession of mechatronics operator combines knowledge and skills in mechanical engineering, electrical engineering, and information technology. The field of work includes assembly and disassembly of machines, plants and devices, connection of hydraulic and pneumatic lines, electrical wiring and measurements, testing, programming of automated processes (PLC controllers, industrial robotics), start-up of plants and devices, device servicing, maintenance, and service of flexible production processes, as well as all knowledge and approaches that include professional communication, teamwork, self-initiative, and innovation. (cf., Ministry of Education, 2021 and 2023; and TŠC Maribor 2023b)

2) **Mechanical Engineering Technician** (EQF 4; 120 credit points and is the upgrade of the 180 credit points vocational programme) It is one of the most employable technical professions with broad horizons of professional technical knowledge. This profession is needed almost everywhere in the machine industry, as well as in the wood, textile, construction industry and elsewhere. The study programme upgrades students' professional knowledge with modern knowledge in the field of classical and CNC metal processing, 3D technologies, automation, robotics. Students are learning computer drawing techniques, reading technical, technological and other documentation and are familiar with the principles of operation of mechanical, hydraulic, electrical, electronic and other control systems. (TŠC Maribor, 2023a; and Ministry of Education, 2023).

3) **Upskilling VET Programmes** (EQF 4; up to 30 credit points) Upskilling VET programmes are aimed at deepening and expanding the knowledge of graduates of upper secondary vocational education. They are carried out by the school together with companies and ITCs. Both the employed and the unemployed are included in them, who thus acquire special professional as well as generic skills, with which they increase their flexibility in the labour market and acquire special skills for working in individual jobs. (CPI, 2016)

4) **Internet Of Things Developer** (EQF 4; 12 credit points). After completing the upskilling training programme in the field of secondary professional education Internet of Things developer, the participant will be able to design the optimal architecture of the Internet of Things according to the given constraints, develop a prototype of a simple Internet of Things system, install and use cloud services for storing and analysing acquired data and for controlling devices, and use security functions to protect data stored in sensor nodes, gateway devices or the cloud. (CPI, 2021d)

HIGHER VET PROGRAMMES (EQF 5; 120 ECTS)

The tertiary education in Slovenia consists of short-cycle higher vocational education and higher education. Both subsystems of tertiary education are interrelated in that they are linked by a system of quality assurance, students' progression from lower to higher level education, and partly by institutional and programme compatibility.

In **2022/2023** academic year, **29 public and 18 private** higher vocational colleges advertised open places for enrolment into 33 various study programmes. **40 %** of the **study programme is work-based learning** and is conducted in the companies with the support of highly qualified mentors. Study programmes are **based on occupational standards** that reflect actual needs of the world of work.

1) **Computing (EQF 5; 120 ECTS)** The development of computer science in the world is making rapid progress, as modern business relies on the use of high and digital technologies. There is a growing need for specialized knowledge in the field of computer science and informatics due to the fast advancement of information technologies, as jobs in manufacturing and service industries are becoming increasingly digitized. All this led

to new degree programme **Computing**, which was accredited in 2021. It is divided in two modules: Software Computing and Network Computing. The programme covers independent solving of complex professional problems in the work process, planning and analysis of software and applications, planning and administration of databases and computer networks, as well as planning and administration of cybersecurity. The study content includes topics in artificial intelligence, cryptography, data security and cybersecurity. (CPI, 2021c).

2) **Prototyping** (70 contact hours and 150 Independent learning; 5 ECTS) Prototyping is a valuable tool that can helps students to improve your products and systems. In addition to generic competencies, students in this course will acquire the following skills: Analysing the types of prototypes according to various functionalities and requirements of final users. This includes understanding the different types of prototypes that can be created, and the different functionalities that each type of prototype can support. Students will also learn how to identify the requirements of the final users, and how to select the right type of prototype to meet those requirements. Designing prototypes for specific end users and planned research. This includes understanding the needs and goals of the end users, and how the prototype can be used to meet those needs. Students will also learn how to plan research to evaluate the effectiveness of the prototype. Making several iterations of the prototype using appropriate tools. This includes understanding the iterative nature of the prototyping process, and how to use appropriate tools to create and evaluate prototypes. Students will also learn how to manage the feedback from end users and researchers, and how to incorporate that feedback into the prototype. (CPI, 2021b).

3) **Artificial Intelligence and Approach Techniques** (80 contact hours and 180 Independent learning; 6 ECTS). Students in this course will acquire analysing the theoretical foundations of AI and contemporary trends and challenges in defining the effectiveness of AI technology. This includes understanding the theoretical foundations of AI design, and the different factors that contribute to the effectiveness of AI technology. Students will also learn about the latest trends and challenges in AI design, and how these trends and challenges are shaping the future of AI technology. Implementing AI systems using a top-down approach. This includes understanding the top-down

approach to AI design, and how to use this approach to create effective AI systems. Students will also learn how to identify the user needs and goals, and how to translate these needs and goals into a functional AI system. (CPI, 2021f).

4) **Programming (EQF 5; 120 ECTS)** In the field of computer science is a need for independent problem solving in more complex professional tasks and in programming. The new study programme is aimed to train professionals who are capable of analysing, planning, developing, and managing information systems to optimize the management and operation of organizations. The purpose of the study programme **Programming** is to equip engineers with the skills for software and application design and analysis, database planning and administration, computer network planning and administration, as well as cyber security planning and administration. The programme supports areas such as database management, programming, business process analysis and modelling, data mining, artificial intelligence, ethical hacking, and cybercrime. The programme was accredited in 2023, and the first implementation of the programme will be in the academic year 2024/25. (CPI, 2023d).
5) **Ethical hacking, and cybercrime** (75 contact and 150 hours of independent learning; 5 ECTS). Ethical hacking and cybercrime are both serious threats to the security of our digital world. However, ethical hacking can be a powerful tool for preventing cybercrime. By identifying and fixing security weaknesses, ethical hackers can help to make our systems more secure and protect us from malicious actors. In this subject student found an estimate of how a hacker can through the port hack into the network and determine countermeasures for protecting devices or networks and looks for security features that prevent attempt any attacks and determine sites of detection and targeting of hidden networks and MAC filtering bypasses, no depending on whether it is performed from blacks or whites lists. (CPI, 2023a).

6) **Data mining** (75 contact and 150 hours of independent learning; 5 ECTS) Data mining is a complex process that requires a lot of expertise. The purpose of the programme is to provide students with an understanding of data mining. This includes understanding the different types of data that can be mined, the different types of patterns that can be mined, and the effective tools that can be used for data preparation, processing, and mining. (CPI, 2023c)

7) **Bionics (EQF 5; 120 ECTS).** The bionics engineer uses computer bionic process tools in work procedures and processes, makes decisions in professional and business matters and solves problems in the field of bionics, prepares implementation plans for bionic systems, participates in the preparation and implementation of bionic projects, participates in planning, implementation of updates, control and optimization of bionic processes, identifies and analyses existing bionic processes and includes new findings; includes renewable and alternative energy sources in bionic processes, monitors information about bionic processes, uses interdisciplinary knowledge of biology and techniques to solve concrete challenges in the environment. The programme was accredited in 2011. (CPI, 2011a).

8) **Bionic artificial intelligence** (150 contact hours; 5 ECTS). The student acquires the following generic competences to follow the development of the profession and to introduce innovations and improvements in work processes, to use systematic methods in solving problems in the field of artificial intelligence, to use written sources and information technologies in solving problems in the field of artificial intelligence, to learn about the fundamental principles of machine learning. In addition to the generic ones, the student acquires the following competences: introduction of artificial intelligence into production processes, independent planning of automation of simple production processes and participation in the planning and introduction of automation of complex production processes, planning of process maintenance in systems with machine learning, identification of possibilities for the introduction of artificial intelligence into production processes, correcting and complementing systems with machine learning. (CPI, 2011b).

9) **Artificial intelligence and energy** (130 contact hours; 4 ECTS). The student acquires the following generic competences to use systematic methods in solving problems in the field of artificial intelligence, learn about the types of natural and alternative energy sources and the basic possibilities of their exploitation, monitor innovations and trends in the field of development of renewable sources, monitor current legislation in the field of renewable energy sources. In addition to the generic ones, the student acquires the following competences: recognition of possibilities for introducing artificial intelligence

into production processes, introduction of artificial intelligence into production processes, analysis of the economic justification of renewable energy systems, integration of renewable sources into existing and planned systems and processes, introduction of renewable energy systems with the aim sustainable use of renewable natural resources. (CPI, 2011d)

10) **Micro technologies and energy** (130 contact hours; 4 ECTS). The student acquires the following generic competences to learn about the functioning of sensors and actuators at the micro and nano level, to learn about the types of natural and alternative energy sources and the basic possibilities of using them, to monitor innovations and trends in the development of renewable resources, to monitor current legislation in the field of renewable energy sources. In addition to the generic ones, the student acquires the following competencies: evaluating the use of advanced solutions in micro and nano fluid systems, using modern sensors and actuators connected to micro fluid systems, analysing the economic justification of renewable energy systems, integrating renewable resources into existing and planned systems and processes, introducing systems of renewable energy sources with the aim of sustainable use of renewable natural resources. (CPI, 2011c)

UPSKILLING HIGHER VET PROGRAMMES (EQF 5; 10 to 35 ECTS)

Upskilling study programmes (13) are intended for employed graduates of short-cycle higher vocational education study programmes. They are primarily intended for refinement, supplementing, updating, and deepening of their knowledge at the level of short-cycle higher vocational education in accordance with the requirements of the positions. (Cedefop, 2021)

Upskilling study programmes are designed according to the same principles as short-cycle higher vocational education programmes as an upgrade in the same professional field. Exceptionally, study programmes for upskilling are also designed according to the cross-

curricular principle, when it comes to training or deepening of competencies that are common to several areas of work (entrepreneurship, environmental protection, etc.). (Ibid.)

Upskilling study programmes do not lead to a higher level of education. When they are formed based on new occupational standards and comprise at least 30 ECTS they can enable the acquisition of a new professional education title. (Ibid.)

1) **Automotive Electrical and Electronic Systems (EQF 5; 24 ECTS).** Through this upskilling course, participants specialise in analysing vehicle faults related to automotive electronics, selecting, organizing, and lead the replacement of parts on electrical elements and components in vehicles, verify the functioning of electrical and mechatronic systems in vehicles, connect computer systems to each other and to equipment manufacturers' servers. All these systems are interconnected through communication networks using CAN and LIN data buses. Upon completion of the specialisation programme in the field of automotive electrical and electronic systems, the participant will be able to: update and adjust electronic components in vehicles, rectify complex faults in the car's computer systems etc. (CPI, 2020a).

2) **Expert In Smart Building Installations (EQF 5; 22 ECTS).** During this upskilling training, participants will be trained to perform final testing and system startup of smart installations, communicate with end-users, manage smart buildings by providing user support, and organizing system maintenance. The professional competencies that candidates will acquire in the upskilling programme for Specialist in Smart Building Installations include organizing maintenance and verification of smart electrical and mechanical installations, monitoring and controlling the operation of energy systems in buildings, adjusting/parameterizing, starting, testing, and diagnosing smart installations etc. (CPI, 2021e)

NATIONAL VOCATIONAL QUALIFICATION - NVQ (EQF 4 to 5)

NVQ (National Vocational Qualification) is an official vocational certificate or professional qualification. In the process of obtaining an official NVQ certificate, various informally acquired knowledge and work experience of an individual can be considered and recognized. (Cedefop, 2021)

NVQs offer the individual the opportunity to evaluate and confirm various skills, knowledge or professional competences acquired through informal or casual learning: through work in the home environment, through voluntary work, through vacation or student work, through work performed by employers, through education, which we attend on our own initiative or are referred there by others, with hobbies and leisure activities, on trips, during meeting new people, using different media, etc. (Ibid.)

CAREGIVER OF PROCESS DEVICES – MECHATRONIC (EQF 4)

With this NVQ, the holder proves to be able to design a process system, perform assembly of an automated process, manage mechatronic process systems, perform control of mechatronic process and equipment, maintain and control the operation of devices in a mechatronic system, maintain software and hardware, and archive documentation for maintenance of mechatronic systems, diagnoses errors, corrects errors in the operation of the mechatronic system, and repairs malfunctions of the mechatronic process. (CPI, 2023b)

INFORMATION-COMMUNICATION EQUIPMENT AND SERVICES EXPERT (EQF 5)

This NVQ, is awarded when the holder proves to be able to produce simple software, follow the development of information and communication equipment and services, analyse the needs of the user/subscriber and select appropriate information and communication equipment and services, install and configure information and communication equipment and services, provides support to users of information and communication equipment and services, manages information and communication equipment and services, and maintains information and communication equipment and services. (CPI, 2021a)

Prepared by Natalija Klepej Gržanič and Alicia Leonor Sauli Miklavčič (Skupnost VSŠ)

3.3.5 Vocational Advanced Manufacturing Qualifications in Spain

The Spanish VET system offers a wide range of VET qualifications related to Advanced Manufacturing. These qualifications include in their latest curriculum revisions also competences related to Industry 4.0 . To better understand the Spanish VET system reader should refer to

the CEDEFOP's publication "Vocational education and training in Europe, Detailed description of VET systems in Europe: Spain" (CEDEFOP, 2021).

Furthermore, since 2020, the Spanish Education Ministry is implementing specialisation courses for certain intermediate (EQF4) and higher (EQF5) qualifications. A number of those specialization courses, described below, are directly linked to advanced manufacturing and Industry 4.0. (Ministerio de Educacion y Formacion Profesional , 2023). The VET law published in 2022 regulates both the aforementioned qualifications and the respective specialisation courses. (Ley Orgánica 3/2022, 2022).

In the following paragraphs there are the qualifications and upskilling programs offered in CIFP MIGUEL ALTUNA (Basque Country) listed as examples of "future proof qualifications for advanced manufacturing.

1) "**Higher Technician in Production Programming in Mechanical Manufacturing**" presents a duration of two years with a total of 80 ECTS-points. Alumni of this qualification obtain competences referring to operational machining processes, special machining techniques, programming as well as assembling and shaping systems based on technical documentation. The qualification also implies knowledge about production processes, quality assurance and personal management. In the first year, the apprentices receive basic knowledge about quality management, product development, manufacturing processes, machining, shaping and assembly processes, as well as graphical interpretation. In the final year of training, the focus is on programming skills, handling CNC machines and CAM systems, as well as management skills and English as a foreign language. This higher-level training also includes intensive on-the-job training. The methodology of the Higher technician in production programming in mechanical manufacturing follows a project-based learning (Todo FP, Ministerio de Educación y Formación Profesional, 2023).

2) **Higher Technician in Mechanical Manufacturing Design** qualification also has a duration of two years with a total of 80 ECTS credits. In this high-level training, students receive basic competences in mechanical product design and manufacturing techniques, as well as in manufacturing automation. These competences are supplemented in the second year of training with design competences for processing tools as well as molds and models for casting. The qualification also includes courses on the mechanical product design project, technical English and management skills. This

training also requires a high proportion of work placements in order to be able to apply competences and knowledge (Todo FP, Ministerio de Educación y Formación Profesional, 2023).

3) **Higher Technician in Automation & Industrial Robotics** qualification combines both computer science and electronics. The qualification covers the basics of electrical, pneumatic and hydraulic systems, industrial computing, sequential programmable systems, measurement and regulation systems, power as well as advanced programmable systems. In the second year, the learners receive final competences in the field of industrial robotics and communication, as well as industrial automation, integration of industrial automated systems, technical English and business management. Again, learners are required to complete work placements during the final second year of training (vgl., Career One Stop 2022).
4) **Higher Technician in Mechanical Production Scheduling** presents another future-proof qualification in the VET sector with a focus on electricity and electronics. The two-year high-level course provides learners with skills in quality and risk management, machine and manufacturing processes, product verification and graph interpretation. In the final year of the qualification, the focus is on programming skills relating to CAM, automated mechanical manufacturing and production systems, as well as business management and technical English. Learners also work in a collaborative challenge-based learning environment on a machining product manufacturing project and complete 360 hours of work placements to apply their knowledge. Participants of the high-level course " Higher Technician in Mechanical Production Scheduling" graduate with a total of 80 ECTS and an EQF level 5 (Todo FP, Ministerio de Educación y Formación Profesional, 2023).
5) . "**High Technicians in Electrotechnical & Automated Systems"present** one of the future-proof qualifications in the electronics sector. This high-level training combines competences in project management, electrical engineering and maintenance. The programme covers electrical installations, process management, ICT, technical documentation and processes, electrical systems and circuits, electrical network and substation developments, configuration of domotic and automatic installations, assembly and maintenance of electrical installations and configurations, and business management. As part of the qualification and the realistic learning methodology, learners complete various work placements (Todo FP, Ministerio de Educación y Formación Profesional, 2023).

6) **Higher Technician in Electronic Maintenance** implies competencies in the field of maintaining and repairing various electronic and industrial systems, planning and organization of repairs, as well as occupational and environmental risk prevention. For this purpose, learners receive basic knowledge of microprogrammable and radio-communicational equipment, as well as electronic circuits, in the two-year training. In addition, students are taught skills related to the maintenance of data, electronic and audio, video equipment, assembly techniques as well as project management and business management skills. To apply the competences, the qualification includes a sum of on-the-job training (vgl., Gunner und Peterken 2023).
7) **Higher Technicians in Industrial Mechatronics** implies competencies in hydraulic, pneumatic, mechanical, electrical and electronic systems. In addition, basic knowledge of machine elements and manufacturing processes is taught. System integration and configuration of mechatronic systems, as well as quality management and maintenance, simulation of mechatronic-proof systems, and technical English are also part of the two-year course as well as corporate management and project management in the industrial mechatronics sector (Todo FP, Ministerio de Educación y Formación Profesional, 2023).

Upskilling Higher Vet Programmes: Specialization Courses for VET qualification (EQF5) related to Advanced Manufacturing

The aim of specialisation courses, as listed and referred to herein, is to complement the skills of those students who already have a vocational qualification and to facilitate lifelong learning for learners and workers who already hold a VET degree. The Royal Decree regulating each specialisation course specifies its entry requirements. As a result, the Spanish specialisation courses at hand, are not necessarily related to a particular vocational qualification. They can be relevant to many of them. There are also specialisation courses that are not related to a professional qualification yet.

1) **Specialisation course in Smart Manufacturing** consists of 36 ECTS credits and is taught over a year. Through this course, participants specialise in developing and managing projects to adapt production processes, identifying production objectives. To do so, they take into account key performance indicators (KPIs) and apply advanced production control technologies and quality and safety requirements. They also acquire knowledge of metrology and smart instrumentation and networked environments and the Internet of Things. The aim of this specialisation is to train experts in intelligent

manufacturing systems (Todo FP, Ministerio de Educación y Formación Profesional, 2023).

2) **Specialization Course in Artificial Intelligence and Big Data** consists of 34 ECTS credits distributed over a year. During this training, students receive general competencies related to the programming and application of intelligent systems that optimize the management of information and the exploitation of massive data, guaranteeing secure access to data and complying with the criteria of accessibility, usability and quality required in the established standards, as well as ethical and legal principles. They also acquire knowledge in AI models and their programming, Machine Learning systems and Big Data systems and their applicability. The most relevant jobs that this specialization programme enables students to perform are Artificial Intelligence and Big Data Developer, Expert Systems Programmer, Data Analyst and AI and Big Data Expert (Todo FP, Ministerio de Educación y Formación Profesional, 2023).
3) **Specialization Course in Cybersecurity in Operational Technology Environments** It is one year programme and it takes 43 ECTS credits. Students acquire the general competence relating to the definition and implementation of security strategies in organizations and industrial infrastructures by carrying out security diagnostics. To this end, they must be able to identify vulnerabilities and implement the necessary measures to mitigate them by applying current regulations and sector standards, following quality, occupational risk prevention and environmental respect protocols. This course aims at generating cybersecurity experts, auditors, consultants and analysts in operational environments (Todo FP, Ministerio de Educación y Formación Profesional, 2023).
4) **Specialization Course in Collaborative Robotics** involves achieving competence in the development of collaborative robotics projects, both robotic arms and autonomous mobile robots. To this end, students must know how to carry out the assembly, commissioning and maintenance of these systems, respecting criteria of quality, safety, accessibility and respect for the environment. The 24 ECTS credits and the one-year duration of the course, enables training for jobs such as assembly supervision team leader and maintenance manager of collaborative robotics systems, collaborative robotics systems designer and commissioning technician and programmer of collaborative robots (Todo FP, Ministerio de Educación y Formación Profesional, 2023).
5) **Specialisation Course in Digitalisation of Industrial Maintenance** is taught over an academic year and has a total of 36 ETCS credits. Students who obtain this qualification will have gained the general competence related to the implementation and management of maintenance digitalisation projects in industrial environments, applying the latest

generation technologies and complying with the requirements of quality, safety, and respect for the environment. The most relevant jobs to which this qualification gives access are expert in the digitalisation of industrial maintenance, expert in automation and industrial digitalisation and industrial digitalisation manager (Todo FP, Ministerio de Educación y Formación Profesional, 2023).

6) **Specialisation course in Installation and Maintenance of Systems Connected to the Internet (IoT)** consists of 36 ECTS credits and is taught over a yea. It requires internalizing the concepts of installation, commissioning and maintenance of devices and systems connected to the IoT internet, for which it is necessary to ensure their functionality and connectivity by applying the current standards and regulations, quality protocols, privacy, digital security, occupational hazards and respect for the environment. This is the purpose of this one-year course (180 hours) that aims to define future network and IoT technicians, installers of electronic systems equipment, installers and repairers of connected systems and devices and installers and repairers of IoT devices (Todo FP, Ministerio de Educación y Formación Profesional, 2023).
7) **Specialisation course in Cybersecurity in Information Technology Environments** is a year programme and consists of 43 ECTS credits. Students acquire the general competence related to the definition and implementation of security strategies in information systems by carrying out cybersecurity diagnoses, identifying vulnerabilities and implementing the necessary measures to mitigate them by applying the current regulations and standards of the sector. They will also know how to follow quality protocols, occupational risk prevention and respect for the environment. Apart from that, they will learn about ethical hacking and computer forensic analysis, as well as how to develop cybersecurity prevention and awareness plans. This course aims aims at generating cybersecurity experts, auditors and consultants, and ethical hackers (Todo FP, Ministerio de Educación y Formación Profesional, 2023).

8) **Specialization Programme in Additive Manufacturing** implies achieving competence in the development and management of additive manufacturing projects using 3D printing, supervising or executing the assembly, maintenance and start-up of these projects. To achieve this, implementation decisions must be taken in the development of company products respecting quality, design, safety and environmental criteria. Once the 36 ECTS credits have been achieved in the year-long course, students will be able to work as experts in additive manufacturing systems, experts in 3D printing, experts in

product design for 3D printing, experts in rapid prototyping and 3D scanning designer (Todo FP, Ministerio de Educación y Formación Profesional, 2023).

3.4. Vocational Advanced Manufacturing Qualifications in Türkiye

Vocational Advanced Manufacturing Qualifications in Türkiye

The "Turkish Qualifications Framework", which is defined on a national basis in the country, is largely compatible with the European Qualifications Framework (EQF). In this context, vocational education centres determine the curriculum and provide education within the framework of EQF level 3 and vocational and technical Anatolian high schools such as our institution determine the curriculum and provide education within the framework of EQF level 4 qualifications. Students who graduate from our institution can be employed in industrial organizations with the title of technician by directly entering business life, or if they continue their higher education in a vocational college, they can become technicians at associate degree level by receiving education within the framework of eqf level 5 qualifications. In addition, they can study in faculties of engineering and science within the framework of eqf level 6 qualifications in faculties of engineering and science and obtain a diploma at undergraduate level. Thus, they can reach the title of engineer or chemist. In our country, seventh and eighth-level qualifications are included in masters and doctoral programs in line with EQF.

Advanced Manufacturing Qualifications offered by GEBKİM VET

GEBKİM Vocational and Technical Anatolian High School (GEBKİM VET) is a vocational education institution operating in Kocaeli.

In Turkey, there are 2395 Vocational and Technical Anatolian High Schools operating within the scope of formal education and 33 Vocational Education Centers operating within the scope of non-formal education. Of these, 62 Vocational and Technical Anatolian High Schools are in Kocaeli province. There are also 4 Vocational Education centers in Kocaeli province. GEBKIM Vocational and Technical Anatolian High School has one of the 8 industrial automation technologies departments operating in Kocaeli. One of the 13 Chemistry Technology departments in this province is also located in the related school.

GEBKİM VET is a boutique school that provides hands-on training in two departments and four fields, namely Chemical Technology and Industrial Automation Technologies, educating

approximately 500 students each year. It provides transition to many fields of universities such as Chemistry, Chemical Engineering, Chemical Technology, Mechatronics Engineering, Control Automation Engineering, Machinery, Graphic Design, Automotive Technologies and provides basic education that will constitute a source for these fields.

1) The Department of **Machinery** is a full-time, two-year associate degree programme and focuses on the following subjects; Occupational Health and Safety, Industrial Measurement and Control, Materials Technology, Computer Aided Design, Quality Control, Mold Design, Advanced Welding Techniques, Hydraulic Pneumatic Systems. To graduate from this department, a total of 120 ECTS course content must be completed and an internship activity must be performed.

2) The Department of **Mechatronics Engineering** is a full-time, four-year undergraduate programme that focuses on the following subjects; Basic Electronics, Electronic Circuit Design, Machining, Computer Aided Design, Computer Aided Manufacturing, Robot Technology, Microcontrollers and IOT, Hydraulic Pneumatic Systems, Automatic Control Systems, Advanced Manufacturing Technologies, Mechatronic System Designs, Artificial Intelligence Systems, Image Processing, Industrial Communication and SCADA Systems, Autonomous Robots, Sensors. To graduate from this department, 240 ECTS course content must be completed, and skills training must be completed in the enterprise for one semester (4-5 months) in the last year.

The following two courses are among the courses offered to GEBKİM VET students, which will form the basis for the above-mentioned fields.

1) **Computer Aided Design & 3D Printing** (2 credits, 72 hours). Introducing SOLIDWORKS programme to students, two-dimensional drawing applications, dimensioning, three-dimensional modeling applications (solid surface creation, solid surface removal from the part ...), assembly, technical drawing of materials for production, recording the drawing document in STL format for 3D printer, introducing 3D printer and slicing programme , slicing programme parameters and giving practical training on the use of 3D printer, 3D part printing.

2) **Microcontrollers (Arduino) & Internet of Things** (10 credits, 90 hours). Giving information to students about number systems, basic logic gates, microcontroller features, working structure, types, selection processes and programming software

(Arduino IDE), Basic coding (Led Blink, button applications), analog-digital conversion operations, analog-digital data read-write commands, explanation of PWM concepts, Stepper, DC, Servo motor applications, various sensor applications (soil moisture, ultrasonic distance, temperature, pressure, rain, fire, carbon dioxide and carbon monoxide etc.), data writing and reading applications to eeprom memory, use of Bluetooth and WiFi communication modules, use of MIT AppInventor application and design and programming of systems that can be controlled remotely with the help of this application.), eeprom memory data writing and reading applications, use of Bluetooth and WiFi communication modules, use of MIT AppInventor application and design and programming of remote control systems with the help of this application.

3.5. Vocational Advanced Manufacturing Qualifications in Canada

The Canadian learning model does not fully align with that of the EQF; however, Canadian college programs largely fall within the bounds of EQF 3-5, providing factual and theoretical knowledge in both broad and specialized contexts within a field of work or study, focusing on generating solutions to practical problems through either direct methodological application or research and innovation. Students take responsibility for their work and exercise self-management within work guidelines for major projects, supervising one another's work and preparing them to enter the workforce at the conclusion of their studies armed with a working expertise in currently-available and cutting-edge systems in regional industry.

In this environment, Industry 4.0 is rarely taught at the college level, in part because most vocational educational training focuses on local industry, which is largely operating at the Industry 3.0 level. Instead, Canadian colleges provide foundational education to students interested in advancing to Industry 4.0, who then develop those skills alongside development at the university level, which more closely approximates an EQF of 6-8.

Camosun College is one of 213 public colleges and institutes operating as the foundation of vocational education in Canada, and one of 60 Technology Access Centres supporting applied research for students and regional industry. As discussed more in-depth in WP6.1, Canada's system of higher education is unusual, with the federal government maintaining no authority over education funding; instead, provincial and territorial authorities manage regional educational priorities and funding. Many colleges, including Camosun, operate 'bridge programs' that provide foundational education to students who will then go on to more abstract or specialized training at regional universities (such as the University of Victoria) alongside direct

vocational education whose purpose is to provide practical and applied education which prepares students to enter the workforce.

Camosun College provides more than 160 programs serving over 14,000 students each year; applied learning, and especially applied research, are foundational to its educational profile. There is substantial crossover between the Advanced Manufacturing fields of the college and many other programs, including visual arts, carpentry, and design programs.

1) The **Mechanical Engineering** programme is a full-time 2-year diploma programme with an emphasis on Computer-Aided-Design and Computer-Aided-Manufacturing, as well as an introduction to robotics and automation, which often includes co-operative education placements with local industry partners. This rigorous programme includes thirty hours per week of direct education accompanied by an estimated 15-20 hours of individual study per week, requiring 87 total credits to graduate.

2) The **Electrical Engineering (Marine & Industrial)** programme is a full-time 2.5-year diploma programme with an emphasis on electrical devices such as VFDs, PLCs, and complex electrical systems common to both marine and industrial projects, including education in computer-aided design, analog and digital circuitry design, and analysis, monitoring, control and design of complex electrical systems, and often includes co-operative education placements with local industry partners. This rigorous programme includes thirty hours per week of direct education accompanied by an estimated 15-20 hours of individual study per week, requiring 85.5 total credits to graduate.

Upon completion of either of the above programs, students may undertake an eight-month "bridge" programme to prepare to enter a university-level engineering degree. Both bridge degrees prepare students to enter an affiliated university programme at a third-year level, developing the qualifications necessary to be a trained technologist and a certified engineer.

The two courses below are among those providing foundational education to students of Camosun's Mechanical Engineering and Electrical Engineering programs, alongside direct vocational education and hands-on applied research experience.

1) MENG 284 - Robotics and Automation (3 Credits, 75 Hours) Students are introduced to the concepts of automation as it applies to production plants and assembly processes. Support systems for automated systems will also be discussed. Sensors, controllers,

actuators, power-transmission systems, computer hardware and software will be examined. Basic principles of robotics will be considered.

2) **ECET 260 - ARM Microcontrollers & the Internet of Things** (3 Credits, 90 Hours). Students will be introduced to the ARM microcontroller family, prevalent in embedded systems such as mobile phones, GPS systems and other consumer devices. They will develop familiarity with the ARM processor and its architecture and implement projects using an integrated development environment (IDE). Students will use the ARM platform to connect and communicate with devices and the Cloud.

3.6. Occupational profiles for Advanced Manufacturing

Occupational profiles and labor demand are changing in response to sectoral developments. Forecasts indicate that the future labor market will see growth in both higher-skilled and lower-skilled occupations. However, forecasting future occupations and job demands involves a high degree of uncertainty due to ongoing changes and their impact on various industries. Factors such as the influence of new technologies, megatrends, and changes in sectoral structures contribute to fluctuating demand for occupational profiles, making it difficult to forecast future employment trends (see,(vgl., Mara Brugia 2018, S. 32). The advent of new technologies and continued digitization have fostered an increase in horizontal and vertical interconnections within and outside companies, resulting in the generation of large amounts of data and information. To effectively use this information about customers, suppliers, products, production, and even competitors, companies need data scientists who can transform raw data into meaningful and valuable insights to improve business operations (Cecimo, 2023, p. 6). **Data scientists** perform various activities, including data mining, analysis, and interpretation, using algorithms, artificial intelligence, data mining, statistical tools, and machine learning. They present interpreted and prepared information to managers and employers, solve problems and improve processes and strategies. Therefore, data scientists must possess analytical and problem-solving skills, mastery of analytical tools, effective communication and presentation skills, attention to detail, teamwork, and understanding of business processes. Given the widespread of new technologies in various industries, job opportunities in this field include areas such as manufacturing and information technology (see,(vgl., Career One Stop 2022a).

Continued horizontal and vertical interconnections between systems and objects, particularly in the workplace, have created a demand for IoT specialists (see, (vgl., Wörwag und Cloots 2020,

S. 29). Those in this role establish efficient automated connections within the enterprise network and between objects, enabling the generation and collection of relevant data without requiring user interaction. **IoT specialists** perform tasks related to implementing IoT strategies, improving functionality and promoting greater hyperconnectivity between systems, objects and sensors (Cecimo, 2023, p. 6). In addition, professionals in this field plan and develop digital solutions based on emerging technologies, programme microprocessors, test and prototype technical feasibility, and implement policies and actions to ensure cybersecurity. This job profile requires skills in programming, data analysis, knowledge of cybersecurity and machine learning, and familiarity with various technologies (see, (vgl., Barcelona Treball 2022) (vgl., Barcelona Treball 2022).

Manufacturing engineers strive to improve production processes to ensure efficient and cost-effective production of goods while minimizing environmental impact. They are responsible for designing new production systems, equipment and processes, installing new tools, analyzing production problems and improving ongoing operations. Skills required of manufacturing engineers include problem-solving skills, effective communication and presentation skills, teamwork, time and project management, and awareness of industry hygiene and occupational health and safety (see Perspectives, 2022).

4. CONCLUSIONS

The international sample on “forward-looking” I4.0 vocational Advanced Manufacturig qualifications presented in this report allows us to further analyze and understand international H-VET qualifications regarding their curricular specifics and educational premises using comparative analysis approach. This next step is crucial for achieving our ambitious goal to harmonize all relevant learning opportunities within our stakeholder network and the LCAMP Alliance with special respect to the overarching premises required by the ELM (EUROPASS, ESCO).

Two key elements stem from this understanding: the LCAMP skills assessment toolkit and the LCAMP learning pathway tool. They shall enable those involved in both higher education and

vocational training, such as students, teachers and professionals, to find personalised ways of retraining and improving skills using future LCAMP services. From a skills enhancement perspective, the data we have helps us to tailor our services so that there is an appropriate correlation between courses and skills enhancement through our micro-credits, in line with the European Council's approach to micro-credentials for lifelong learning and employability.

Our consortium partners play a key role in this process strengthening our I4.0 skills and technology framework. The main objective is to equip our training model with future-proof skills that are vital for advanced manufacturing.

On the one hand, the data on vocational Advanced Manufacturing qualifications here at hand helps us to answer our open research questions at multiple levels. Here are some examples:

- How up-and reskilling in Advanced Manufacturing already are tackled on national level?
- Is there a common educational and curricular approach that we can agree on?
- Which (innovative) learning pathways already exist among the consortium and are used in each partner country?
- What are the specific curricular prerequisites in each school and partner county to develop an interoperable learning model the masters the transition between international VET and HVET schools?
- Which Advanced Manufacturing competencies and related skills are considered most relevant in each country?
- Which kind of training methods in Advanced Manufacturing are used by our partners and are the most efficient for up- and reskilling pathways?
- How is work-based training represented in national VET qualifications?
- How new cutting-edge Advanced Manufacturing Learning Offers need or can be designed / improved to deliver the most efficient learning experiences? An answer to this question is paramount to LCAMP’s future CLFs and how its training offers can be harmonized with national (H-)VET curricula.

A first look at the datasets on qualifications and their structure allows the following statements to be made in advance:

- There are no vocational Advanced Manufacturing qualifications available at EQF3. It appears that qualifications at this basic level are not pertinent to Advanced Manufactuiring, given that both the workplaces and the occupations in this domain necessitate a more advanced understanding and set of skills.
- While many national qualifications might appear unchanged, they have, in fact, been updated mostly in every country to address the challenges brought about by disruptions in technology, environment, society, demography, and geopolitics.
- There is a growing trend towards offering Micro-Credits for Lifelong Learning, evidenced by short and specialization courses (as seen in Spain and Germany). These are designed to align swiftly with the evolving needs of the labor market.
- Integrated hands-on learning methods, project-based learning scenarios, such as learning factories, along with gamified simulations, are emerging as effective, future-ready, and workplace-aligned instructional strategies that cater to the demands for continuous upskilling and reskilling.

The above-mentioned questions and analytical starting points aim at meeting the standards of other European initiatives and Advanced Manufacturing projects to ensure broad interoperability of our learning and training offers in and outside of the LCAMP Alliance and the associated industry.

Ultimately, our aim is to develop a simple, well-harmonized model for skills upgrading and retraining those answers, enabling our future platform to make the European labor market in the field of Advanced Manufacturing more resilient and dynamic.

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