EXAV4.0

THE EXCELLENT ADVANCED MANUFACTURING 4.0

Position Paper: VET 4.0 for Advanced Manufacturing

VET 4.0 for Advanced Manufacturing

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EXAM 4.0
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TABLE OF CONTENTS

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Acronyms and Abbreviations

AR	Augmented Reality
AM	Advanced Manufacturing
AI	Artificial Intelligence
AFM	Spanish Association of Machine Tool Manufacturers
CEDEFOP	European Centre for the Development of Vocational Training
CLF	Cooperative Learning Factory
CPS	Cyper-physical-system
CoVE	Center of Vocational Excellence
DESI	Digital Economy and Society Index
DHBW	Duale Hochschule Baden Württemberg
EACEA	Education, Audiovisual and Culture Executive Agency
EAFA	European Alliance for Apprenticeships
ECTS	European Credit Transfer and Accumulation System
ERP	Enterprise Resource Planning
EXAM 4.0	Excellent Advanced Manufacturing 4.0
EQF	European Qualification Framework
I4.0	Industry 4.0
IoT	Internet of Things
IIoT	Industrial Internet of Things
HVET	Higher Vocational Education and Training
KET	Key Enabling Technologies
KPI	Key performance indicator
LF	Learning Factory
LLL	Lifelong Learning
M2M	Machine-to-machine
OECD	Organisation for Economic Co-operation and Development
OMR	Optical Mark Recognition
PHE	Professional Higher Education
PLM	Product Lifecycle Management
RFID	Radio Frequency Identification
ROC	Regional occupation center
SAT	Self assessment tool
SME	Small medium enterprises
VET	Vocational Education and Training
VR	Virtual Reality
WBL	Work based learning
WP	Work Package

1 Abstract

The following report is based on the observation that digitalisation in the world of work does on the one hand trigger processes of change, leading to shifts and new constellations in the required qualifications and institutional / faculty development. However research is showing a lack of clarity and specificity in the statements made about possible qualification needs resulting from Industry 4.0. There is a general consensus that requirements are increasing, due to the convergence between mechanical electronic software-based components or systems (Ahrens & Spöttl, 2018).

For the new arrangements of I4.0 occupations as well as the adaption of the curricula, work-process oriented approaches and closeness to the work environment are required, when designing occupational profiles.

On the other hand, the effects of digitalisation on qualification requirements are depending on the skills demands defined by the world of work. There is broad agreement professions and occupations will change under the challenges of digitalisation, but will certainly continue to determine the basic framework of qualifications for jobs in the digitalised industry. The technological developments in the course of Industry 4.0 clearly shows that digitalisation is linked to existing concepts, e.g. in manufacturing technology, production logistics or corporate communication. This is accompanied by the widespread assessment that digitalisation is more of an evolutionary than a revolutionary change in industrial organisation.

In this respect, the most important component in the vocational education and training of engineers and technicians continues to be anchored in the traditional engineering sciences with the objective of teaching engineering fundamentals and methods. Supplementing or revising traditional curricula is largely deemed an appropriate means of meeting the curricular requirements that result from digitalisation.

2 Introduction

Nowadays, the term 4.0 is used everywhere: Society 4.0, Economy 4.0, Industry 4.0, Technology 4.0, Work 4.0, School 4.0, Qualification 4.0, Agriculture 4.0, VET 4.0, etc. (Hamilton Ortiz, 2020).

At the European level EXAM 4.0 contributes to the implementation of the digital agenda through exchange of information on an ongoing basis between academia, policy-making and practice.

Industry 4.0 (I4.0) challenges the traditional boundaries of disciplines, knowledge and competence areas that are important for the identification and the definition of the limits of qualifications. For example, the application of sensors and activators within networking of cybernetic-physical systems (CPS) requires interdisciplinary individual and collective competences that integrate knowledge and skills from the fields of machinery production, electronics and information-communication technologies (Bruhn & Hadwich, 2017). Since digital innovation affects manufacturing processes and work organisation, it will also affect different qualification profiles.

The processes of controlling physical infrastructure digitally also leads to digital work systems that are intelligent, effective and efficient so as to increase production results and minimize production costs. It can also help to achieve higher levels of wellbeing and become more sustainable. These changes have an impact to key qualifications, such as communication, interdisciplinary process management and responsibility, or the use and generation of information, even more than the changes in technological qualifications.

Particular attention is paid to the potential for networking between people and between people and machines. Well-trained employees are needed who are able to actively shape work processes, optimize them continuously and consciously reflect developments in the company. They must have extensive knowledge of, for example, project management, lean management or total quality management and be able to use their relevant methods. Further relevant topics are software orientation, technical networks, CP-systems and their embedding in processes. Beyond these skills, social competences such as cooperation and communication in heterogeneous teams and taking over responsibility is becoming more and more important. This has a deep impact on curriculum development. (Hamilton Ortiz, 2020)

Work processes are currently changing profoundly as a direct result of CPS in all elements of the world of work. The future research agenda in this field is both broad and rich, as are the implications of I 4.0 for the development of qualifications and qualification systems in the sectors of economy and countries.

The EXAM4.0 consortium has worked with businesses in I4.0 to analyze today's industry demands and skills challenges and developed the frameworks of I4.0 technology enablers and of relevant future skills. The research studies were based on a mix of quantitative and qualitative surveys (for more information on the methodology, see the reports in WP2).

The EXAM 4.0 Skills Framework is neither intended to be a rigid, general categorization nor to replace the other more generic frameworks. Instead, it seeks to map the latest trends and demands in the I4.0 Economy, predict skills gaps, and in so doing deliver short to medium-term triggers for education policy as well as higher education and further training institutions. The framework forms the conceptual basis of the future skills initiatives of the EXAM4.0 platform.

In addition, I4.0 initiatives, tightly related to digitalisation in Advanced Manufacturing (AM), is beginning to show its limits. The EC is supporting the shift to Industry 5.0 (I5.0). While the technologies in 4.0 and 5.0 are the same, I5.0 moves from a profit driven to a human centric, sustainable, and resilient industry. To support I5.0, VET/HVET needs to develop "Learner centric approaches", to bring human centeredness to AM VET/HVET.

Therefore, European regions which have AM as a priority in their Smart Specialisation Strategies, should help their AM industries to be competitive and develop skilling, upskilling and reskilling programmes following flexible pathways and innovative methodologies to overcome the challenges of the twin transitions. This is the only way to continue being competitive and to guarantee high life quality standards for citizens that focus on the holistic competences of humans that plan, manage, oversee or operate technologies

Apart from the development and basic facts described here, the future relationship between human and machine must still be clarified. Competence development must go as far as ensuring that human beings keep their dominance over machines.

VET4.0 and collaboration platforms need to support this. Centres of Vocational Excellence (CoVEs), understood as VET /HVET providers that follow learner centred approaches and provide several services apart from I-VET in alignment with Smart Specialisation and other regional strategies and collaborating with different agents in the Strategic Triangle,. The CoVE platform can and should play a major role at regional level to address the challenges of the twin transitions in AM.

New learning methods and tools, the use of learning factories and collaboration among them with other national and international VET/HVET institutions as well as the changing role of VET teachers and trainers and their competence development in the context of I 4.0 and 5.0 are further important research fields.

The report deals with the question of what VET/HVET institutions can do that curricula correspond to the changing requirements of digitalisation under the new organizational circumstances of Industry 4.0. In Chapter 3 the report provides **a guide for the implementation of initiatives related to Industry 4.0**. such as training and education in new technologies, the development of labs and how to proceed in change management. Chapter 4 presents a table with suggestions and recommendations of the EXAM 4.0 HUB for several stakeholders (European and regional policy makers, VET/HVET authorities, VET/HVET providers, AM companies and Employers Association, Networks) on how to face the challenge of Industry 4.0. In Chapter 5 different national approaches to work based learning and latest policy developments are shown. Chapter 6 will give an outlook to VET4.0 describing future design plans. Chapter 7 introduces the work-based training solutions in the form of learning factories for VET/HVET centres and how collaboration is possible among different EU institutions and labs. Chapter 8 summarizes the research covering the EXAM 4.0 skills framework centred around the relevance and quality of specific skills in Advanced Manufacturing, making skills and the role of skills more visible also at ESCO. Finally the report elaborates the strategy for a CoVE Platform development in Advanced Manufacturing.

3 Guide for the Implementation of Initiatives Related to Industry 4.0

3.1. Designing plans and proposals for the VET centre 4.0

This section is the **Guide for the implementation of Initiatives related to Industry 4.0.** A guide to encourage and support European VET/HVET centres on the implementation of initiatives to introduce 4.0 technologies in labs and even to create new labs for advanced manufacturing.

We understand those initiatives as part of the digital transformation of the institutions more than an isolated initiative addressing technologies for labs. This guide addresses technical education institutions and we must bear in mind that, when we talk about Digital Transformation, the connotations and peculiarities are in many cases different from industry.

However, in creating this guide, we have been inspired by how industrial transformation is being approached in the advanced manufacturing companies. The EXAM4.0 approach is to create highly technical spaces (labs) for training use. We want these labs to be as similar as possible to real manufacturing plants, to make students 'experience as enriching as possible.

In this context, when we propose plans to integrate KETs for VET4.0 centres, we include many of the assumptions used in industry for their own digital transformation. We can adopt the following statement also for VET centres: Since this transformation is a highly complex undertaking, it can take several years. It should be planned and implemented in such a way as to ensure that positive impacts on profitability – i.e. growth and efficiency – occur at various stages throughout the transformation. Benefits should be made visible at any point during the transformation in order to support its overall success. This approach enables quick wins while also driving towards the overall transformation goal. (Schuh et al., 2017)

The guide we are describing is represented by **seven stages** that will support the implementation of enabler technologies in VET centres. The guide also gathers some tools and methods that can be used in the different stages in order to make the guide more understandable.

Guide for the implementation of Initiatives related to Industry 4.0 in VET/HVET centres

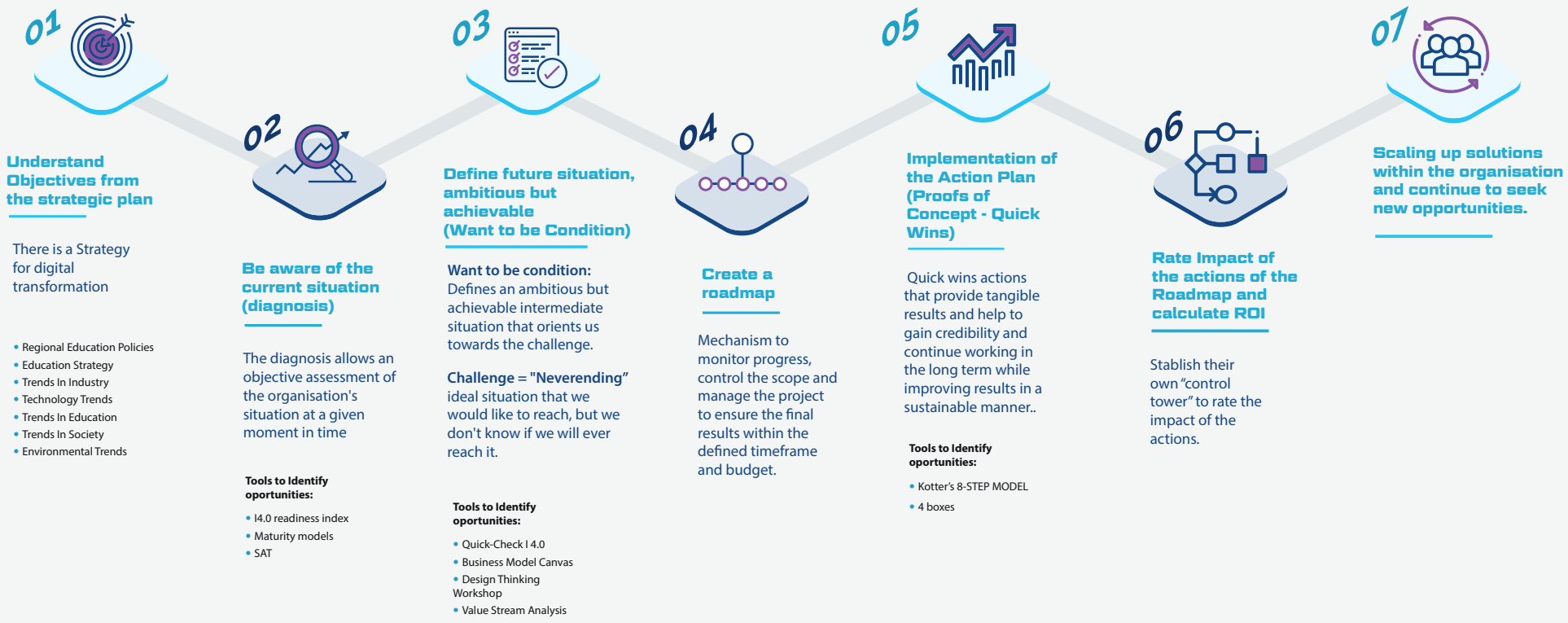


Figure 1. Guide for implement Advanced Manufacturing labs in VET/HVET centres Source: Exam 4.0

3.2. Understanding objectives from the strategic plan

In order to tackle the implementation of enabling technologies, it is essential to define a digital transformation strategy that organises the priorities and projects to be undertaken and gives them a structured meaning so that they can be carried out.

As educational centres, the digital transformation we are referring to, not only encompasses technological transformation but has to be fully aligned with the educational strategy of the centre. We cannot forget the influence of regional education and specialisation policies on the educational strategies of VET centres, besides the technological changes in industry.

As it happens in industry, since an institution's desired target state will depend on its educational strategy, it is up to each institution to decide which maturity stage represents the best balance between costs, capabilities and benefits for its own individual circumstances. When approaching digital transformation, even in VET centres, the factors to consider in planning are highly dynamic. Enabling technologies develop and evolve at very different rates, which implies large differences in maturity, costs, adoption times, technology and supplier alternatives.

Therefore, when facing a digital transformation, a VET institution has to consider external factors that directly affect it: technological industry trends, employees needs, social and environmental trends, sustainability, educational and industrial policies, pedagogical trends, and so on.

3.3. Be aware of the current situation (diagnosis)

The diagnosis allows an **objective assessment** of the VET/HVET centre's situation at any one time. It is recommended to carry out a diagnosis taking into account a global vision of the organisation to achieve a representative starting point. This general view will help us identify the organisation's **strengths and weaknesses**. It will also allow us to focus on the **areas for improvement** that, along with the organisation's strategy, will guide the Digital Transformation Roadmap.

Whatever the area of the VET/HVET centre that is studied, it is important to consider 3 dimensions: the organizational, the technological and the educational

ORGANIZATIONAL	TECHNOLOGICAL	EDUCATIONAL
Management of activities, routines, work dynamics, indicators, results obtained, etc.	IT systems, the level of digitalisation and automation, applications available, technology, etc.	Study programs, learning outcomes, expected competences, upskilling programs, learning methodologies, skill gaps etc

A widely used method to diagnose a current (digital) situation of an organization is the **digital maturity models or digital readiness models**. Many of those are embedded in **Self-Assessment Tools (SAT)** for digital diagnosis purposes. SATs give companies the ability to check their own Industry 4.0 readiness.

There are several of those models published, most of them developed for industry, that include manufacturing companies. It is interesting to note that whatever the model , all of them cover at least the following areas:

- Strategy
- Processes
- People
- Technology
- Products

The following is a non-exhaustive selection of digital maturity/readiness model and tools:

- **IMPULS Industry 4.0 Readiness Online Self-Check for Businesses source: (IMPULS, 2015)**

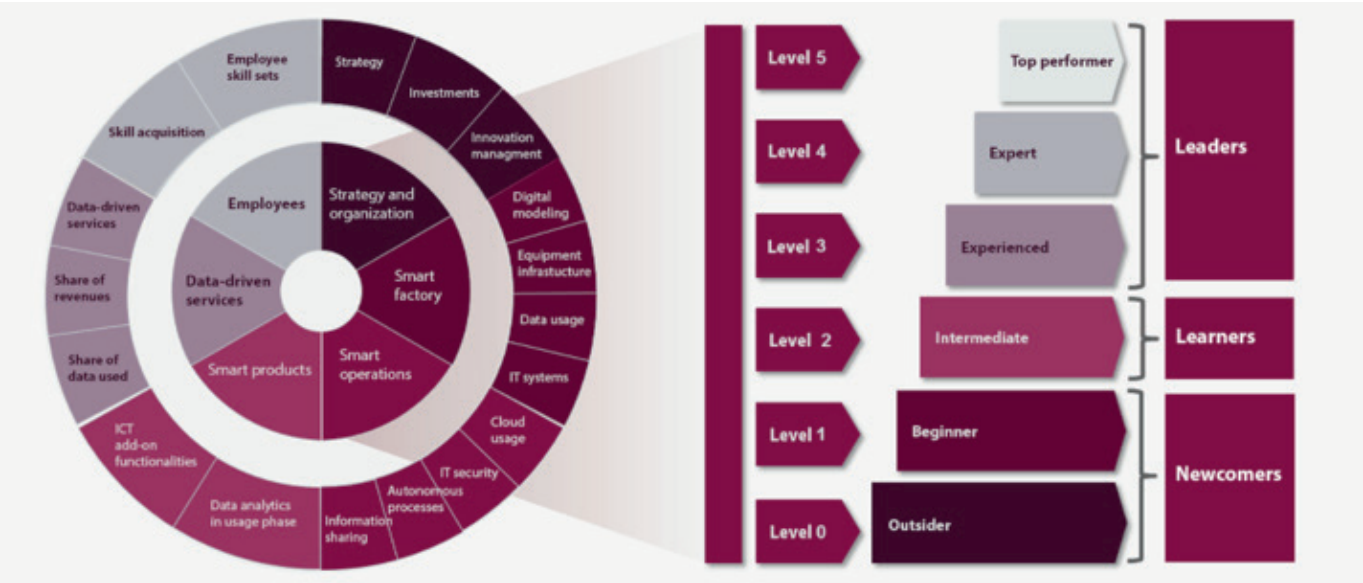


Figure 2. Industry 4.0 readiness Source:IMPULS

- **Acatech, Industrie 4.0 Maturity Index (Acatech, 2020)**

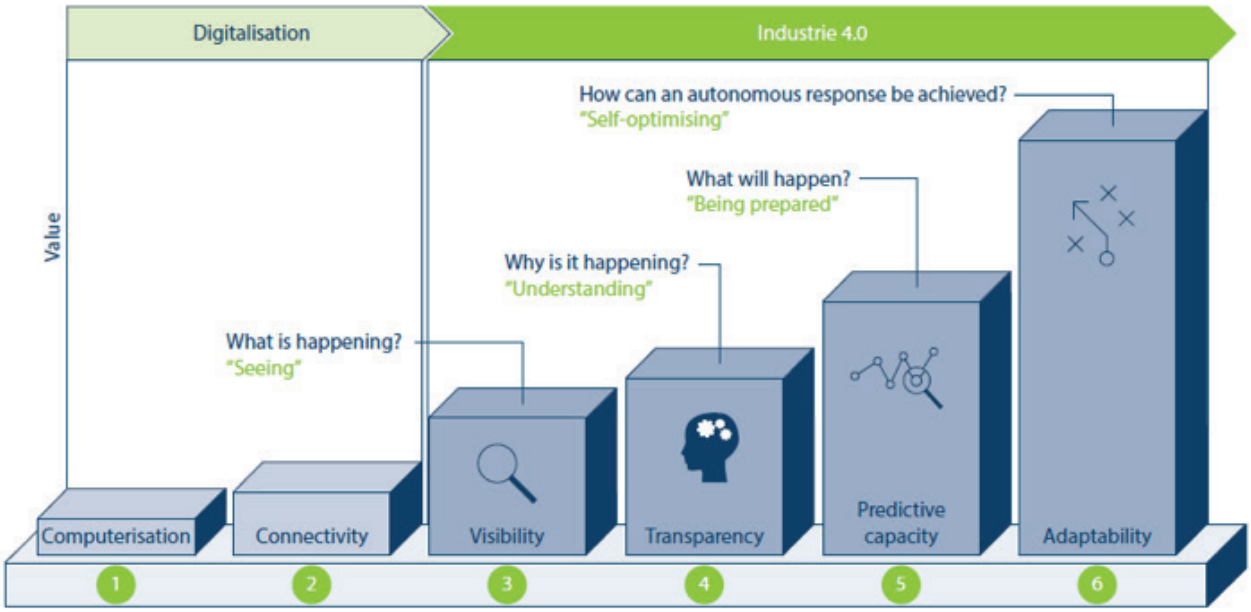


Figure 3. Stages in the Industry 4.0 development path Source: FIR e. V. at RWTH Aachen University

- **ADMA European Advanced Manufacturing support (ADMA, 2020)**
- **Industry 4.0 maturity index, i4.0m centre (Schuh, 2017)**
- **The Singapore smart industry readiness index (SEDB, 2021)**

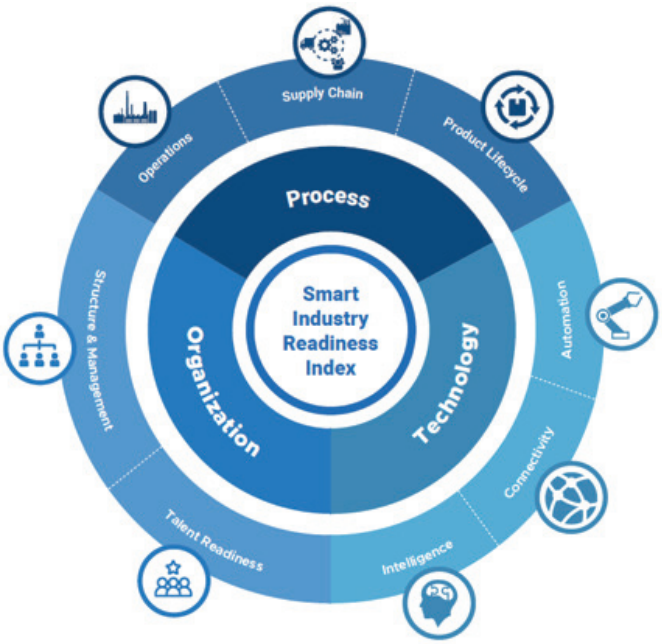


Figure 4. The 3 building blocks and the 8 pillars of the SIRI model. Source: Singapore Economic Development Board SEDB 2021

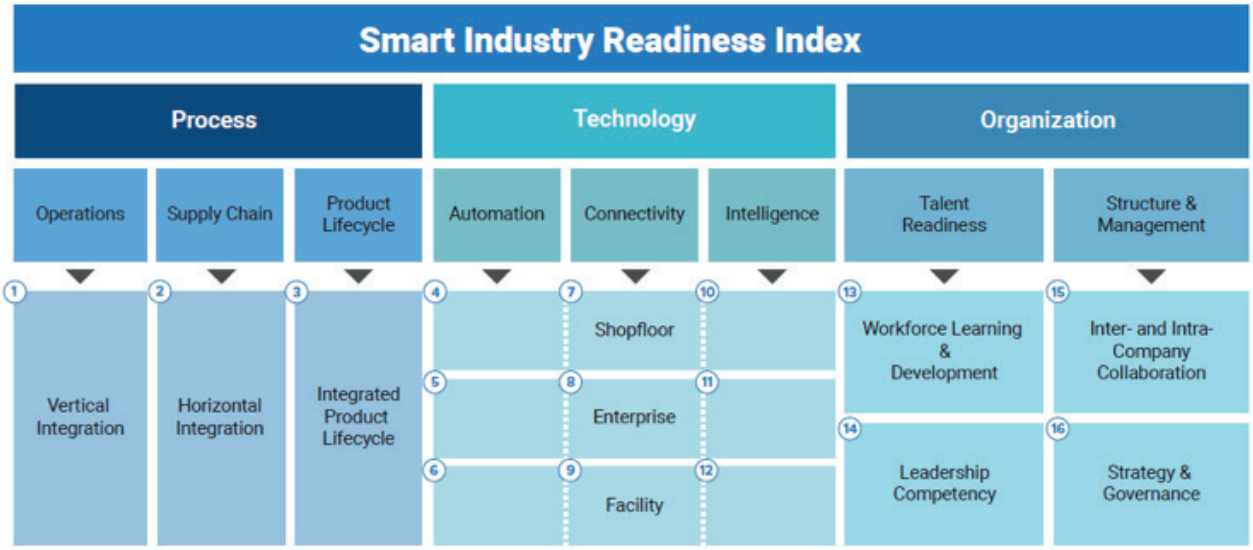


Figure 5. The 16 dimensions of assessment Source: Singapore Economic Development Board

- **HADA (Spanish) The Advanced Digital Self-Assessment Tool (HADA) Herramienta de Autodiagnóstico Digital Avanzada (Industria Conectada, 2018)**

Figure 6. HADA self Assessment tool for digital transformation Source: Industria Conectada 4.0

- **CapGemini Digital manufacturing maturity assessment (Capgemini)**
- **Stratechi, PROCESS MATURITY LEVELS (Stratechi, 2021)**

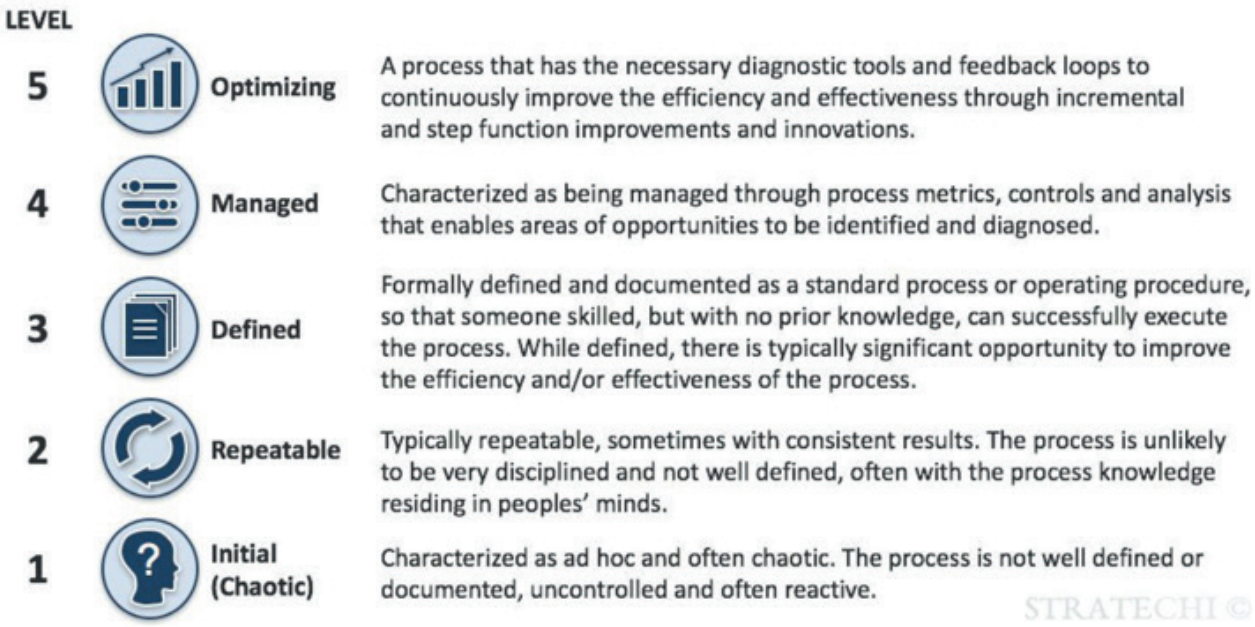


Figure 7. Process maturity levels – Source: Stratechi

Maturity models and Self-assessment Tools (SAT) for education

The EU commission set up the SELFIE SAT for students and staff in VET SELFIE (Self-reflection on Effective Learning by Fostering the Use of Innovative Educational Technologies) is a free tool designed to help schools embed digital technologies into teaching, learning and assessment. (EUROPEAN COMMISSION 2018). SELFIE has a strong basis in research and was developed based on the European Commission Framework on promoting digital-age learning in educational organisations (Kampylis, P., Punie, Y. and Devine, J., 2015)

However, the Selfie SAT is not focused on industry 4.0 technologies related to Advanced Manufacturing labs. A practical solution for a VET/HVET centre could be to select an industry-oriented maturity model and adapt it to the requirements of VET/HVET lab analysis.

3.4. Define future situation, ambitious but achievable (Target Condition)

Once we are aware of the current situation of our institution regarding the digital transformation, it is time to define what we would like to achieve: In this case, we are focusing on industry 4.0 related implementations in VET/HVET institutions, interventions to enhance hands-on education and training at advanced manufacturing lab level.

In order to define this achievable desired situation we can use Continuous improvement methods as Toyota KATA. (Wikipedia, 2021)

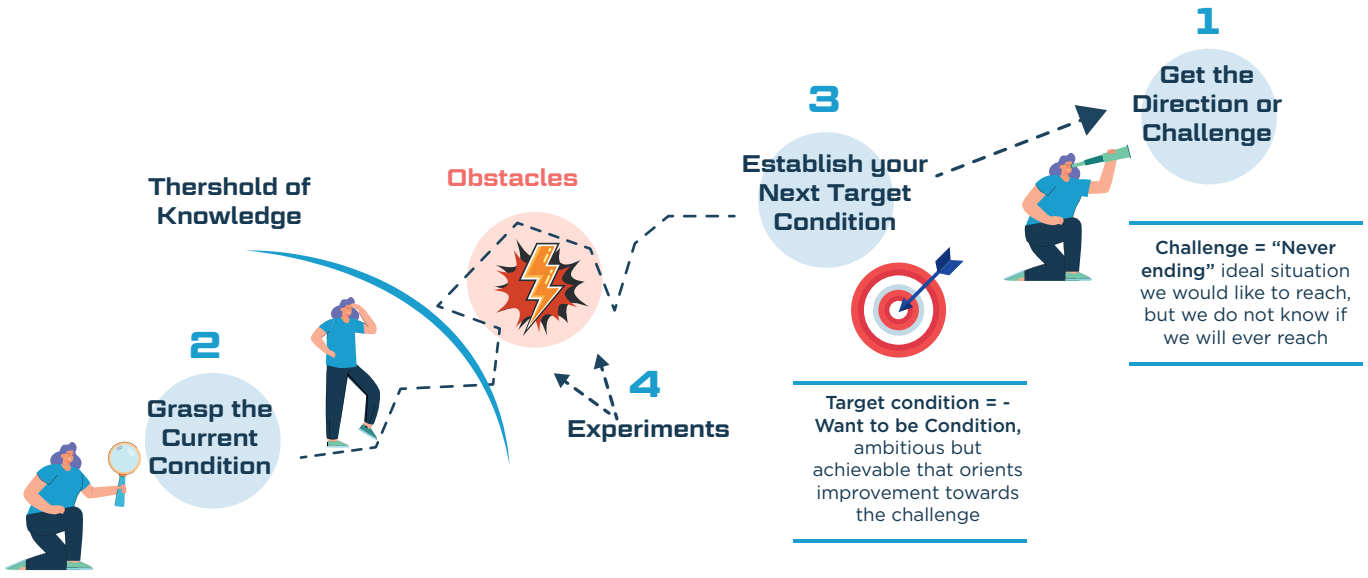


Figure 8. The improvement Kata pattern
Source: Exam 4.0

As a result of this analysis, we would have identified those actions or activities we need to prioritize in order to achieve the challenge.

A useful tool for identifying action is the “4 boxes”, a tool to guide improvement in the medium-long term. Using the four-box tool, we start from the current situation of the organisation to determine the actions to be taken to reach a desired scenario.

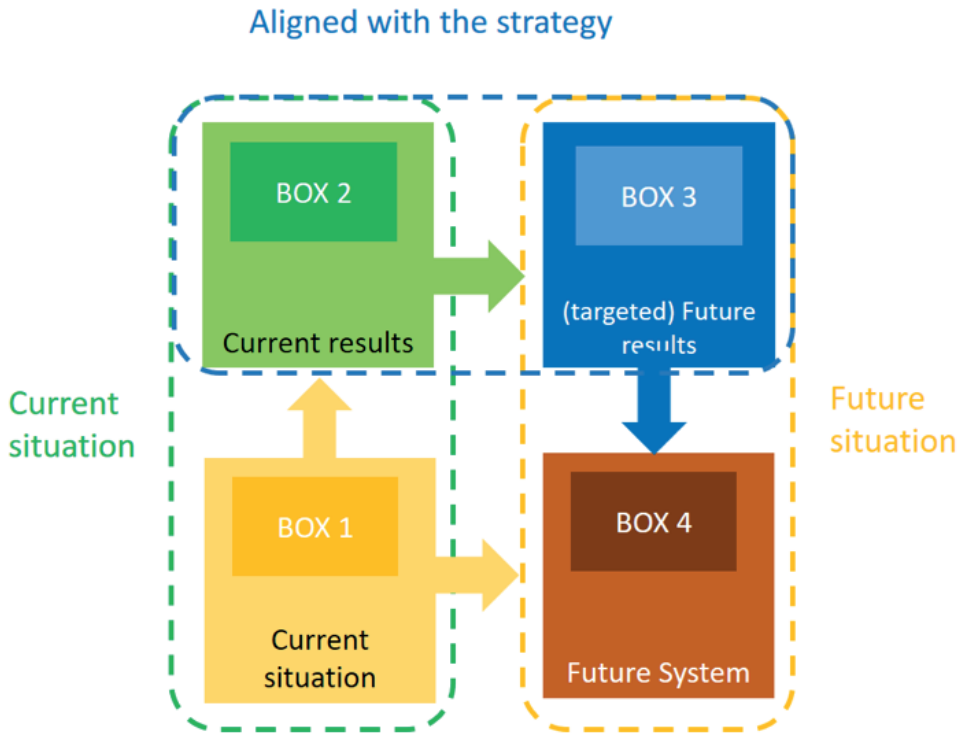


Figure 9. 4 boxes, a tool to guide improvement in the medium-long term. Source: Renault Consulting

BOX 1 Current system (understanding how our system works)	The first step is to identify what our system’s current situation is in order to understand the starting point. It is important to consider all the pillars of the system
BOX2: Current Results: They are the consequence of the functioning of the system	The objective is to improve the profitability and competitiveness of the company in a sustainable way. Normally in this box, we put Performance KPIs related to Competitiveness and Profitability
BOX3: Future results: what we aim to improve in a given period Want to be Condition	The objectives of the situation must come from the deployment of the strategy. In this box we must put the ambitious but achievable Want to Be that we have set as an intermediate situation in order to get closer to the "challenge" set. The same KPIs should appear as in Box 1 with a different value.
BOX4 Future System: what we need to change in our system	We must build the best possible system, in order to achieve future results.

Figure 10 – Stages of the 4 box method ; Source:Exam 4.0.

Other tools to Identify opportunities

- Quick-Check I 4.0
- Business Model Canvas
- Design Thinking Workshop
- Value Stream Analysis

3.5. Create a roadmap

WHAT IS A ROADMAP?

A roadmap is a **planning** tool that visually represents the sequence of steps to be taken to achieve an objective. It can be understood as a short, medium and long-term action plan, and is responsible for bringing strategic objectives closer to more tangible and achievable goals.

It is a mechanism to **monitor progress**, control the scope and manage the project to ensure the results within the defined timeframe and budget.

It is also a **mechanism to communicate** the overall vision of the project and the progress made and to engage project stakeholders.

The following figure shows the main features of a roadmap:

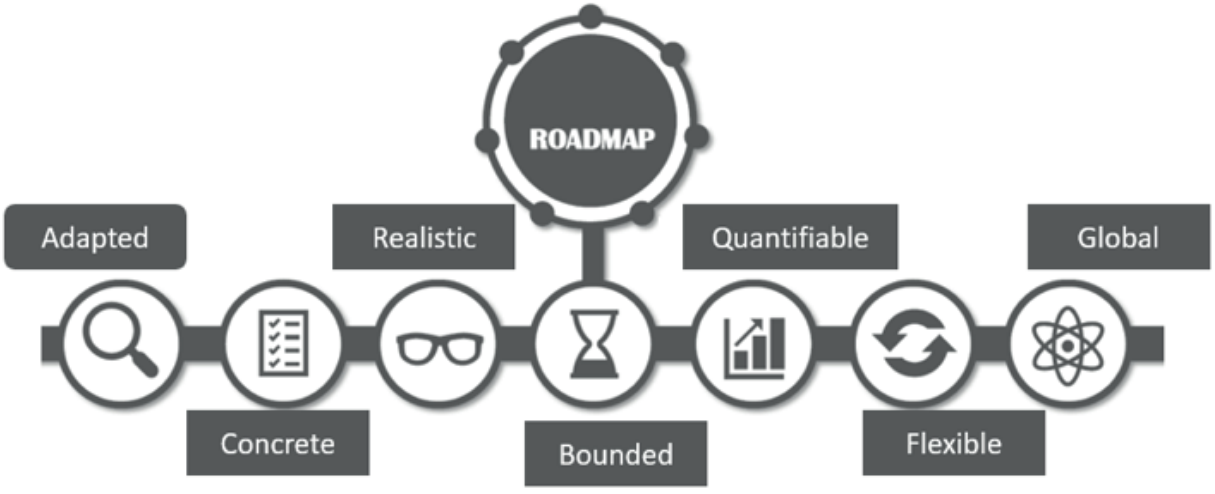


Figure 11. Features of a roadmap Source: Renault Consulting

ADAPTED	The Roadmap must be ADAPTED to the time frame which it is defined for. • **An organisation's overall Digital Transformation Roadmap** will have a time frame of 2-3 years and the actions represented will have a low level of detail. • **The Roadmap of a specific Digital Challenge** will have a time frame of months or a year with more detailed actions.
CONCRETE	The Roadmap should be CONCRETE and divided into PHASES. - The Roadmap should express in a simple and concrete way the steps that will be taken to achieve the stated objectives.
REALISTIC	The Roadmap should be adapted to the available resources. We must include only those tasks that can be developed within the established time frame, with the existing competencies, availability and budget to avoid frustrations or false expectations.
TIME-BOUND	Each phase should have specific dates. This will help to ensure that deployment is not delayed and that we have an overview of the time frame of the transformation, project or digital challenge.
QUANTIFIABLE	The tasks associated with the Roadmap must have a series of metrics that allow us to measure the progress of the actions and the evolution of the associated KPIs.
FLEXIBLE AND DYNAMIC	It should adapt to changes and be as flexible as possible so that it can be readjusted and follow the correct orientation.
GLOBAL	The Roadmap should, as far as possible, consider the fundamental pillars of the Digital Transformation (people, processes and technology) in a coordinated manner so that progress is sustainable.

Table 1: Characteristics of a roadmap Source:Exam 4.0

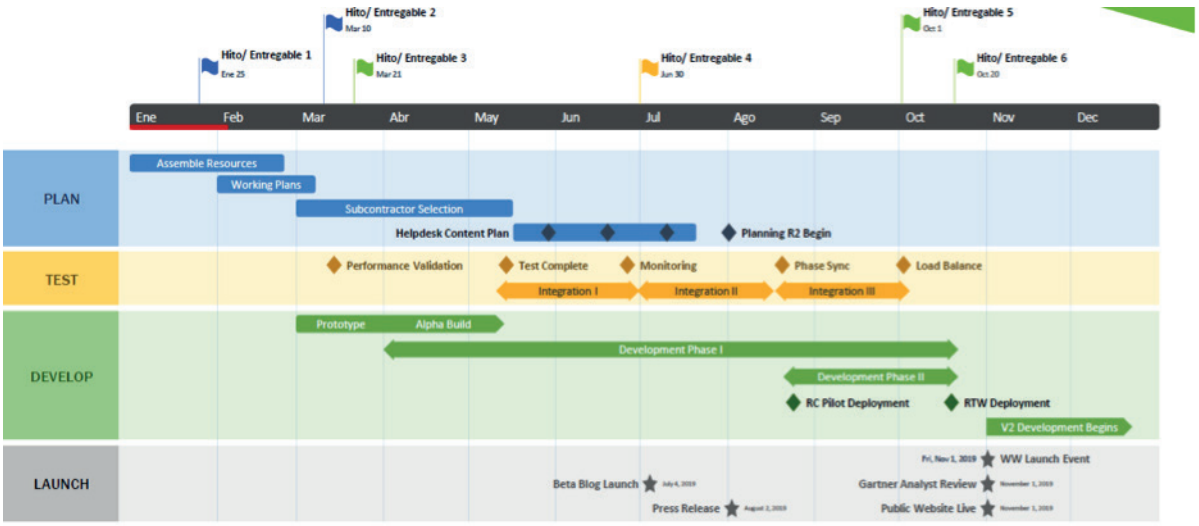


Figure 12. Example of roadmaps Source: Renault consulting

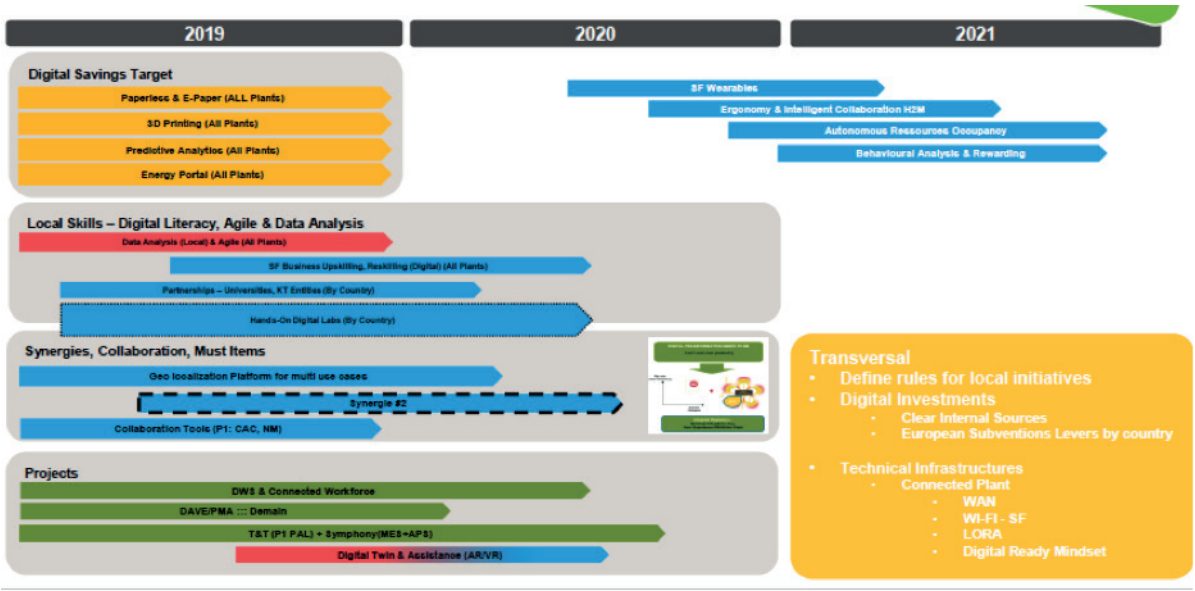


Figure 13. Example of roadmaps Source: Renault consulting

3.6. Action plan, quick wins

The Digital Transformation Roadmap must, on the one hand, contemplate transversal actions focused on achieving cultural change (improvement of competencies, communication, involvement of all collaborators) and, on the other hand, simultaneously carry out those **quick win actions that provide tangible results and help to gain credibility and continue working in the long term while improving results in a sustainable manner.**

Some TIPS:

Implementantion in Double - Direction

Start in a "**top-down**" mode from the strategic vision (objectives and actions to be deployed at different levels of the organization).

Incorporating a "**bottom-up**" approach by starting with the implementation of quick wins.

Figure 14. Top-down and bottom up implementations: Source Exam4.0

One of the main challenges that all institutions, VET/HVET centres will face is the **Resistance to change** among part of the staff. There are many methods available in change management literature; We have taken *Kotter's 8 steps for change management* as an example (Kotter, 2016)

KOTTER'S 8-STEP MODEL FOR CHANGE MANAGEMENT	
8. Anchor change in the company's culture	They must institutionalize these new changes: changes are "susceptible to a regression and degradation" until they have taken root in the company's structure and culture. To achieve this, they must communicate the improvements and ensure that the top management of the institution is committed to the change.
7. Sustain acceleration	Build on the same change. Efforts must be made to ensure that each improvement is consolidated.
6. Generate short-term wins	Communicate all successes and small wins. Kotter argues that, since real change is long and difficult, it is important to motivate workers with each new breakthrough. Yet, do not declare victory prematurely.
5. Enable action by removing barriers	Reduce barriers and facilitate change by motivating all employees to act in accordance with this vision.
4. . Communicate the vision	Communicate that vision
3. Form a strategic vision and initiatives	Create a vision of how the company should be digitally transformed.
2. Build a guiding coalition	Establish a good organizational and teamwork system, creating a team of change leaders.
1. Create a sense of urgency	Help others see the need for change through a bold, aspirational opportunity statement that communicates the importance of acting immediately.

Table 2: Kotter's 8 Dimensions Source: (Kotter, 2016)

3.7. Rate impact of the actions of the roadmap and calculate ROI

Each institution must establish their own “control tower” to rate the impact of the actions.

Usually a monitoring scheme is built, where the impact is rated, and some decisions are taken:

For instance

- Monthly follow-up meetings to monitor ongoing projects
- Impact rate: In VET/HVET the method to rate the impact must be decided in many cases in different terms from industry: %of programs using labs, Number of students/staff impacted, % efficiency of labs… The ROI calculation varies also from industry.
- Profit validation committee for validating new projects, to decide whether they are accepted or not.

In EXAM4.0, we are proposing recommendations addressing VET/HVET institutions. Being those education bodies, the parameters to rate the impact are different from those used in industry. VET/HVET institutions will not be focused only on efficiency and profitability. The Return of Investment (ROI), is widely used in industry as a performance measure. The ROI is used to evaluate the efficiency of an investment or to compare the efficiency of several different investments. However, the ROIs in educational institutions should be calculated considering also some pedagogical aspects.

We therefore need to define the right KPIs to assess impact in VET institutions. KPIs linked to our educational and training activity more than efficiency of production facilities.

3.8. Scaling up solutions within the organization and seeking new opportunities

The final step included in this guide is the scaling up of the finding to other areas of the VT/HVET centre.
Needless to say that this is a process of continuous improvement, once implemented, its scalability will encompass the transformation of the entire organisation.

4 Stakeholder Perspective

The following table contains suggestions and recommendations of the EXAM 4.0 HUB for several stakeholders (European and regional policy makers, VET/HVET authorities, VET/VET providers, AM companies and Employers Association, Networks) on how to face the challenge of Industry 4.0 (technologies and skills needs) and on the approaches to foster the incorporation of emergent technologies into the VET/HVET systems and AM companies.

STAKEHOLDER GROUP	RECOMMENDATION
EUROPEAN POLICY MAKERS	Support the collaboration in the Advanced Manufacturing Strategic Triangle at European level through projects, tenders, conferences, and workshops.
	Support collaborative research with Universities, Advanced Manufacturing VET/HVET centres, Advanced Manufacturing companies, and experts/researchers in I4.0, I5.0 and Advanced Manufacturing, to: • identify new occupational profiles in Advanced • identify new qualifications and update curricula • Manufacturing. • Define the paradigm shift from I4.0 to I5.0 • Identify digital skills • Identify soft skills • Micro credentials • Validation of prior learning • Implementation of new technologies (I4.0 enabling technologies) in VET/HVET labs.
	Support the scaling up of EXAM 4.0 and only allow the establishment of a new platform of centres of vocational excellence in Advanced Manufacturing if it is related to the pioneer EXAM4.0
	Recognise the relevance of VET/HVET in Regional Smart Specialisation Strategies.

STAKEHOLDER GROUP	RECOMMENDATION
REGIONAL POLICY MAKERS	Support the collaboration in the Advanced Manufacturing Strategic Triangle at regional level through projects, tenders, conferences, and workshops.
	Support collaborative research with Universities, Advanced Manufacturing VET/HVET centres, Advanced Manufacturing companies, and experts/researchers in I4.0, I5.0 and Advanced Manufacturing, to: • identify new occupational profiles in Advanced • identify new qualifications and update curricula • Manufacturing. • Define the paradigm shift from I4.0 to I5.0 • Identify digital skills • Identify soft skills • Micro credentials • Validation of prior learning Implementation of new technologies (I4.0 enabling technologies) in VET/HVET labs.
	Recognise the relevance of VET/HVET in Regional Smart Specialisation Strategies. Invest more resources in Advanced Manufacturing VET/HVET, especially in the updating of Advanced Manufacturing labs through the introduction of cutting-edge technologies and the promotion of Work Based Learning in all its forms.
	Keep an eye on the latest developments in European VET/HVET and Industrial policies and align regional strategies to them.
	Promote the European initiative on Platforms of centres of vocational excellence at regional level.
VET/HVET AUTHORITIES	Design new Advanced Manufacturing curricula including in it I4.0 technologies and following the EXAM 4.0 competence framework.
	Design micro-credentials for Advanced Manufacturing workers.
	Support the implementation of I4.0 cutting edge technologies in VET/HVET centre labs.
	Keep an eye on the latest developments in European VET/HVET and Industrial policies and align regional strategies to them.
	Promote the European initiative on Platforms of centres of vocational excellence among their VET/HVET centres.
	Support teachers in their up- and reskilling process.

STAKEHOLDER GROUP	RECOMMENDATION
VET/HVET PROVIDERS	Follow learner centric approaches and methodologies.
	Align with regional Smart Specialisation Strategies.
	Collaborate with Universities and Research and Technology centres with expertise in Advanced Manufacturing and I4.0, with Advanced manufacturing companies, with other Advanced Manufacturing VET/HVET centres, with social partners and employers, and with educational and labour authorities.
	Adapt Advanced Manufacturing courses to the changes of I4.0 and I5.0.
	Design new Advanced Manufacturing courses including in them I4.0 technologies and following the EXAM 4.0 competence framework.
	Keep an eye on the latest developments in European VET/HVET and Industrial policies and align strategies to them.
	Join the EXAM4.0 platform and community.
	Implement new technologies in Advanced Manufacturing labs following the Collaborative Learning Factory model developed in EXAM4.0.
	Strengthen Work Based Learning in all its forms.
AM COMPANIES	Collaborate with VET/HVET centres and authorities in the design of new Advanced Manufacturing curricula including in it I4.0 technologies and following the EXAM 4.0 competence framework.
	Collaborate with VET/HVET centres and authorities in the design of micro-credentials for Advanced Manufacturing workers.
	Join the EXAM 4.0 platform and community.
	Keep an eye on the latest developments in European VET/HVET and Industrial policies and align strategies to them.
	Reflect on the implications of the I5.0 paradigm.
	Collaborate with VET/HVET centres to strengthen Work Based Learning in all its forms.

STAKEHOLDER GROUP	RECOMMENDATION
AM EMPLOYER ASSOCIATIONS	Collaborate with VET/HVET centres and authorities in the design of new Advanced Manufacturing curricula including in it I4.0 technologies and following the EXAM 4.0 competence framework.
	Collaborate with VET/HVET centres and authorities in the design of micro-credentials for Advanced Manufacturing workers.
	Join the EXAM 4.0 platform and community.
	Keep an eye on the latest developments in European VET/HVET and Industrial policies and align strategies to them.
	Reflect on the implications of the I5.0 paradigm.
	Collaborate with VET/HVET centres and authorities to strengthen Work Based Learning in all its forms.
NETWORKS	Promote the European Initiative on Centres of Vocational Excellence among their members.
	If they are Advanced Manufacturing specific networks, sign Memorandums of Understanding with the EXAM4.0 platform and community.
	Invite their Advanced Manufacturing members to join the EXAM 4.0 platform and community.
	Disseminate EXAM 4.0 among their members.

Table 3: Stakeholder groups recommendations Source: Exam 4.0 2021

5 Systems perspective - Work-Based Learning

5.1. Work-based learning and its role in Advanced Manufacturing

Educational policy strategies in Europe give work-based learning (WBL) and dual learning pathways a prominent role in addressing Globalisation, technological changes and the industry-to-service economy transition. There is increasing discontent among employers regarding graduates' lack of appropriate skills on entry into graduate employment (Moore & Morton, 2017), in what has been labelled the 'skills gap' (Schwartz & Riss, 2021). For example, it is predicted for Germany that in the next five years around 2.4 million employees will lack the necessary cross-disciplinary skills (Tobias Enders, Viktor Hediger, Solveigh Hieronimus, Julian Kirchherr, Julia Klier, and Jorg Schubert, and Mathias Winde, 2019).

These challenges demand closer collaboration among VET/HVET institutions, policy makers and the world of work to gain a more in depth and industry specific understanding of the changes in the labour market, thus affecting VET/HVET education. It is no longer sufficient to provide students with disciplinary knowledge.

In this context, work-based learning (WBL) emerges as a relevant approach as it provides students learning experiences oriented for the appreciation of work and practical knowledge.

Graduates are also expected to be adaptive, innovative and flexible. As these competencies are better developed in connection with practice, this implies modifications in the learning design.

The European Qualifications Frameworks for Lifelong Learning (EQF for LLL), for instance, makes a distinction between three types of learning: 'knowledge' acquisition, 'skills' development and 'autonomy and responsibility' (EC 2008). The New Skills Agenda 2020 puts improvements in education and training systems as critical steps for the EU to improve its competitiveness and achieve sustainable growth (CEDEFOP, 2016).

As dual VET systems have mostly institutionalized stronger linkages between school- and work-based learning contexts when compared to more school-based VET systems (Rözer & van de Werfhorst, 2020), dual VET can offer students alternative learning content and methods that are more attractive to young people who are less interested in academically oriented school-based education (CEDEFOP, 2016).

However, despite the increasing awareness of the benefits of WBL, there are several structural issues that (still) restrain its expansion in the EU. First, the WBL tradition is not consistent across European borders. While it has a long tradition in some countries, it is still an emerging concept in others (CEDEFOP, 2016). Second, there is a great disparity in WBL adoption across disciplinary areas.

5.2.Vocational Education and Training Policy Development in Europe

At the European Council in Lisbon in 2000, heads of state and government addressed questions of education policy for the first time, with the result that education and training, along with employment, business and research, were seen as central elements in the economic and social agenda of the European Union.

In Copenhagen in November 2002, a resolution was adopted on the promotion of enhanced European cooperation in VET (Council of the European Union 2003). The key priorities for cooperation within the Copenhagen Declaration were as follows (European Union 2002, 2–3):

- **European dimension** – Strengthening the European dimension in VET and promoting mobility and the development of inter-institutional cooperation.
- **Transparency, information and guidance** – Increasing transparency in VET through the implementation and rationalisation of information tools and networks; strengthening policies, systems and practices that support information, guidance and counselling.
- **Recognition of competences and qualifications** – Promote the transferability and recognition of competences and/or qualifications through the development of reference levels, common principles for certification and joint actions, including a credit transfer system for VET; ensure better compatibility between different countries.
- **Quality assurance –** Place special emphasis on the exchange of models and methods as well as on common criteria and principles for quality in VET; consider the learning needs of teachers and trainers in all forms of I–VET and C-VET.

The adoption of the Bruges Communiqué in December 2010 outlined a series of actions to increase the quality of vocational education and training (VET) in Europe in order to make it more accessible and relevant to the labour market. The Bruges Communiqué is the update to the Copenhagen Process for European co-operation on VET – European Quality Assurance in Vocational Education and Training EQAVET is a result of this process (EQAVET, 2019).

The Bruges Communiqué, which defines the European VET strategy up to 2020, called for an active policy to enhance the potential of VET to support smart and sustainable growth, and to turn VET across the EU into a highly attractive learning choice (Rethinking Education: Investing in skills for better socio-economic outcomes, 2012).

European cooperation on vocational education and training (VET) has been further enhanced by the Riga Conclusions (2015). EU Member states, Candidate countries, European Economic Area Countries, social partners and European VET providers have agreed on a set of deliverables for the period 2015–2020:

- Promote work-based learning in all its forms
- Further develop quality assurance mechanisms in VET
- Enhance access to VET and qualifications for all through more flexible systems–
- Further strengthen key competences in VET curricula
- Introduce systematic approaches to initial and continuous professional development of VET teachers, trainers and mentors (Riga Conclusions, 2015).

As mentioned, the Copenhagen Declaration (European Union 2002) set out a strategy for achieving the Lisbon objectives: it reaffirmed the commitment to strengthening cooperation in VET in order to remove obstacles to occupational and geographical mobility and promote access to lifelong learning. This meant implementing concrete measures to increase the transparency and recognition of competences and qualifications within VET systems. Part of this strategy has been developed in Spain at the training level, especially by facilitating access to I–VET and allowing VET graduates to move into higher education.

At the time the Bruges-Copenhagen process resulted in an agreement on the European Qualification Framework (EQF), the Spanish National Qualification System was just being enforced, shifting it immediately to the EQF structure. Spain first adopted European proposals in the early 1990s, and since these proposals were implemented, there has been an accommodation process that has resulted in the EQF becoming a tool to compare Spanish VET qualifications with those in other European countries.

Spain has not only adopted the wording behind the Copenhagen Declaration but also aligned itself in the same direction: the foundation of its current VET system can be clearly correlated with the Copenhagen principles and pillars such as transparency, modularity, competency and lifelong learning.

Today, the EU Commission's work on VET is supported by two agencies: European Centre for the Development of Vocational Training (Cedefop) and European Training Foundation (ETF). Financial instruments that support VET policy are: Erasmus+ Programme (with Erasmus+ Strategic partnerships) and European Social Fund (ESF). The Advisory Committee on Vocational training endorsed an "Opinion on the future of VET post 2020" (2018).

Taking into consideration the proposal for a Council recommendation on VET for sustainable competitiveness, social fairness and resilience, as well as the updated European Skills Agenda, the Osnabrück Declaration focuses on four main areas for the years 2021 to 2025:

1. Resilience and excellence through quality, inclusive and flexible VET
2. Establishing a new lifelong learning culture – relevance of C-VET and digitalisation
3. Sustainability – a green link in VET
4. European Education and Training Area and international VET

(OSNABRÜCK DECLARATION 2020, 2020)

BOX 1. SELECTED KEY EU DOCUMENTS

Memorandum on Vocational Training in the European Community (1990)

Copenhagen Process and The Copenhagen Declaration for enhanced European cooperation in vocational education and training.

Maastricht Communiqué (2004) on the Future Priorities of Enhanced European Cooperation in Vocational Education and Training (VET); expands upon the Copenhagen declaration and includes national level priorities.

Bruges Communiqué (2010) - "…vocational excellence for smart and sustainable growth." "VET providers to collaborate with enterprises, design centres, cultural sector, and HE in forming "knowledge partnerships"

Rethinking Education Communication (2012) called on Member States to promote "high-quality dual VET systems, aligning VET policies with regional/local economic development strategies namely for smart specialisation"

Riga Communique (2015) set out the deliverables for European cooperation on vocational education and training for the period 2015-2020

New Skills Agenda for Europe (2016): Working together to strengthen human capital, employability and competitiveness

New Skills Agenda for Europe (2020): For sustainable competitiveness, social fairness and resilience.

Strengthening Innovation in Europe's Regions: Towards resilient, inclusive and sustainable growth at territorial level (2017) was the first document dedicated to Smart Specialisation that strongly promoted the role of VET

Platforms of Centres of Vocational Excellence (2018): Networks of VET institutions will be tasked to link their activities with S3 and cooperate at European level with the support of the Erasmus+ programme

Council Recommendation (2020) on vocational education and training (VET) for sustainable competitiveness, social fairness and resilience

Osnabrück Declaration 2020 on vocational education and training as an enabler of recovery and just transitions to digital and green economies. Declaration of the Ministers in charge of vocational education and training of the Member States.

5.3. Work-based Learning Today

For VET/HVET institutions embedded Work-based Learning in the operational strategy. Today, three different formal I–VET levels are offered: lower secondary basic VET (ISCED 353), targeting learners over 15; upper secondary intermediate VET (ISCED 354), targeting learners aged 17–18; and higher VET (ISCED 554), targeting learners over 18. All three provide VET qualifications that have academic and professional validity. They are modularised and include compulsory workplace learning. Learners need to pass all modules to obtain the relevant qualification. Modularisation allows partial certification and re-engagement from a lifelong learning perspective. VET qualifications today are based on learning outcomes with a strong focus on work-based learning and following ECVET guidelines (CEDEFOP, 2021c).

VET and education sectors have examples of positive partnerships between education and training institutions and workplaces.

Work-based learning extends across all areas of education, training and employment, i.e. apprentices with the day to day requirements of their job with related learning, adult learners in the labor market, taking part in continuous learning and skills development, young people and adults gaining occupational and soft skills through activity in a workplace or in the work environment (Grazia Violi et al.).

From a strategic perspective, the provision of high-quality Work-based Learning lies at the heart of current education and training policy, with education – industry collaboration regularly prioritized (at all levels) and work-based learning increasingly recognized as a means of ensuring that learners of all ages are provided with the competencies required by a labour market.

While many of these programs and partnerships are successful, large businesses are more likely to have the resources and impetus to support these programs. They can demonstrate a commitment to work-based learning because they see its value to their businesses, and work-based learning is often supported by the senior executive leadership" (Atkinson, 2016). On the other hand, small to medium enterprises (SMEs) can struggle to find the resources, time and effort required to supervise programs.
This is where the EXAM4.0 platform and collaborations among education and training providers, the world of work and intermediaries can play a vital role — in promoting work-based learning to SMEs and supporting them to engage in work-based learning. Emerging technologies and work organisation formats are expected to be captured faster through skills anticipation systems and translated to VET provision in terms of needed skills, curricula and qualifications.

The EXAM4.0 platform services and monitoring activities, such as the skills assessment and sector-specific profiling highlight the fact that cooperation and support for SMEs is crucial. Involving education and coaching targeting training supervisors at the companies and focusing on labour market legislation, pedagogical skills, soft skills and behavioural psychology aspects may overcome SMEs reluctance to employ trainees or apprentices.

5.4. Systematic Integration of Work-Based Learning

5.4.1. Apprenticeship Models

Apprenticeships are an effective form of work-based learning in vocational education and training that ease the transition from education and training into work. In order to ensure that apprenticeships are beneficial for both the apprentices and the employers, EU Member States agreed on a European Framework for Quality and Effective Apprenticeships (EFQEA). (EUROPEAN COMMISSION, 2021b).

The European Commission defines apprenticeships as formally combining and alternating company-based training (periods of practical work experience at a workplace) with school-based education (periods of theoretical/practical education followed in a school or training centre), and lead to nationally recognised qualification upon successful completion.

The European Commission's definition of an apprenticeship highlights the following:

- it is part of the formal VET system;
- it involves a dual learning principle which combines or alternates enterprise-based training (periods of practical experience at a workplace) with school-based education (periods of theoretical/practical education in a school or training centre);
- completing the apprenticeship leads to a nationally recognised IVET certificate/degree;
- there may be a contractual relationship or agreement between an employer and apprentice

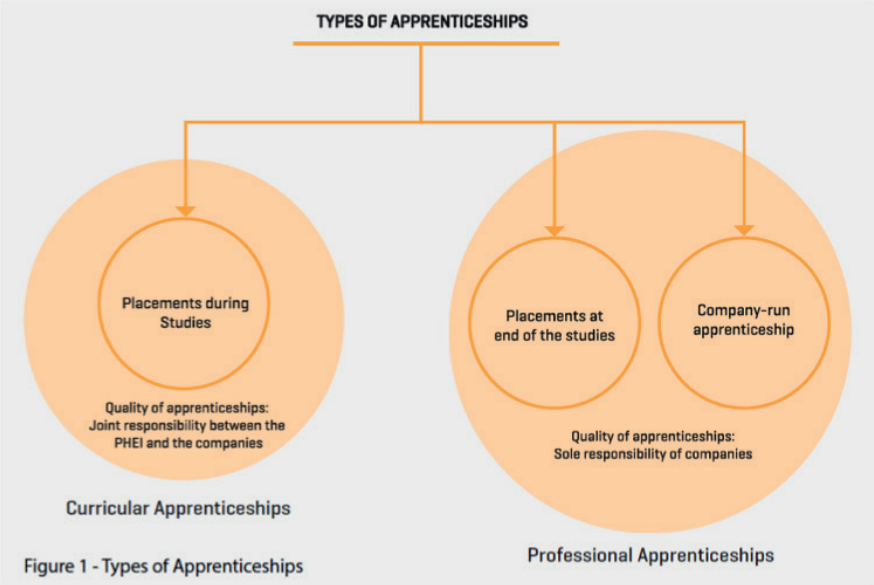


Figure 15: Types of Apprenticeships Source: DHBW AppQ Project 2019

5.4.2. General Overview of Themes in EU Countries:

Apprenticeship as a separate track

In these countries an apprenticeship is primarily led by an enterprise and is seen as part of the initial VET system. In these situations an apprenticeship is one option, alongside school-based formal initial VET, that is available to young people after completing compulsory education. It is one way to achieve a legally-recognised vocational qualification. For these countries apprenticeships combine in-company training with school-based/theoretical learning. Apprentices are formally employees and apprenticeship contracts are employment contracts. Examples of this type of provision can be seen in France, Finland, Ireland, UK and Italy.

Apprenticeships are integrated into school based initial VET

In most countries with school-based initial VET and without an apprenticeship tradition, the legal/formal definition of an apprenticeship is often missing. The apprenticeship does not form a separate vocational pathway in initial VET. In these systems initial VET includes work-based learning and work placements. Sometimes the work-based learning parts of these schemes are referred to as apprenticeships. In these systems apprentices are legally students and where there are contracts, they are usually concluded between school and enterprise. Typically the share of work-based learning is lower than in the first model. Examples of this type of system can be found in CZ and SK.

Work-based learning programmes

Some countries have developed apprenticeship-like programmes (they are usually called 'work-based learning programmes'). These are not legally part of the formal VET system even though they include some theoretical study in a vocational school. The programmes (e.g. in EE and LV) usually lead to a recognised certificate or qualification and address various labour market needs such as finding ways for the unemployed to return to work.

Apprenticeships are integrated into school based initial VET

Some countries (Germany, Austria, Switzerland) have developed apprenticeship-like dual study programmes (they are usually called 'Dual study"). These are legally part of the formal HVET or PHE system and they have alternating phases of theoretical study and work-based training in a company.

Traineeship

In some countries there are short-term vocational programmes. These are traineeships which are not connected to the formal education system – they do not lead to a nationally recognised certificate or qualification even though they are often referred to as an 'apprenticeship' (e.g. EL). These programmes usually focus on those who are unemployed and/or NEET in order to support their entry into the labour market.

5.5. Dual System

In the case of Germany and Switzerland **Education (Bildung)** and **vocation or occupation (Beruf)** were and still are conceived as congruent, not rivalling concepts. The concept of **Beruf** as an element and part of **Bildung** has shaped the educational discourse. German firms employ a high proportion of the workforce with intermediate level qualifications, in particular in the big companies and the craft sector.

Higher education system in Germany – e.g. with the Cooperative State University in Baden-Württemberg (vocational academies which combine academic and practical training) now called 'dual universities' is a collaborative system among the stakeholders - students, world of work and companies. They copy the structure of learning sites of the dual system by also focusing on specific structural features of cooperation between companies and higher education institutions. Two learning venues, the practical relevance of an apprenticeship together with the simultaneous scientific relevance of the competences needed in a company, the strong involvement of companies, and an explicit reference to degrees needed in the labour market, as well as the didactic and curricular interlocking of theory and practice – all these principles were inherited from the much older apprenticeship system.

They form a marginal sector within the vocational training systems, dual apprenticeships exist in nearly all branches of the German economy including the professions and parts of the civil service. When training in a 'declared trade' or 'recognised training occupation' (Ausbildungsberuf) trainees make use of two learning sites: the training company (Ausbildungsbetrieb) and the part-time vocational school (Berufsschule), with compulsory school attendance for all young people under the age of 18 not attending a higher or a full-time vocational school.

In addition on the tertiary level dual study programs were first developed in the early 1970s through initiatives by powerful corporations in the southwest of Germany and in response to demographic changes that also affected the education space: After an increase in new high schools in the 1960s and 70s, Germany faced a growing number of high school graduates who wished to pursue a higher education degree. This raised questions about the appropriate organization of education and the potential of graduates to obtain high-quality and future-oriented jobs. The specific school-based institution, which is oriented towards the world of work and differentiated from the general academic track of the school system is one reference model for work-based learning and training in Europe, Dual systems are often described as comparatively resilient to change as there is a broad social and political consensus with regard to the functionality of the dual approach to initial vocational training, its pedagogical value, its social estimation, and its benefits for the national economies. In other countries, dual systems in this narrow sense of the word, do not exist, with the exception of Austria, partly Denmark and the Netherlands.

5.6. Launch of Apprenticeship Alliances

Apprenticeships have been constantly a policy priority in VET at the European level, from the Bruges communiqué (2010) to the Osnabrück Declaration (2020), leading almost all EU Member States to engage in actions of reforming existing apprenticeship schemes or introducing new ones.

The Osnabrück declaration (OSNABRÜCK DECLARATION 2020, 2020)has recognised once more that apprenticeships and workplace-based learning improve employability by equipping people with "knowledge, skills and competences that are relevant for the ever-changing labour market and offer upskilling and re-skilling for inclusion and excellence".

In the same year, the Council Recommendation on VET (EUROPEAN COMMISSION, 2020a) has renewed the emphasis on the potential of apprenticeships to prevent young people unemployment and prepare them for current and future labour market opportunities and challenges, including the green and digital transitions.

Since 2013, the EU has supported Member states on expanding existing apprenticeship schemes or introducing new ones also through the European alliance for apprenticeships (EAfA), which was relaunched in 2020 (CEDEFOP, 2021a).

Quality is key to assuring positive outcomes for all stakeholders involved in all types of VET/HVET integrated apprenticeships, to securing and developing high quality work-based training that will in turn help foster stronger collaborations between employers, providers and students. The EU project "Mainstreaming Procedures for Quality Apprenticeships in Educational Organisations and Enterprises" (ApprenticeshipQ) addresses this issue through comprehensive quality criteria to give guidance and orientation on how to structure those parts of VET/HVET which take part in the world of work.

To launch an apprenticeship alliance, the ApprenticeshipQ toolkit provides a clear framework for quality management of apprenticeships at organisations, particularly educational institutions and placement providers by:

- ensuring systematic feedback;
- foster mutual trust and respect through regular cooperation and better quality management between the apprenticeship partners;
- ensure the content of HVET programmes is responsive to changing skill needs in companies and society;

- ensure fair, valid, and authentic assessment of learning outcomes in apprenticeships;
- support the continuous professional development of in-company trainers and improving their working conditions

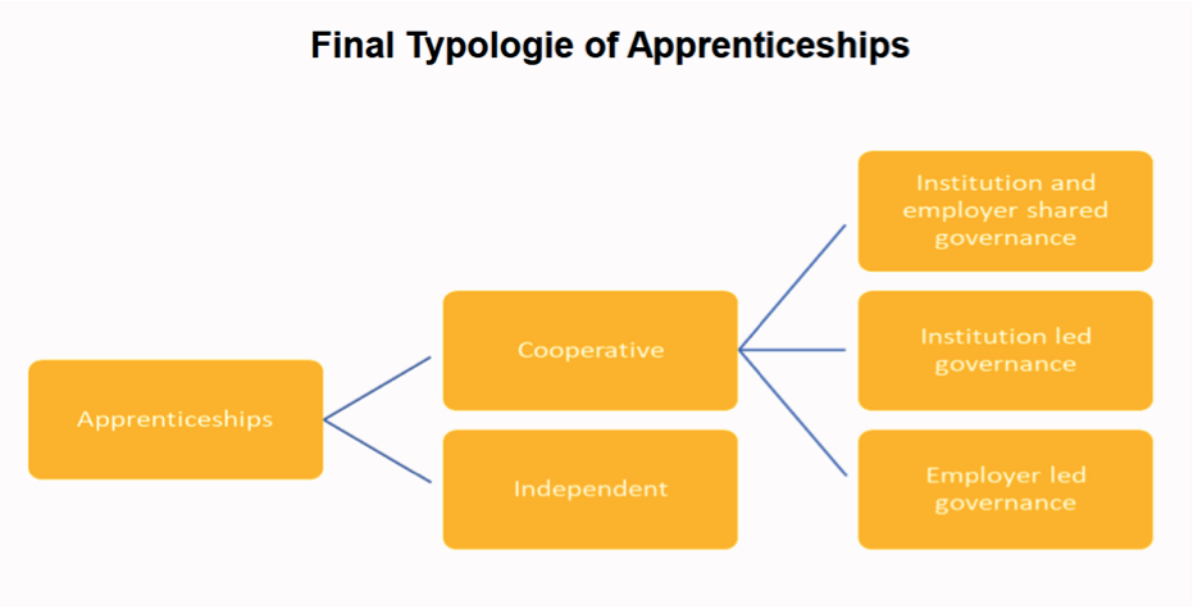


Figure 16: Typology and Governance of Apprenticeships Source: AppQ Project DHBW 2019

The prerequisites to launch an apprenticeship alliance are:

- a typology and governance structure of the apprenticeship alliance model used, aimed at providing a common understanding of the strategic alliance (see Figure 17 – DHBW 2019)
- an academic discussion of what constitutes quality in the apprenticeship alliance;
- quality criteria and measurement indicators for the management of the apprenticeship model in place, including the perspectives of the three stakeholder groups: educational institutions, placement providers and students / apprentices;
- a common agreement and guiding principles for educational organizations and a guiding manual for placement providers, which include:
  - the quality criteria and measurement indicators;
  - best practice cases of apprenticeships' management from the world of education and the world of work;

- documented information on how to implement the quality criteria into the organisation;
- an self assessment online tool, to analyse processes of apprenticeships quality in educational organizations, placement providers, conformity assessment bodies and regulators;

The AppQ toolkit reduces the gap between the different understandings of the mutual combination of work and education, guidance and learning, theory and practice. Therefore, giving a strong vision for an innovative partnership between the sphere of education and industry in several European countries and enhancing high quality HVET as a tool to boost student mobility and cooperation across countries. The project ApprenticeshipQ has built upon several projects, were EXAM4.0 partner institutions have been involved in the studies, e. g. HAPHE, PROCSEE or BEEHiVES and is complementary to several projects, for example , ApprEnt, SAPS, WEXHE or ApprenticeTrack. The results of the HAPHE project were used to discuss the typology of Apprenticeships, as the project has developed approaches aimed at harmonising professional higher education. The BEEHiVES project was initiated to boost European Exchange on higher VET and employer involvement in education structures, which is why the ApprenticeshipQ project built upon its results. Additionally, the ApprenticeshipQ consortium applied the results of the PROCSEE project, which aims at strengthening Professional Higher Education and VET in Central & South Eastern Europe.

5.7. Impact of Covid-19 Pandemic in Apprenticeship Opportunities

Apprenticeship programmes have been significantly disrupted with jobs being lost, restricted opportunities for both on-the-job and off-the-job training, and many training providers facing severe financial difficulties. Given the likely depth of the mounting recession, there are questions about how much provision can be sustained using the current model and what is the best use of the apprenticeship levy. A network of high-quality, authentic learning factories with the capacity to deliver more widely and at scale through technology could play some role in filling this gap.

5.8. Policy Recommendations

Promoting and expanding the role of work-based learning in education and training remains central to EU vocational education and training (VET) and skills policies post 2020. The European skills agenda for sustainable competitiveness, social fairness and resilience, the Council recommendation on a bridge to jobs, and the Council recommendation on VET all advocate increasing the share of young people benefiting from work-based learning and increasing its quality. The VET recommendation foresees a reinforced European Alliance for Apprenticeships (EAfA) and proposes several measures to develop apprenticeship provision, notably in sectors driving the green and digital transitions (CEDEFOP 2020).

Within the strategic framework for European cooperation in education and training (ET 2020), as well as the revised priorities for European cooperation in VET, a number of key policy priorities and instruments have been set up by national and EU policy-makers. Some of these refer to the need to promote work-based learning in all its forms, improve the quality of education and training systems, offer efficient and integrated guidance services and make validation of non-formal and informal learning feasible.

The European Skills Agenda for sustainable competitiveness, social fairness and resilience was launched in July 2020 and marks a new, higher commitment to invest in people through their skills, competencies, and knowledge. It sets targets for the reskilling and upskilling of more than 100 million people across all EU member states, and it sets out the conditions and measures to attain these targets.

Other policy initiatives are also high up in the policy agenda, such as continued efforts to improve the transparency and comparability of qualifications across Europe via the development of National qualification frameworks (NQFs), which link to the European qualification framework (EQF).

6 VET 4.0

In many European countries, traditional VET occupations such as construction worker or plant operator are expected to become relatively less important in the coming decade, while occupations requiring a higher level of skills in fields that are often outside the scope of traditional VET programmes – but could potentially be delivered within VET systems – are growing (CEDEFOP 2020). As VET programmes need to evolve in order to adapt to changing skill needs, VET teachers must not only update their knowledge and practice, but also exploit new approaches to teaching, such as the use of Learning Factories.

Even more than in other forms of education, VET needs to be connected to the labour market and adjust as it changes. For this reason, various forms of interaction and exchange between VET schools and industry are encouraged, including work-based learning for both students and teachers. (see Chapter 3 – Typology of Apprenticeships).

New technologies such as virtual/augmented reality, robotics and simulators have the potential to foster innovation in VET teaching and learning to become VET4.0. In order to increase the use of technology in VET, access to digital devices, high-tech equipment and technical support need to be improved. Countries such as Denmark and Spain have established government-funded centres to strengthen the quality of teaching in VET provision. They also provide high-quality PD to VET teachers on the latest technologies in industry. Initiatives such as the Knowledge Centres for IT in Teaching and for Automation and Robot Technology in Denmark, and the Centre for Innovation in VET in Aragon and TKNIKA in Spain, show that these centres are beneficial to both VET institutions and employers (OECD 2020, 2020).

Building and maintaining a network of stakeholders, fostering the strategic triangle of learners, the world of work and VET institutions and generating a pool of effective leaders in VET would be a major benefit to VET institutions and wider society. The EXAM4.0 platform design and collaboration network in Advanced Manufacturing are addressing these needs.

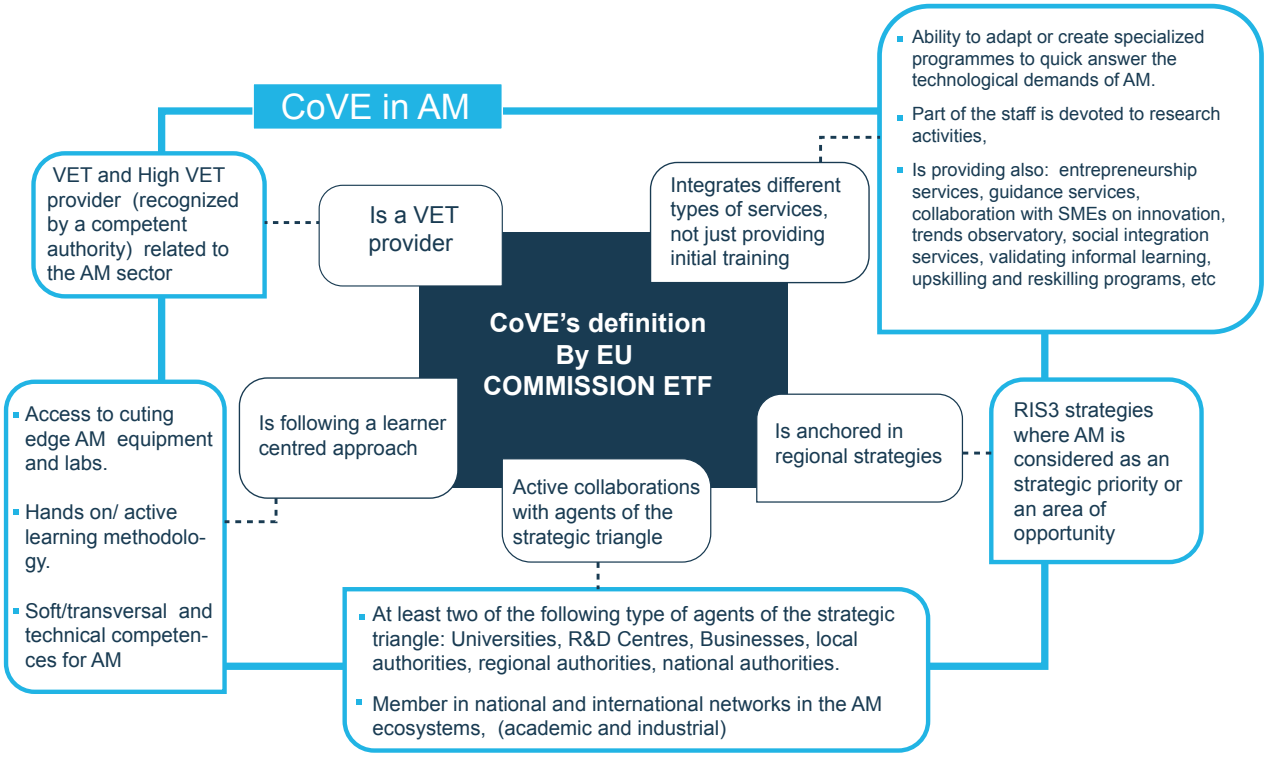


Figure 17: Features of CoVE's for Advanced Manufacturing .Source: EXAM4.0

6.1. VET Systems in Contrast to Academic Higher Education Institutions

In contrast to general and academic higher education, which have (at least in parts) comparable curricula as well as comparable structures and institutions across countries and cultures, vocational education and training (VET) is often strongly regionally and nationally oriented, with diverse histories, self-conceptions, objectives, curricula, structures and practices.

Today VET systems are expected to develop 'fast response' mechanisms of both stable quality assured core qualifications/skills pathways and flexible formats of adding new or higher-level skills, requiring strong governance involving social partners, both employers and trade unions" (EUROPEAN COMMISSION, 2020a).

VET would need to combine and balance a process-oriented, input and supply driven model with a result and outcome-oriented approach, in view of meeting expectations of learners in terms of adequate skills, of employers in terms of skills needs and productivity gains and of society in view of a contribution to growth and social cohesion in Advanced Manufacturing.

6.2. VET 4.0 – Spain

In the 2021 Digital Economy and Society Index (DESI) of the European Commission, Spain ranks 9th in the ranking of the 27 European Member States.

	Spain		EU
	rank	score	score
DESI 2021	9	57.4	50.7

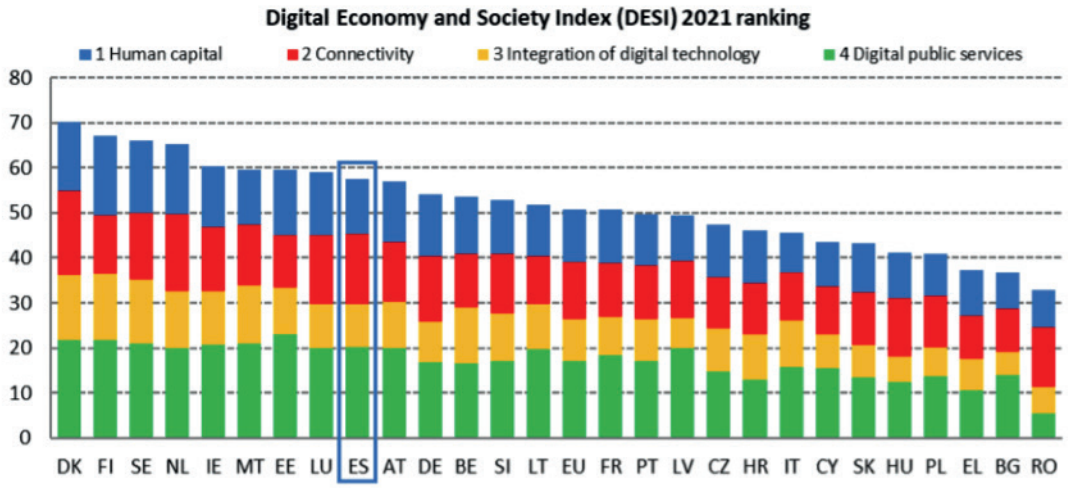


Figure 18: Economy and Society Index Source: DESI Index

According to the same report, the strength of Spain are

- Digital public services.
- Connectivity (with gaps between urban and rural areas).
- The Digital Spain 2025 agenda and other plans to promote digitalisation, including a Digital Competences Plan, an SME Digitalisation Plan 2021-2025, and a National AI Strategy.

But there are still a lot of areas for improvement:

- Close the gap in connectivity issues between urban and rural areas.
- Improve digital skills. Although Spain ranks 12th on Human Capital, it needs to improve: 57% of the people in Spain have at least basic digital skills but the goal of Europe is 80% by 2030; 36% of the workforce lacks basic digital skills; not enough ICT specialists.
- Integration of digital technology in companies. Spain ranks 16th in Europe-27.

According to Cedefop's Skills Panorama, Spain started to come out of a deep economic depression in 2014. Employment is supposed to grow until 2030 and, although Spain still offers a lot of employment options for low qualification levels, most future jobs will require high qualification levels. In 2020, the share of workers employed in the high-tech sector was 5,7% and an unemployment rate of 14,1% in 2019 (CEDEFOP, 2021b).

VET

In general, the situation of the country poses a strong challenge and demand for the VET system. VET offer in Spain has two forms:

1. VET of the Education System.
2. Professional certificates of the Ministry of Labour.

VET of the Education System

In Spain VET offers more than 150 training cycles within 26 professional families, with theoretical and practical contents adapted to the different professional fields.

Within each professional family, the following are offered:

1. Basic VET (secondary education). Title: basic professional.
2. Intermediate VET (post-compulsory secondary education). Title: technician.
3. Higher VET (tertiary education). Title: Higher Technician.

The qualifications obtained after completing VET education are official and have the same academic and professional validity throughout the national territory.

There are also some specialisation courses to be completed after finishing Higher VET and one of them deserves a specific mention due to its relation to the topics of EXAM 4.0 project: Specialisation Course in Intelligent Manufacturing. We will come back to it later.

There are different modalities to obtain these qualifications:

- Dual education,
- Part time studies,
- Blended studies (theoretical subjects are done online),
- At night.

Basic VET, Intermediate VET and Higher VET, have a minimum duration of 2000 hours divided into two academic years and with a compulsory work placement in a company of, at least, 350 hours.

VET of the employment system: professional certificates
There are 583 professional certificates in the same 26 professional families.

New developments
The Spanish Ministry of Education and VET is carrying out a deep reform of the Spanish VET system and their main element to do that is the Plan to Modernize VET (Sancha Gonzalo, 2020).

The main goal of the Plan is to:

1. Create an ecosystem for economic relaunch based on a commitment to human capital and talent.
2. This Plan is based on the following principles:
3. Permanent public-private collaboration.
4. The implementation of a new, effective and efficient single vocational training system that guarantees vocational training and lifelong learning throughout the life of students and the active population.
5. The generalisation of the procedures for the recognition and accreditation of the professional
6. The generalisation of procedures for the recognition and accreditation of the professional competence of the active population, in particular of people expelled from the labour market during this COVID 19 crisis.
7. Support for people expelled from the labour market during this crisis COVID 19 through absolutely flexible VET plans adapted to exceptional circumstances, complementing the accredited competences.
8. Redimensioning of the VET offer.
9. The creation of a collaborative and specialised VET ecosystem

The Spanish Ministry (Ministerio de Educación y Formación profesional, 2020) is also creating an offer of "Specialisation Courses" in relation to some technology demands. **For the goals of this project, the most relevant ones are:**

1. Cybersecurity in Operational Technology Environments.
2. Implementation of 5G networks.
3. Additive Manufacturing.
4. Artificial Intelligence and Big Data.

5. Cybersecurity in IT Environments.
6. Digitisation of Industrial Maintenance.
7. Intelligent Manufacturing.

6.3. VET 4.0 – Germany

In Germany vocational education and training (VET) is based on close cooperation between the State, companies and social partners. Apprenticeship in the dual system is (still) the main pathway into employment for young people. Depending on the occupation it is also a widely accepted option for young people with university entrance qualification. Many companies consider training as a social task and take pride in being a training company. The relatively smooth transition into employment and the resulting low youth unemployment are seen as important strengths of the system.

The foundation of the system is the **occupational concept**. Apprentices are trained in a recognized training occupation according to nationally valid standards. The overall aim is to equip the individual with abilities, knowledge and skills – referred to as **professional ability to act** – necessary for the exercise of a qualified vocational activity in a changing working environment.

The core of the dual apprenticeship system is the institutionalized cooperation of the Federal Government, the Federal States and the social partners based on a principle of **consensus**. The offer of in-company training places is the decision of the company and subject to **market conditions**.

The cooperation is regulated by law. Trainees in the dual system typically spend part of each week at a vocational school and the other part at a company, or they may spend longer periods at each place before alternating. Dual training usually lasts two to three-and-a-half years. The shared responsibility between government, employers and trade unions also helps in responding to emerging new challenges such as digital innovations like the Internet of Things. Companies provide apprenticeships in accordance with the training regulations, developed by the four stakeholders (Federal and State governments, companies and trade unions). These regulations allow for flexibility to agree on company training plans with apprentices. Regular revisions to training regulations guarantee keeping pace with rapid technological and organisational changes.

Germany's VET is a successful model, largely based on the dual system (apprenticeship) leading to high-quality vocational qualifications, valued on the labour market. Apprenticeship enables smooth education-to-work transitions, contributing to low youth unemployment: in 2019 this was 5.8% of those aged 15 to 24, versus 15.1% in the EU-27. About 50% of upper secondary school learners are enrolled in a VET programme; of those, 70% participate in apprenticeship. A growing share of apprentices has a higher education entrance qualification (29.2% of apprentices starting their training in 2017). The success of the German apprenticeship system was also the main driver for implementing the European Alliance for Apprenticeships. (CEDEFOP, 2021c)

A key challenge and policy responses needed are in the area of increasing the attractiveness of VET to secure a future skilled workforce by promoting:

- vocational educational pathways up to EQF levels 6 and 7 and underlining the equivalence to academic education through new designations of bachelor professional and master professional.

6.4. VET 4.0 – Netherlands

In the 2021 Digital Economy and Society Index (DESI) of the European Commission, the Netherlands ranks 4th in the ranking of the 27 European Member States

	Netherlands		EU
	rank	score	score
DESI 2021	4	65.1	50.7

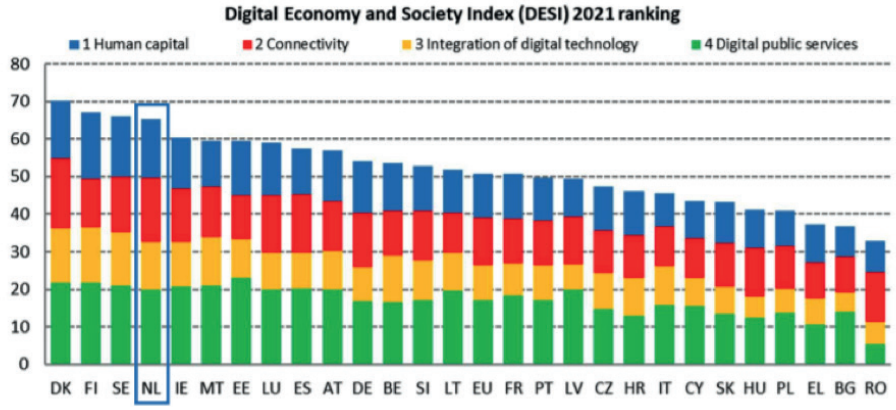


Figure 19: Economy and Society Index Source: DESI Index

However, its Human Capital ranking fell somewhat. This, according to the DESI 2019 Country Report, reflects both an increasing demand of professionals with digital skills outside the core ICT industries, and the difficulty -acknowledged by the current Dutch government and all stakeholders- of adapting education policies to the complex challenges posed by the digital transformation of all sectors (Westerhuis, 2020)

The Netherlands is among the top performers in connectivity, but needed to speed up on 5G coverage. Also the integration of digital technology is high in the EU. The new National Growth fund is used to give a boost to different initiatives especially on AI.

Over the years, the Netherlands has increasingly prioritised and focused its efforts. Current priorities of the strategy are:

(i) artificial intelligence (AI)

(ii) better and responsible use of data

(iii) digital government

(iv) digital connectivity,

(v) digital security and resilience

(vi) digital skills and inclusion.

The European and international aspects are integral parts of the strategy and new topics such as sustainability are gaining momentum. Finally, to prepare the public for future developments, the Netherlands has launched a foresight report 'Digitalisation 2030', which includes major economic, technological and societal trends that impact the digital transition and vice versa. Digital public services are becoming better. Care should be taken to ensure that local and regional digital public services are interoperable and well aligned within the country. National strategies towards digital public services should also remain in line with the EU approach. It is important that the Netherlands remains ambitious in its digital transformation, benchmarking itself with the other leading countries in digitalisation.

VET system in the Netherlands

The figure below shows the whole educational system in the Netherlands. The heterogeneous and multifunctional nature of upper secondary VET in the Netherlands is unique. Key distinctive features are:

- most publicly funded VET is provided by large multi-sectoral regional training centres (ROCs) with an average student population of 12 000. There are also sector-specific schools and agricultural training centres that also provide VET programmes. ROCs

provide VET for young people and adults (IVET) and general education for adults. The ROC's are also active on the continuing VET market, with privately funded programmes. Government-regulated IVET programmes are also offered by private providers under certain conditions;

- school-based and dual pathways in upper secondary VET lead to the same diplomas. Participation in each corresponds to the economic cycle stages: in periods of economic boom, the number of students in the dual pathway increases, while it decreases in the school-based pathway; the opposite happens during an economic recession;

- education institutions have a relatively high degree of freedom to shape VET provision. The VET law only provides a broad framework outlining key elements at system level; institutions receive a lump sum for their tasks;

- The Netherlands promotes a culture of evidence-informed VET policy and practice and encourages innovation. Recent initiatives include providing VET schools regularly with up-to-date regional labour market information and early school leaving data, and implementing plan-do-check-act mechanisms as a basis for organisation and programme development. To reduce the gap between research and practice in education, research and intelligence are increasingly used to improve VET quality and effectiveness, not only by involving professional researchers, but also by encouraging teachers to engage in research activities. To encourage knowledge sharing, VET teachers have opportunities to present their research projects and findings to a wide VET audience, for instance during teacher days.

6.5. VET 4.0 – Sweden

Sweden is ranked as third in the 2021 edition of the Digital Economy and Society Index (DESI) (EUROPEAN COMMISSION, 2021a). Human capital is one of Sweden's strongest competitive advantages, ranking second in the EU. Even though the population ranks high in digital skills, action is necessary in order to increase the number of digital experts in the country, a shortage of ICT specialists is estimated to occur in the upcoming years. Sweden is ranked fifth regarding connectivity, the newly finished 5G auction has had a positive impact on the connectivity development. The integration of digital technologies has been successful in Sweden and the country is ranked as third in this area. The acceleration of the growth is however slowing down and other countries are still progressing. Sweden is ranked in fifth place in the DESI regarding Digital public services, this is due to the general level of digital maturity in the country (European Commission, 2021). Sweden's unemploy-

ment is at 8.3 % (SCB, 2021), ranked as the fourth most unemployed country in the EU (Europaportalen, 2021). The largest future employment growth is estimated to be within health and social care, followed by education, public sector and defence (CEDEFOP, 2021b)). The recent years trend is an increasing working age and the percentage of people with high level education has increased in recent years, from 29 % in 2011 to 37.6 % in 2019 (CEDEFOP, 2021b).

Sweden's government has a strategy for new industrialisation, which is called Smart industry. Smart Industry is settled in order to increase companies' competitiveness. Smart industry focuses on the areas of I4.0, sustainable production, industrial skill boost and test bed Sweden (Skolverket, 2020). The last mentioned is an ambition for Sweden to have a leading position in research which will help to strengthen industrial production. Industrial skill boost is mainly relevant for the education sector and VET (Skolverket, 2020). Industrial skill boost is a system implemented in order to meet the industrial sector's needs and boost long-term development. This is done in the form of supplying skills at local, regional and national level (Regeringen, 2016) and through matching the industrial sector's requirements and the educational contents as well as by ensuring that the students get the right competencies and skills needed to work in a knowledge-based society. The system's aim is to increase the interest in engineering and science as well as making industry-related study programmes more attractive (Skolverket, 2020).

Based on the proposals made in 2016 for upper secondary school to improve digital competences the National Agency for Education also decided that programming skills are important for VET students to learn. This was therefore implemented into education but there is not yet enough data to confirm how the long-term effects are because of this implementation (Skolverket, 2020).

VET-programmes offer the possibility for students to deepen their digital skills and also connect these skills to their specific VET-area. A lot of industrial processes are highly automated and digitalised, students within industrial technology programmes do therefore get educated in the logic, tools and technologies that steer these processes. The structure of the VET courses is determined nationally, educational institutions are however rather autonomous (Skolverket, 2020). One factor that might change the courses is the companies located in the same area as the institution. An example of this is Curt Nicolin Gymnaiset situated in Finspång, Sweden. A large regional company is heavily investing in additive manufacturing and uses metal printing as a part of their production. Curt Nicolin Gymnasiet do therefore have courses focused on this type of technology, and one lab at the school is a scale-down learning factory of this company's workshop. Curt Nicolin Gymnasiet gets support from this company and the company does at the same time secure future workers with the correct competences and skills.

6.6. Policy Recommendations

Establishing an agenda for policy change works best when there is a shared belief across stakeholders in VET – especially institutional leaders and VET teachers – about the importance of fostering the development of soft and digital skills and the adoption of technology in VET. In order for reform to take place, it needs a coordinated effort among policy makers, VET teachers, industry, researchers and education technology providers to expand the use of technology and promote innovative pedagogical approaches (OECD 2020).

Only if all stakeholders work together will it be possible to produce systemic reform in VET/HVET, changing perceptions and behaviour around these skills. This will be crucial in the current context, as most countries urgently need systematic policies to fully incorporate soft skills and digital skills into VET/HVET students' education and development.

7 Design Plans Proposal for the VET centre 4.0

7.1. Collaboration with Micro-Credentialing

Short-learning programmes awarding ECTS-bearing micro-credentials have been touted as a means by which to fill the gap between programmes that VET/HVET institutions provide and the skills that jobs require. Conventional programmes are ill-suited to provide for this unprecedented acceleration in demand for specific skill sets. VET/HVET institutions processes cannot keep up with the increasingly nuanced combinations of rapidly changing expectations posed both by their students and the workplace. These challenges can be addressed by moving from structured degrees and courses to stacks of smaller credentials, which verify highly-demanded skills and competences acquired through non-formal and informal learning.

Future VET/HVET institutions will involve institutions efficiently providing high quality education in their areas of speciality (deepening their offer), and leaning on collaborations with other institutions to complement it (widening their offer.

Full-time graduate students as well as adults returning to formal education to pursue professional development, should be able to piece together a range of different competencies and areas of knowledge and skills that align with employer requirements, as well as acquire these competencies from a range of learning sources. VET/HVET institutions are being asked to rise to the twin challenges of digitisation and greening the economy, to do it better by improving access and personalisation, and to do it for cheaper given the economic imperatives of an aging population. No institution can meet these challenges alone.

EXAM 4.0 platform members aim to jointly develop and share micro-credentials /short courses that focus on digital skills development could prepare the current workforce to adapt to and manage changing roles at work. The collaboration will enable institutions to take advantage of the opportunities of unbundled, flexible learning provision models.

Micro-credential policies have to support the collaboration in order to:

- Work with VET/HVET institutional leadership to identify and dismantle barriers to making course offerings more flexible via micro-credentials;
- Establish policies and regulations within the network of institutions to recognise micro-credentials from within the network for access and progression.
- Assist institutions to extend their educational offerings in the field by integrating modules from other national and international providers.

- Launch combined course offerings made up of micro-credentials, specifically tailored to emerging industrial needs.
- Enable students to engage in virtual mobilities, taking advantage of these micro-credentials to enhance their studies and integrate them into their final qualifications

7.2. Platform of Collaboration among CoVEs in Advanced Manufacturing

The EXAM 4.0 platform aims at becoming the European reference platform for knowledge generation and exchange, innovation, collaboration and service provision for VET/HVET centres and companies working in Advanced Manufacturing. The EXAM 4.0 platform strategy and conceptual design was b orn under the European initiative on Centres of Vocational Excellence (CoVE) and the EXAM 4.0 consortium will continue supporting it based on their agreed collaboration and work in the collaborative learning factory they have build up. And, according to the *European Skills Agenda for Sustainable Competitiveness, Social Fairness and Resilience* *https://ec.europa.eu/social/main.jsp?langId=es&catId=89&newsId=9723* (European Commission 2020 c) and the Commission Proposal for a Council Recommendation on VET, (European Commission 2020 d) the Commission plans to continue launching calls for projects on platforms for Centres of Vocational Excellence.

From the analysis of the EU context the EXAM 4.0 platform will:

1. Support the EU initiative on VET excellence and CoVEs.
2. Cooperate with the ETF initiative on VET excellence.
3. Include greening, in relation to AM and VET/HVET and companies, as one of the priorities of the platform.
4. Include digitalisation, in relation to AM and VET/HVET and companies, as one of the priorities of the platform.
5. Boost cooperation between the AM sector and VET/HVET in AM to upskill, reskill and to meet skill needs.

The EXAM 4.0 platform could play a role in helping Europe to achieve its goals regarding digitalisation. The consortium defined a vision and mission for the development of the CoVE platform in Advanced Manufacturing:

- **VISION:** The EXAM 4.0 platform aims at becoming the European reference platform for knowledge generation and exchange, collaboration and service provision for VET/HVET centres and companies working in Advanced Manufacturing.

- **MISSION:** Collaboration and networking between VET/HVET centres and companies/company associations working in the Advanced Manufacturing sector to reduce skills gaps in the industry and to transfer knowledge between VET centres and companies.

The platform strategy, tools and services have a strong potential in boosting joint action to maximise the impact of skills investment. Skills policies and actions are shared between many actors. Ministries, education and training providers, the industry itself, research organisations, social partners, chambers of commerce and employment agencies are only a number of those who contribute to making up- and reskilling a reality. Concerted efforts can bring clarity to individuals and companies throughout the value chain, reduce costs and focus on priorities. (European Commission 2020 c: 6). The following projects need to promote cooperation between relevant actors, mainly AM companies and VET/HVET centres, to address these needs. Further research is needed to determine industry specific skills demands and observe the latest developments on digitalisation and align them to the European Digital Strategy. The impact of Artificial Intelligence, Digital Skills and Jobs, Women in ICT, and paying attention to the greening aspect of VET/HVET companies in AM, are subject of further research work in upcoming projects.

Skills reform agenda and policies often focus on the supply of skills, reforming qualification systems, introducing competency based curriculum, strengthening training institutions and training markets, less attention is paid to the demand for skills and its role in supporting employment and economic growth. How skills are used in the workplace and how businesses engage with the local skills ecosystem are important factors that shape the real demand for skills and have a strong impact on the curriculum design and system development, with the implementation of Learning Factories in the education system as one example. This in addition is a core research field and should be part of the work the Advanced Manufacturing CoVE platform provides.

7.3.Learning Factory Model

VET/HVET institutions will have to prepare their students to use I 4.0 technologies in the workplace, ideally making use of the new digital technologies available in institutions. They have to implement new learning strategies for the practices of the curriculum of Advanced Manufacturing in the direction of active and experiential learning that integrate the latest industry global trends with academic content, physical infrastructure and engineering practices.

Initiatives such as the Learning Factory (LF) have sought to develop experiences through the inclusion of industrial projects under the active learning approach on the curriculum of some engineering programs (Abele E., 2015). Preliminary studies have shown a better performance in the development of skills and acquisition of knowledge than traditional approaches (Tisch et al., 2013). The LF concept was mentioned for the first time in an initiative of a group of universities from the United States in 1995, since then, there have been multiple proposals of LF; additionally, institutions such as the European government adopted as an official initiative for the education of engineers (Abele E., 2015). Currently, a LF is defined as an idealized replica of sections of the value chain industry where informal, non-formal and formal learning take place (Enke et al., 2017). These LFs have been used for educational purposes, research and training in areas such as manufacturing (TU Darmstadt)], energy efficiency (Green Factory Bavaria), service operations processes (McKinsey Capability Center Atlanta) among others.

The concept of a ‘learning factory’ (LF) refers to a facility with aspects of an authentic production environment designed and used primarily for the purpose of learning.

A learning factory is not a simple duplicate of an industrial factory but designed to best suit and serve an intended experiential learning process. The LF facility may be physical or virtual, or a blended combination. It generally involves more than one machine or operation, and can extend to include, data management, supply chains and customer services. Facilities may be primarily education-based or industry-based, or part of a hybrid institute.

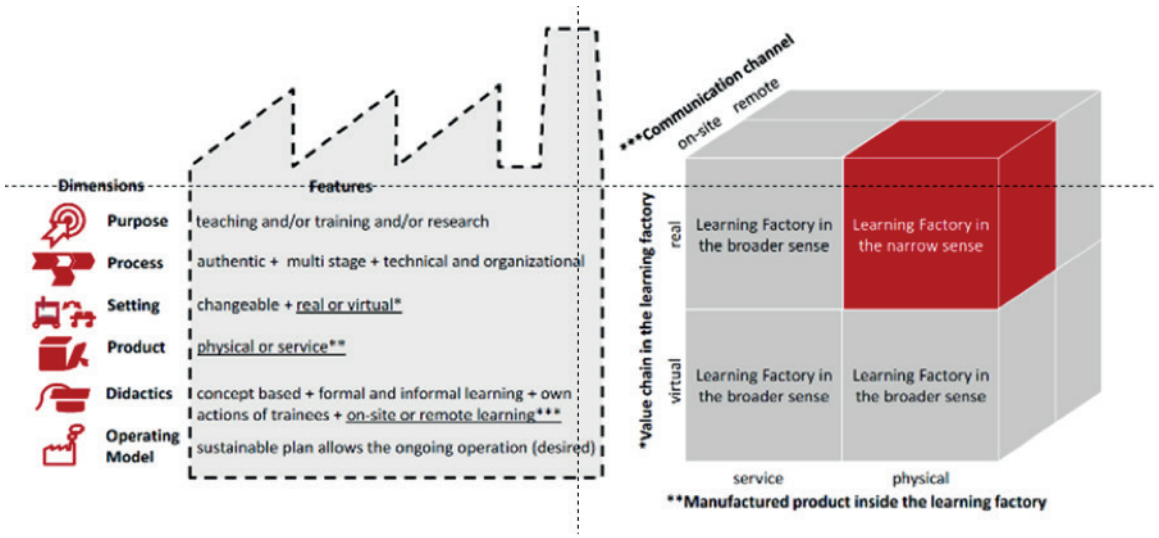


Figure 20: Key features and variants of Learning Factories – Source Abele 2015 at all.

The LF range of different learning purposes are mainly:

- to enhance academic education through offering more realistic hands-on practical experience;
- to enable the acquisition of technical and vocational skills and the associated workplace behavioural and social competencies;
- to raise awareness and understanding of technological developments and their implications for innovation transfer;
- to facilitate experimentation for research, innovation or process improvement, and the acquisition of the skills and understanding that these activities require.

Looking at international practice, learning factory facilities could play a significant part in the national digital ecosystem. Initiatives like the Learning Factory 4.0 in the State of Baden-Württemberg in Germany prove a good strategy for training both teachers and students on the practical implications of I 4.0 and the use of new technology in industry.

7.4. Learning Factories in VET/HVET

Learning factories are based on a didactical concept emphasizing experimental and problem-based learning. The continuous improvement philosophy is facilitated by own actions and interactive involvement of the participants. (Laperrière, 2015)

On the other hand, one of the main characteristics of the VET educational systems is its practical and hands-on approach, the work based learning approach.

The prominently practical character of European VET systems make LFs more than suitable scenarios to materialize training programs in Industry 4.0 and specifically in Advanced Manufacturing.

Following the morphology of LFs proposed by the IALF (IALF, 2021) it is possible to design and implement LFs that respond to specific needs. The proposed structure is adaptable to a wide range of contents, target audience and qualification levels.

In addition to highlighting the practical nature of VET, the LFs offer several advantages:

a) They provide the opportunity to reproduce the **entire value chain** of a production process. (From raw material to final product), thus giving students a holistic view of the processes.

b) They allow the implementation of a wide range of Industry 4.0 technologies in the value chain; giving the possibility of integrating them or using them in isolation throughout the process. This matter offers great versatility in the use of LFs.

c) It is **scalable**, i.e., starting from a more or less simple base, it is possible to add layers of complexity to the system, depending on the needs and the resources.

d) It offers an **ideal scenario for virtualization**, which also facilitates dissemination and accessibility of the proposal.

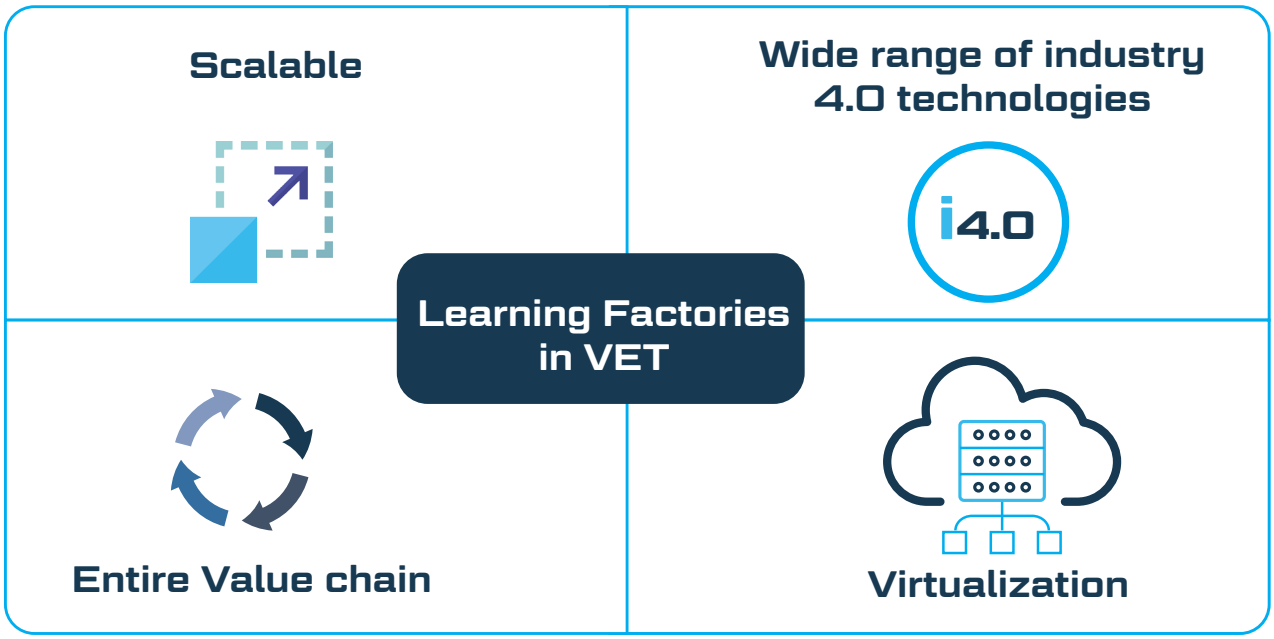


Figure 21: Image of Advantages of LFs: Source Exam4.0

All this points to the fact that the potential of LFs in VET environments are very promising.

It is also true that the implementation of LFs in VET institutions is a great challenge. There are three key aspects to consider:

- The technical complexity of implementing a number of industry 4.0 enabling technologies in VET labs: Technological partners, advanced knowledge, retrofitting of existing equipment, upskilling of internal staff, etc. are required.
- The investment required, depending on the size and complexity of the LFs, can be significant. Setting up LFs involves medium-long-term projects, scaled over time.
- It requires a highly involved and motivated team of teachers and trainers, with a clear and well-defined strategy and a strong culture of digital transformation. The methodological and curricular changes that the implementation of LFs can bring about can be highly disruptive.

7.5. Preparing for I 4.0: A Learning Factory Example in a VET School (Baden-Württemberg State, Germany)

The Ministry of Economy, Labour and Housing in the State of Baden-Württemberg is promoting the establishment of smart learning factories in VET schools. Preparing for future challenges imposed by changes in industrial manufacturing – driven by I 4.0 and the Internet of Things – the State of Baden-Württemberg founded the Allianz Industrie 4.0 in 2015, involving key players in the state. As part of this alliance, the state government developed a "learning factory 4.0" at the vocational school BSZ Bietigheim-Bissingen (Lernfabrik Bietigheim-Bissingen, 2020, with support from the Ludwigsburg district. (Lernfabrik 4.0, 2021)

The learning factory incorporates an interlinked machine system, a production system that produces model cars fully automatically, making use of real industrial components. It was developed by the company teamtechnik Maschinen und Anlagen GmbH, together with the learning factory team of the BSZ vocational school centre. Original I 4.0 components were installed: a manufacturing execution system computer, a Quick Response (QR) Code scanner, a marking laser and a collaborative robot. The basic laboratory includes 16 workstations where the students work in pairs on training modules. As part of their training, students can program training modules with programmable logic controllers. They can analyse the functionality of each individual component and evaluate their suitability for I 4.0 manufacturing processes. All training modules are mounted on mobile units that can be connected to the IT network, the power supply and the pneumatic system at each of the stationary workstations.

Many students from full-time VET courses at the BSZ and the Carl Schaefer School benefit from the learning factory, in particular students of mechatronics and industrial mechanics, IT specialists, technicians, and students at the technical high school. Students from commercial courses such as industrial clerks and the business school also benefit from the learning factory. VET teachers and industry professionals have access to these facilities as well. They are introduced to the learning factory and its technologies usually through training courses and seminars.

7.6. EXAM 4.0 Collaborative Learning Factory

7.6.1. Definition and objectives of the Collaborative Learning Factory

The EXAM4.0 consortium, aware of the contributions that the adoption of the LFs bring to VET institutions, has formulated a LF model to converge solutions to gain skills 4.0 and co working opportunities offered by a CoVE's network. The model defined and piloted in EXAM4.0 is called Collaborative Learning Factory (CLF).

A collaborative learning factory model can be defined as:

It is a LF made up of Labs , usually LFs, from remote locations. Following the philosophy of the LFs, the CLF produces products but unlike conventional LFs, in the CLF the manufacturing is carried out in a distributed way, also geographically. The product is divided into sub-components that are produced in the different LFs that make up the whole CLF.

Therefore, the entire value chain is designed and operated collaboratively, from design, production, assembly, control and logistics. From an operational perspective, the corresponding IT infrastructure must be in place, along similar guidelines of Smart Factories.

Through this approach, we reinforce co-creation and collaboration and accelerate the use of I4.0 enablers in educational contexts in the local LFs..

The pilot experience tested in EXAM4.0 supposes the basis to move from education and training manufacturing labs to the first Collaborative Learning Factory in Europe.

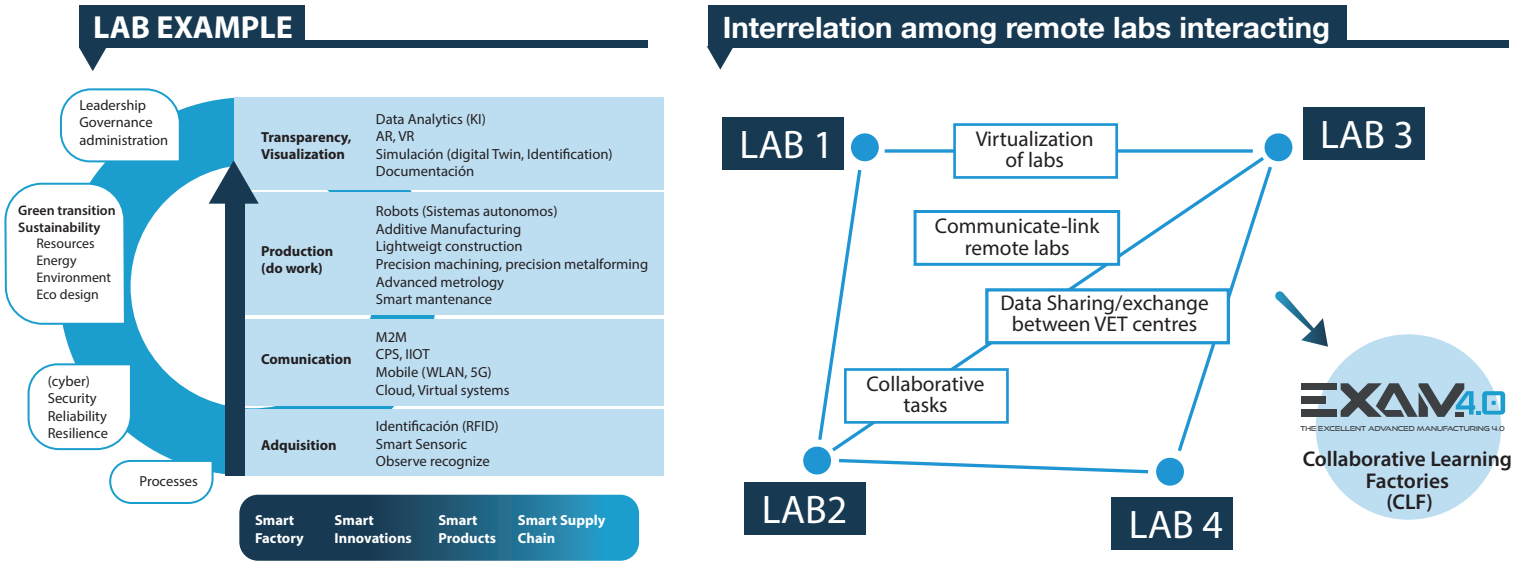


Figure 22 Image of the schematic interrelation among remote labs interacting in the CLF: Source Exam4.0

The CLF pursued the following objectives:

- to co-create in LF environments among international VET centres.
- to enrich the regional LF proposals .
- to accelerate the implementation of I4.0 enabling technologies at the participating centres.
- Formulate a collaboration model where more VET schools can join in.
- Improve skill provision systems for Advanced Manufacturing.

Figure 23: Image of a Collaborative Learning Factory's goals: Source: Exam4.0

7.6.2. Process of Creation a CLF

With the aim of implementing a model that guides the actions to transform the existing national labs of the partner institutions in direction of a Collaborative Learning Factory (CLF), a research process has been developed. It composed by following stages:

Identification of relevant aspects of the CLF as: thematic, objective group, educational purpose, teaching-learning strategies, technological infrastructure in different national LFs of the partnership. **The characteristics of the proposed CLF ecosystem are defined in the four pillars:**

- Governance/Strategy and Organisation
- Functional areas & core processes including IT/OT infrastructure

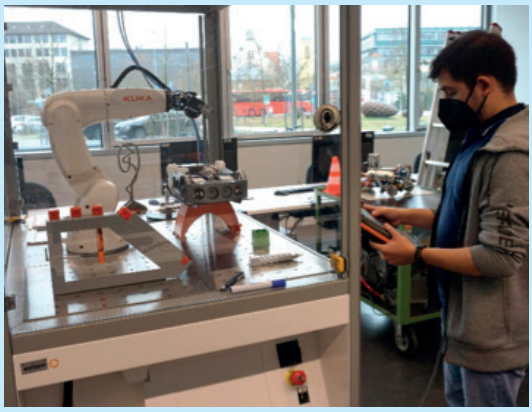
- Product design/process engineering
- I4.0 Applications and Skills Trainings

In order to use a established and easy to compare system to categorize de CLF, we describe our proposed CLF using the LF morphology proposed by the AILF: in this model the LF morphology is described by 7 dimensions: 1) Operational model, 2) Targets and purpose 3) Process 4) Settings 5) Product 6) Didactic 7) Metrics . (Abele, Metternich, & Tisch, 2019) (LMS, 2015)

The CLF has been carried out by joining several independent LFs. The sum of the contributions of each LF makes up the final result, i.e. the product generated in collaboration: the EXAM4.0 autonomous educational robot.

When describing the CLF following the morphology proposed by the IALF, some of the required dimensions will refer to regional LFs. This is the case for dimensions 3 process, 4 setting and partially 6 didactic. For further details on the definitions of the local LFs that compose the CLF, the reader can check the EXAM 4.0 website.

DIMENSION	EXAM4.0 CLF	ASPECTS CONSIDERED IN THIS DIMENSION:
1.- OPERATIONAL MODEL,	Operated by EXAM4.0 partners and embed in the EXAM4.0 platform	For the intended sustainable operation, it is not enough to possess required production equipment and a facility. In order to operate and adapt the learning factory concept continuously three dimensions of sustainability are identified: • Economic or financial sustainability of the LF concept, • Conceptual or thematic sustainability of the LF concept, • Personal sustainability of the LF concept.
2.- TARGETS AND PURPOSE	Education and training	Operating at VET and High VET institutions, the CLF is clearly oriented to education. Upskilling programs and LLL are also included in the targets

DIMENSION	EXAM4.0 CLF	ASPECTS CONSIDERED IN THIS DIMENSION:
3.- PROCESS	Sum of the involved LF's processes	The range of products manufactured at the CLF is divided into subassemblies. Each participating lab/LF would have their own processes and set up that are described separately. However, there are some necessary common setting in order to assure the smooth collaborations ie IoT platforms, business collaboration platforms, cloud systems etc 
4.- SETTINGS	Sum of 4 involved LF's settings	
4.- PRODUCT	Autonomous mobile educational robot	The product built in collaboration is an autonomous robot. This is a low-cost autonomous robot or vehicle, equipped with control electronics and a series of sensors to ensure its mobility The product is customizable to a certain extent, (omni wheels, tracks.,colours, some extra elements etc. It is pre-prepared to integrate and communicate with other types of elements that can be placed on top (cobots, cameras,). 

DIMENSION	EXAM4.0 CLF	ASPECTS CONSIDERED IN THIS DIMENSION:
5.- DIDACTIC	The didactics of the CLF vary: • At regional level, where each training centre adapts the new characteristics of CLFs to the programmes, curricula and competences included in their educational systems. • At consortium level, where it is necessary to reach a consensus on the competences to be worked on collaboratively in the CLF so that all the agents involved can then integrate them into their respective national systems In any case active methodologies are used. PBI, CBL, gamification, and others are implemented	The "didactics" are an integral part of learning factory concepts, which address one of the primary purposes of education and training Regarding this dimension, the following questions and aspects are important: • What should be learned? • The format of the learning modules • Does any standardization exist? • What is the role of the trainer? • Competence classes, • Learning scenario strategy, • Degree of autonomy of learners, • Role of trainers • Evaluation level • Learning success evaluation and other.
6.- METRICS	Not established yet	Quantitative characteristics of LF concepts are considered:, such as: • Nº of participants per learning module, • Participants per year • Nº of standardized trainings • the average duration of individual learning modules • Available learning area. • Capacity utilization • Size f the LF

Table 4: Aspects of the CLF Dimensions Source: Exam4.0 2021

7.6.3. I4.0 technology enablers introduced in the CLF

The holistic approach of LFs gives room to the application of a large number of I4.0 technologies. In addition, the remote location of the facilities in the CLF requires appropriate (industrial) communications infrastructure and collaboration tools.

It is interesting to note that these implementations present opportunities in three pedagogical areas:

1) Competences related to the **implementation** of I4.0 elements

2) Competences related to the **use** of these technologies once implemented in the CLF

3) Improvement of **transversal skills**

Before deciding upon I4.0 technologies, VET institutions need to answer the following questions: What do I want to reach? and, even more relevant, Why do I need this improvement? In EXAM4.0, in order to identify the key technologies for the CLF, both **pedagogical** aspects (what competencies should be developed in the LF depending on the target audience) and **technological trends** in industry and their current scope have been considered. The reports that reflect these analyses are Labs for Advanced Manufacturing, Validation report (EXAM 4.0, 2021b) and 5.2 The ERP, Enterprise Resource Planning, adapted to the project needs. (EXAM 4.0, 2021a)

The tested I4.0 enabling technologies during the piloting process are listed in the following table.

STAGE	Tested I4.0 enabling technologies	Ongoing
Product design	PLM system. Sensor, electronic integration, communications	PLM integration; Digital twins. Eco design, virtual desktops
Process engineering	PLM-MES-ERP integration, IoT platforms, digital workplace	Integration; Digital twins, energy efficiency
Manufacturing	Machining, Additive manufacturing, IIoT, MES, PLM, ERP, Augmented Reality, RFID, digital workplace	Enhanced ERP, PLM integration, IIoT platform, data exploitation tools. Smart maintenance systems
Assembly	Automation, robotics, rfid, artificial vision, AR	Digital twins, Cobots, traceability
IT/OT tools	IIoT platform, cybersecurity	Cloud/edge computing solutions.

Table 5: Tested I4.0 enabling technologies during the piloting process; Source: EXAM4.0

All the above technologies are necessary for the proper functioning of the CLF. However, it is perhaps worth mentioning **some elements because of their integrative nature.** For example, PLM-MES-ERP systems have an important role in ensuring the operability of the collaborative system. The current approach is to implement local MES systems connected to a centralised and common PLM-ERP system. On the other hand, the IIoT platform serves as a tool for data acquisition and exploitation, both locally and remotely, allowing users in other places to use the data created in one place, for different didactic purposes.

Virtual tools are also worth mentioning. The potential of these technologies is enormous. The acknowledgement of virtualisation solutions, from virtual, augmented, extended, mixed realities, simulations... to different variants of digital twins, leads to not only powerful didactical applications but also to opportunities for remote collaboration and dissemination. Augmented reality solutions in the CLF environment of labs are currently being tested.

7.6.4. Didactics of the CLF

The final goal of the EXAM 4.0 CLF is to train people in Advanced Manufacturing. So far, it has described and referenced the most technological and operational part of the CLF. All this deployment pursues a didactic objective.

The analysis of the equipment and technologies needed in the CLF in parallel with the target competences has been conducted. The aforementioned technological and competency frameworks included in WP2 define and measure the collection of skills and attributes necessary to carry out specific tasks, in many cases emerging tasks due to digital transformation.

The aim of CLF is to create a scenario where learners acquire these predetermined competences. Therefore, the competences required in the CLF, strongly specify its implementation. CLF didactification, refers to the adaptation of technological contents and ways of learning to ensure that certain students achieve the predefined skills.

The complexity of the CLF model lies in, among other factors, the fact that student competences and different educational systems are being dealt with jointly. Note that the CLF is composed of training centres from 4 different countries. Therefore, the didactic nature of

CLFs has to be worked on at least two levels:

- At **regional level,** where each training centre adapts the new characteristics of CLFs to the programmes, curricula and competences included in their educational systems.
- At **consortium level**, where it is necessary to reach a consensus on the competences to be worked on collaboratively in the CLF so that all the agents involved can then integrate them into their respective national systems.

The didactification of the CLF, for both levels, includes the development of didactic solutions for the predefined competences worked on in Advanced Manufacturing. These didactic solutions will include aspects such as:

- Creation of specific contents
- Modularization of contents in order to achieve flexibility
- Delivery mechanisms/Learning method according to contents, target audience: e.g. active methodologies, gamification, micro learnings, mobile learnings, digital twins for training, pbl, cbl...
- Work methodologies for join tasks among international students
- Learning pathways aimed at specific occupations
- Updating of curricula and training programmes
- Creation of new courses
- Assessment systems
- Accreditation and micro-credentialing systems

In the EXAM4.0 piloting phase, the focus has been established on evaluating the impact of the CLFs at regional level. That is to say, to evaluate the impact of implementing a CLF on the didactic aspects of the training programmes involved. At this stage, the influence of a CLF implementation on other side programs of the involved organizations has been also evaluated (EXAM 4.0)

Reference documents:

8 Report on skills acquired by the students taking part in the piloting

6 Protocol of exploitation of CLF by SMEs

7 Protocol of exploitation of CLF by Entrepreneurs

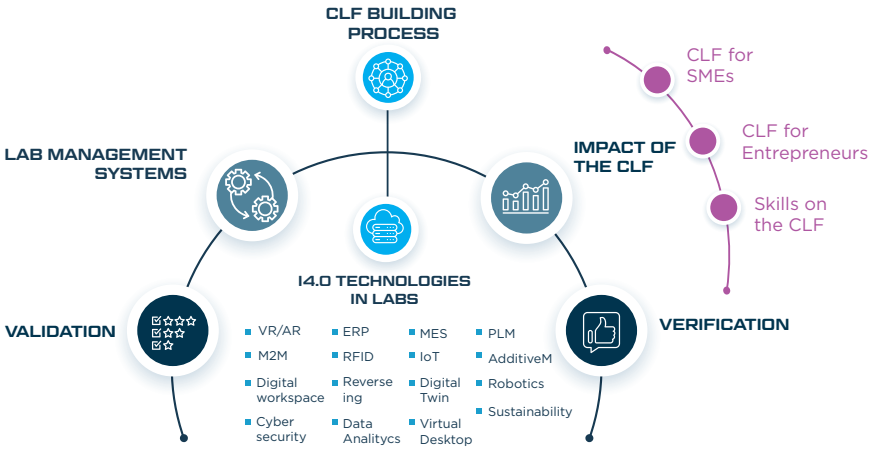


Figure 24: Reports on the influence of a CLF implementation on VET side programs; Source EMAM4.0

7.6.5. EXAM 4.0 Applications

As seen in the sections describing LFs, each institution can design its LF in a way that best suits its objectives. Therefore, among the applications covered by Industry 4.0, a priori there is no specific field of application for LFs. On the contrary, it is possible to find suitable LFs for different applications.

That means that a LF can address different Industry 4.0 drivers as Smart Solutions, Smart Innovation, Smart Supply Chains, Smart Factory or others

The model proposed in EXAM 4.0 is a way of extending the individual applications put in place in the regional LFs. Each institution starts from its own LF, which is initially designed for specific applications. Consequently, the staff of each LF will have specific expertise in these applications.

However, by entering into collaboration with international institutions through the CLF, it is possible to interface with perhaps more unfamiliar industry 4.0 applications.

It is possible that LFs focusing on the same application area, e.g. Smart Factories, may jointly deepen their expertise in this area. It may also be the case that LFs with different backgrounds (e.g. smart factory and smart logistics) exchange knowledge at a given moment.

Obviously, interdisciplinarity also requires a higher degree of complexity in the CLF model or at least in the interactions between LFs.

In any case, a flexible approach is pursued that leaves room for the participation of LFs of different kinds in a common goal.

7.7. Policy Recommendations

The opportunity now exists – made more urgent in the context of COVID-19 – for a more concerted development and deployment of learning factory facilities. The scope for learning factories to make a bigger contribution needs to be seen in a systems context, not just in terms of the capacity and capability of individual facilities, labs and institutions.

This is not just about encouraging more facilities to be built and equipped; a more coordinated, collaborative approach is needed to maximise the contribution of existing assets, avoid waste and duplication, and focus on where gaps most need to be filled, whether internationally or locally.

Applying the concept of collaboration on a CoVE platform and creating a 'skills value chain', learning factories have the potential to help join up the skills and innovation systems in a much broader sense, by being cost-effective, acting as a physical or virtual manifestation of that linkage.

8 VET/HVET Institutions Development and Challenges

8.1. Introduction

Industry 4.0 evokes many changes and developments concerning all economic sectors, as well as aspects of life. The changes impact the technical field of companies such as products, services, processes as well as qualifications, organizational and life aspects. The digitization of work provokes progressive mechanisation and developments of systems and devices. However, digitalisation not only evokes changes in technologies, but also leads to changes in skills and competences for future employees working in an advanced manufacturing environment. In the course of the research project EXAM4.0, a competence model was developed concerning future skills and competence requirements for employees. The European multilingual classification of skills, competences, occupations and qualifications provides information about 2 942 occupations and 13 485 skills on the plattform (CEDEFOP, 2021b). The research in this report focuses on comparing future skills requirements concerning occupational groups referring to the AM sector, for example mechanical engineering technicians, computer scientists and industrial engineers, provided on ESCO to the EXAM4.0 Competence Model (CEDEFOP, 2021b68

8.2. VET/HVET Adaption and Focus on Skills Development

Digitisation and environmental considerations are driving employers of all shapes and sizes to transform their operations in everything from production efficiency to product customisation, with improvements in speed to market, service effectiveness, and new-business model creation, compelling changes in the ways we work, live and learn, and requiring us to develop new skills and competencies.

VET/HVET institutions and policies must adapt to these changes. To address this urgent need, innovative ways of acquiring and verifying skills are strengthening and spreading. Moving from an institution infrastructure based on Fordist models of production that is optimised to reproduce standardised education at scale to one based on personalisation, flexibility, responsiveness and choice requires a wholesale transformation of pedagogy, management and governance within institutions. Short-learning programmes awarding ECTS-bearing micro-credentials have been touted as a means by which to fill the gap between programmes that institutions provide and the skills that jobs require.

Across industries, geographies, and job families institutional leaders and faculty heads must have the ability to understand the current skills base in near-real time in order to accurately forecast, anticipate and prepare for future job contents and skills requirements. This will be increasingly critical for institutional and curricula development policymakers, workers' organizations and learners to succeed. The International Labor Organization (ILO, 2021) in the context of a changing world of work and education indicates that challenges are emerging on both the supply and the demand side of work and education. The arrival of the COVID-19 Pandemic further exacerbated many of these trends/disruptions and unleashed a series of mega shocks to society as a whole, and to work and education in particular. The COVID-19 crisis has given an additional push to the ongoing trend of the digital transformation of the labor market.

The accumulation, transformation, and creation of new knowledge at VET/HVET institutions as well as institutional processes, such as the accreditation of study programmes, take a long time, whereas the digitization and transformation of the industry is accelerating. A faster curriculum redesign and adaption to the market demands is needed. Faculty leaders and curriculum developers cannot afford to disregard this dynamic change process but instead must come to understand and maximize its potential for education.

To develop I4.0-specifc study programmes that can deliver an excellent manufacturing education at a higher speed, institutions must:

- Keep up to date on using and implementing new technologies.
- Communicate closely and work with industry to understand current technical needs and update curriculum.
- Collaborate with industry, professional organizations and government on skills assessment projects.

EXAM4.0 consortium recommends that educators, industry, professional organizations and government work together to:

- Keep curricula current by monitoring trends in education and industry needs.
- Use curriculum and instructional resources shared among Platform Members to speed up the processes of curriculum re-/design.

The proposal for a Council Recommendation on Vocational Education and Training (VET) for sustainable competitiveness, social fairness and resilience was announced in January 2020. It emphasises the need for flexibility and opportunities to progress within and

between education and leading towards employability as key elements of future-fit VET systems. As part of this, the proposal reinforces the importance of modularisation - breaking vocational qualifications into smaller parts of learning outcomes to provide more flexible, customised content to the needs of individuals. It also recognises the role of validation of non-formal and informal learning and micro-credentials, supported by European Transparency tools in upskilling and reskilling and in supporting excellence in the internationalisation of VET.

The **EXAM4.0 platform** initiative aims to support a paradigm shift in the way VET/HVET institutions interact with the world of work and leaners. The network of partners is fostering the bottom up and learner-centred approach to excellence, where the institutions are capable to quickly adapt skills provision, providing approved and recognized micro-credentials both for initial specialized training of young people as well as continuing up-skilling and reskilling for adults.

8.3. Skills Agenda in Europe

In 2016, the European Commission launched the New Skills Agenda for Europe, which aims to 'work towards a common vision about the strategic importance of skills for sustaining jobs, growth and competitiveness' (EUROPEAN COMMISSION, 2016). This is centred around the relevance and quality of skills and making skills and the role of skills more visible.

In 2020 the European Commission launched the New Skills Agenda for Europe, a five-year plan to help individuals and businesses develop more and better skills and to put them to use, by:

- strengthening **sustainable competitiveness**, as set out in the European Green Deal

- ensuring **social fairness**, putting into practice the first principle of the European Pillar of Social Rights: access to education, training and lifelong learning for everybody, everywhere in the EU

- building **resilience** to react to crises, based on the lessons learnt during the COVID-19 pandemic.

The Pact for Skills is the first and latest development in the new Skills Agenda for Europe initiative. It was launched on 10 November 2020 and is an invitation to join forces for upskilling and reskilling the Europeans (EUROPEAN COMMISSION, 2020b).

The European Centre for the Development of Vocational Training (CEDEFOP) promotes closer European cooperation on the provision of vocational education and training policy, which are cornerstones for skills enhancement. CEDEFOP defines skill as "the ability to apply knowledge, use know-how to complete tasks and solve problems and carry out the tasks that comprise a particular job" (CEDEFOP, 2021b)

The OECD works to improve skills governance by providing evidence-based research, such as OECD Skills Strategy 2019, Getting Skills Right or the OECD Future of Education and Skills 2030 project, where they define skills as *"the ability and capacity to carry out processes and to be able to use one's knowledge in a responsible way to achieve a goal. Skills are part of a holistic concept of competency, involving the mobilisation of knowledge, skills, attitudes and values to meet complex demands*" (OECD, 2020).

The European Commission states:

Skills are a pathway to employability and prosperity. With the right skills, people are equipped for good-quality jobs and can fulfil their potential as confident, active citizens. In a fast-changing global economy, skills will to a great extent determine competitiveness and the capacity to drive innovation. They are a pull factor for investment and a catalyst in the virtuous circle of job creation and growth. They are key to social cohesion.

(European Commission, 2016, p. 1)

8.4. AM Sector Skills and Profiles

As automation and digitalisation in the workplace rapidly change job requirements, today's vocational education and training (VET) need to equip their students not just with vocational skills, but also with strong digital and soft skills. These skills are today crucial in the workplace and essential for the use of technology. Policy makers need to highlight the importance of these skills and promote their incorporation into VET teaching and learning, to guarantee a smooth transition of VET graduates into the labour force and increase their adaptability.

Pedagogical approaches such as inquiry-based, project-based and collaborative learning can help develop fundamental soft skills such as critical thinking, creativity, complex problem-solving, teamwork and communication. These pedagogical approaches can incorporate innovative elements such as gamification, blended learning and experiential learning. The use of innovative technology such as robots, virtual reality (VR), augmented reality (AR) and simulators allows teachers to develop students' vocational skills while also fostering their digital and soft skills. These technologies are likely to become more common in VET in the years to come, as they have advantages in terms of flexibility, cost and safety. They are also well suited to facing the challenges imposed by digitalisation and I 4.0.

Among the most fundamental changes in workplaces are the implementation in Advanced Manufacturing / smart factories and the Internet of Things (IoT), which suggest a greater need for higher-level digital skills among workers. IoT and other hyper-connectivity solutions are likely to have a strong impact on occupations not only in the manufacturing and automotive sectors.

Advanced Manufacturing is an application of I 4.0,1 which uses intelligent production systems and processes as well as suitable engineering methods and tools to successfully implement distributed and interconnected production facilities. In smart factories, workers, machines and robots, logistic systems and products communicate and cooperate directly with one another, and a large number of processes are completely automated. Data analytics and real-time information management support production processes and achieve higher productivity, shorter manufacturing times, decreased defect rates and lower physical prototyping and testing costs. Operating these plants requires highly complex engineering processes at all levels. Plant operators make use of their digital skills in several processes: tele-operated motion processes (e.g. use of collaborative robots, automated guided vehicles or drones), virtual testing of parts and packaging from suppliers through virtual reality, and troubleshooting through augmented reality. Smart factories also need workers to have strong analytical and AI capabilities to make intensive use of Internet of Things (IoT) applications, perform real-time analytics for edge computing, or operate self-triggered order placement systems based on inventory levels.

8.5. Digital Skills

In the Survey of Adult Skills (PIAAC) (OECD, 2016), "basic functional digital skills" refer to the skills of those who are familiar enough with computers to use them to perform basic information-processing tasks (adults with computer experience). They are enough to pass the PIAAC ICT core test, which assesses the basic ICT skills, such as the capacity to use a mouse or scroll through a web page, needed to take the computer-based assessment. However, they are not sufficient to solve basic problems making use of these technologies.

8.5.1. Basic Functional Digital Skills

Basic functional digital skills enable an individual to access and engage with digital technologies. These are the entry-level skills required to make rudimentary use of digital devices and applications.

They can be seen as the essential skills needed to access and begin to use digital technology. Users with basic digital skills are able to connect to the Internet, set up accounts and profiles, and access information and resources. These users are able to understand basic information and communications technology (ICT) concepts, adjust settings and manage files.

There are a number of foundational skills that allow an individual to operate devices and implement these basic activities: psychomotor skills, basic numeracy and literacy skills. These "basic skills" are continuously changing, as new devices and interfaces are made available.

8.5.2. Generic Digital Skills

Generic digital skills enable an individual to use digital technologies in meaningful and beneficial ways. These require a wide range of intermediate skills and competences which are included and expanded in frameworks including the *European Digital Competence Framework for Citizens (Carretero Gomez, S., Vuorikari, R. and Punie, Y., 2017) or the UK Standards for Essential Digital Skills (UK Department of Education, 2019)*.

While these frameworks vary in how they describe these types of skills, they share a number of skill and competence areas:

1. **Information literacy** and **data literacy** are the ability to use information and data. For example, the European Digital Competence Framework identifies several aspects of information use, such as an individual's awareness of their information needs; the ability to locate and retrieve digital information and content, to evaluate and judge the relevance and reliability of information sources, and to store, manage, and organise digital information and content.

2. **Digital communication** and **collaboration** are the ability to use digital technologies to interact and share with others. These digital citizenship and digital participation skills range from the capacity to participate in online communities and groups to contributing to a collective understanding of the responsibilities that digital users have towards each other.

3. **Digital content creation** refers to the skill and confidence needed to publish content, contribute to existing platforms and build digital environments, emphasising collaborative co-creation and re-creation of existing content, as well as the individual authoring of original content.

8.5.3. Higher Digital Skills

Higher-level digital skills enable an individual to use digital technologies to empower and transform. **This includes those advanced skills that form the basis of specialist ICT occupations and professions:**

- proficiency in programming languages, data analysis, processing and modelling skills.

They include the specialist skills needed to program or develop applications and manage networks (Spiezia V. & Sabadash A., 2018). These are high-level technical skills that are not developed through everyday technology use, but are usually the result of advanced education and training, as well as extensive self-tuition and practical experience.

It has become common for plant and machine operators to programme machines or robots to do the tasks that they need to perform. This increasingly complex computer use implies that VET graduates will need to be able to learn how to use new machinery and digital devices, setting them up to a desired specification while working in highly digitalised work environments.

8.6. Soft Skills

The increasing need for soft skills in the workplace represents an important challenge for VET institutions. As soft skills become more prominent, VET institutions should gain deeper knowledge about how to develop them among their students, and how they can be effectively developed in practical settings. Teachers will increasingly have to teach their students how to think creatively, solve complex problems, make use of technology and collaborate with colleagues in highly technological environments, while developing good relationships with their peers.

8.6.1. Socio-emotional Skills

Social and emotional skills are a set of individual capacities that can be manifested in consistent patterns of thoughts, feelings and behaviours (Chernyshenko, O., M. Kankaraš and F. Drasgow, 2018). These skills differ from cognitive abilities such as literacy or numeracy because they mainly concern how people manage their emotions, perceive themselves and engage with others, rather than their raw ability to process information. However, some socio-emotional skills are also fundamentally dependent on cognitive skills, such as perception, memory, and reasoning. Some components of cognitive skills are so closely linked with socio-emotional skills that it is difficult to tell them apart and attribute the acquisition of these skills to one category or another. For example, the socio-emotional skill “empathy” also requires cognitive skills such as perspective taking (OECD, 2017).

Among several conceptual frameworks to describe socio-emotional skills, one of the most used is the so-called Big Five framework (Gosling et al., 2003). Social and emotional skills in this framework are arranged hierarchically, with five domains (conscientiousness, emotional stability, agreeableness, openness to experience and extraversion) that can be split into narrower, lower-order skills. **The OECD Study on Social and Emotional Skills (OECD, 2017) includes the following skills under those domains:**

- **Conscientiousness** (task performance) includes achievement orientation, responsibility, self-control and persistence.
- **Emotional stability** includes stress resistance, optimism and emotional control.
- **Agreeableness** (collaboration) includes empathy, trust and cooperation.
- **Openness to experience** (open-mindedness) includes creativity, curiosity and tolerance.

- **Engaging with others** (extraversion) includes sociability, assertiveness and energy. In addition to these skills, the framework for the OECD Study on Social and Emotional Skills (OECD, 2017) includes a group of three compound skills, representing combinations of two or more individual skills:

- **Critical thinking** (a mix of cognitive capacities and open-mindedness skills such as independence) is the ability to evaluate information and interpret it through independent and unconstrained analysis.

- **Meta-cognition** (a result of self-awareness, openness to experience and self-control) is the awareness of inner processes and subjective experiences, such as thoughts and feelings, and the ability to reflect on and articulate such experiences.

- **Self-efficacy** (a result of conscientiousness, emotional stability and extraversion) is the strength of individuals' beliefs in their ability to execute tasks and achieve goals.

The 21st century skills framework, broadly used as a reference in educational contexts (Scott, 2015), argues that there is a group of four soft skills that are fundamental to prepare individuals for adult life (the so called 4C's): *communication, collaboration, creativity and critical thinking.*

- **Communication and collaboration skills,** including empathy and sociability, enable people to interact respectfully with each other.

- **Creative thinking skills,** such as curiosity, allow people to think unconventionally and imagine new scenarios. Finally, critical thinking is a crucial component in judging information, identifying problems and reacting to them (Erdoğan, F., & Yıldız, F., 2021).

8.7. EXAM 4.0 Competence Framework

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

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

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

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

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

The second category, quality, risk and safety, implies competences such as quality management, safety and health for workers. Emergency management and industrial hygiene are also considered in the model. Data security was identified by participants from all partner countries as one of the biggest risks of Industry 4.0. Companies are increasingly introducing intelligent systems and technologies that collect customer information and analyse relevant data. For this reason, skills in this area are crucial for employees.

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

Communication presents the fourth competence category of the model, pertaining the interpersonal exchange of information. This includes verbal, written and public communication skills, as well as presentation skills and conflict management. Virtual collaboration

will become increasingly important in the future, as employees in Industry 4.0 will predominantly work in teams that extend beyond national and company borders.

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

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

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

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

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

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

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

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

8.8. ESCO

ESCO is the European multilingual classification of skills, competences, occupations and qualifications (ESCO). The objective of the platform is to contribute to a better understanding of education and training providers concerning what skills are required by labour markets so they can adapt their curricula accordingly to prepare students better for their working lives and labour markets. Furthermore, ESCO presents a useful platform not only for education and training providers but also helps potential employers to get insights of students' learning outcomes regarding respective qualifications. The platform contributes to a better understanding between employers and institutions and fosters transparency regarding required skills and competences when working in specific occupations, the

demand of qualifications on the labour market as well as learning outcomes of qualifications. The database presents an extension of the International Standard Classification of Occupations (ISCO). On the website it provides 2 942 occupations and 13 485 skills linked to the occupations. Within the occupational profiles displayed on the platform, ESCO lists definitions and explanations of the respective jobs as well as required skills, knowledge and competences. There can be a similar observation regarding the required skills, competencies & knowledge, ESCO also differentiates between essential and optional skills, knowledge and competences.

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

8.9. Occupational Profiles in Industry 4.0

8.9.1. Mechanical Engineering Technicians

The occupational field of mechanical engineers opens up a broad spectrum of career paths and presents a high level of diversification and field of application. Employees referring to this occupational group pertaining technicians and the ISCO level 3, are working in different economic sectors such as agriculture, marine industry or production industry. Therefore, the provided list displaying optional competences, skills and knowledge of mechanical engineers is more extensive than the list presenting essential knowledge, skills and competences of this occupational group. According to ESCO, essential skills and competences of mechanical engineers imply designing engineering components as well as adjusting and reading engineering designs, analysing test data and liaise with engineers. The first presented skills and competencies concerning design can be compared to the competence of design methodology in the EXAM4.0 Competence model. Regarding the EXAM4.0 model, the competence of systems analysis implies the skill of analysing test data. The essential skill of liaising with engineers can be compared to the ability to work in interdisciplinary environments and the category of communication competences. According to ESCO, troubleshooting is also an important skill to obtain by mechanical engineering technicians that can be compared to complex problem solving skills in the EXAM4.0 competence model. Employees referring to this occupational group should also occupy knowledge regarding engineering principles and processes, mechanical engineering and mechanics. Interdisciplinary understanding of processes, technologies and organisations also presents an important competence regarding the EXAM4.0

model. In addition, knowledge of mechanical engineering principles and math can also be found in the model, for example concerning manufacturing skills and knowledge in STEM. With regard to optional skills of mechanical engineering technicians, the EXAM4.0 Competency model implies the majority of displayed skills and competences in ESCO. For example regarding the competence of equipment safety, it implies skills such as maintenance of equipment and ensuring their availability. Furthermore, performing test runs and testing equipment can be compared to the competence of modelling & simulation as well as data management concerning record of test data. Overseeing quality control presents another optional skill on ESCO that can be compared to quality management in the EXAM4.0 model. Regarding the competence category of Management & entrepreneurship, analysing production processes for improvement refers to the competence of strategic analysis. Concerning optional knowledge of mechanical engineering technicians, health and safety in workplaces are important and can be compared to the competences of health & security as well as industrial hygiene.

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

The EXAM 4.0 Competence model implies a vast majority of essential as well as optional skills, competences and knowledge presented in the occupational field of mechanical engineering technicians on ESCO. Although, there are some skills missing in the model, for example managing and ordering supplies. The competence of supply chain management should be added to the model. However, inverse the occupational profile of ESCO does not include competences concerning the category of emotional intelligence or innovation, but complex problem solving skills. Moreover, general competences concerning management are also missing as well as data security.

8.9.2. Computer scientist

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

In the occupational profile, ESCO also lists optional skills and competences for computer scientists, for example data mining and processing data. Those skills are implied in the competence of data management in the EXAM4.0 model. Regarding the category of innovation, creating solutions and innovating in ICT present further skills applied by computer scientists. An open mind-set towards lifelong learning and continuous improvement will be crucial for employees working in an advanced manufacturing environment. Asa result, knowledge in and keeping up to date about emergent technologies is important for computer scientists. About the displayed skills, competences and knowledge of computer scientists, an interesting observation can be made. The occupational profile evinces a lack of competences referring to categories such as quality, risk & safety and emotional intelligence. Skills such as flexibility & adaptability, responsibility, stress tolerance, decision making, intercultural competences, as well as quality management, equipment safety, health & security and data security are not presented in the profile. Regarding the further categories, there are only a few interfaces between ESCO and the EXAM4.0 model. In addition, employees of this occupational group refer to higher qualifications but do not present managerial responsibilities. However, the list of optional knowledge implies several topics, for example different computer languages required in specific fields and sectors which are not yet included in the EXAM4.0 model.

8.9.3. Industrial engineer

Similar to computer scientists, employees referring to the occupational group of industrial engineers pertain to a professional level of occupations. In contrast to the latter occupational group, industrial engineers present a high level of diversification and open up to a broad field of applications. Employees of this occupation can work in several economic sectors for example aircrafts, agriculture, automotive, and further production industries. Essential skills and competences of this group imply adjusting and approving of engineering designs, using technical drawing software, and performing scientific research. Listed skills such as adjusting and approving of engineering designs as well as using software for technical drawings can be compared to the competence design method, whereas performing scientific research equates to a structured and systematic working approach and strategic analysing competence. According to ESCO, it is important for industrial engineers to occupy interdisciplinary understanding and knowledge concerning engineering principles, industrial engineering, technical drawings and processes pertaining engineering, manufacturing and production. In the EXAM4.0 Competence model, manufacturing skills referring to technical competences include a comprehension of manufacturing processes and applications. The optional skills, competences and knowledge for this occupational group appear more extensive compared to the other occupational profiles due to the high level of diversification possibilities. Regarding the displayed skills and competences on ESCO, the category of management and entrepreneurship of the EXAM4.0 model implies skills such as time and project management, as well as coordinating and encouraging engineering teams, which equates to leadership and teamwork skills. Identifying customer needs, advising customers and performing market research can be compared to marketing skills and the competence of technology strategy implies consulting technical resources. Skills such as conducting quality control analysis, maintenance of equipment, ensuring health & safety, implementation of quality management systems, inspecting quality and equipment and managing health & safety standards compare to several competences referring to the category of quality, risk, and safety. Communication presents another relevant competence for industrial engineers for example communicating with different groups such as engineers, managers, suppliers and customers as well as technical communication skills. Innovation presents another category of the EXAM4.0 Competence Model implying skill such as creating solutions to problems, encouraging teams for continuous improvement and troubleshooting.

Furthermore, the occupational profile of this group also displays specific competencies referring to technical competences such as life cycle analysis and CAE/CAD skills as well

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

8.10. Conclusion

ESCO provides a lot of data and information about different occupational groups. Training and education providers get information about required skills and competences for respective occupations and employers receive insights what students and graduates learned regarding respective qualifications. The occupational profiles displayed on ESCO provide information about the hierarchical structure and specification possibilities as well as essential and optional skills, competences, and knowledge, referring to specific areas and occupational fields. Due to the distinction between competences, skills and knowledge on ESCO, it is rather difficult to compare the required skills and competences in the occupational profiles to the EXAM4.0 Competence Model, which presents a more abstract list of competences required for employees working in an advanced manufacturing environment. However, the displayed skills, competences and knowledge do not display all skills required in an I4.0 environment for employees of the respective occupational groups (CEDEFOP, 2021b). Especially soft skills and non-technical skills are not presented in the respective profiles. Skills concerning the competence category of emotional intelligence such as decision making, stress tolerance, intercultural skills, mind-set towards lifelong learning, flexibility or the ability to thrive on failures are not listed in the profiles of the mechanical engineering technicians, computer scientists or industrial engineers. In the future, communication skills will become more important, both virtual as well as conventional exchange of information. Innovation will also be increasingly important for future employees. This competence implying skills like integration, experimentation, abstraction, critical thinking and transfer skills will be crucial

in order to be optimally equipped for the increasingly complex work environment. The developments of I4.0 and the progressing implementation of linked and interconnected technologies and machines evoke a great risk regarding data security and safety. Therefore, skills referring to the competence category of quality, risk & safety will be required of future employees to prevent new forms of crime and threat.

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

8.11. Policy Recommendations

As automation and digitalisation in the workplace rapidly change job requirements, today's VET/HVET institutions need to equip their students not just with vocational skills, but also with strong digital and soft skills. Pedagogical approaches such as inquiry-based, project-based and collaborative learning can help develop fundamental soft skills such as critical thinking, creativity, teamwork and communication. These pedagogical approaches can incorporate innovative elements such as gamification, blended learning and experiential learning. The use of innovative technology in learning factories, the training with robots, virtual reality (VR), augmented reality (AR) and simulators allows teachers to develop students' vocational skills while also fostering their digital and soft skills.

Platforms of collaboration will foster innovation through partnerships between the VET/HVET sector nationally and internationally, industry and research institutions. In addition, policies need to raise awareness about the importance of innovation, ICT and soft skills in teaching in VET/HVET.

The changes in requirements for employees due to I4.0 have not yet been sufficiently taken into account in contrast to technically advanced developments by adapting curricula. Companies have adapted to changes over the years by implementing I4.0 technologies in order to stay competitive and economical.

In order to prepare and qualify future and existing employees for the demands of working in an I 4.0 environment, there is a need to adapt teaching methods and current curricula in all professional areas. Future employees are required to occupy competences referring to quality, risk, communication, safety, entrepreneurship, communication, innovation and emotional intelligence additionally to technical competences. Learners should also be enabled to apply their skills and knowledge to technologies, systems and tools and to work on business problems in order to transfer their knowledge and competences to practical examples and to train working in teams and an interdisciplinary environment.

Implementing and integrating new technologies is currently missing in curricula. However, teaching relevant skills and knowledge for specific I4.0 technologies is important for current learners, as companies will integrate further technologies and systems in the future. Deciding and predicting which technical development will be promising and highly relevant for companies in the future presents a high risk due to cost-intensive technologies and rapid innovation cycle. Collaborations between institutions, learning factories and companies offer a feasible possibility for educational institutions to react quickly and to provide relevant competences to learners. Furthermore, non-technical skills, which also represent key competences in a future working environment, should be taken more into consideration. Due to interconnecting business departments caused by the transformational process, soft skills will become increasingly important for employees in the future. Therefore, it is necessary to teach learners and employees competences regarding interpersonal and virtual communication, management and entrepreneurship, innovation as well as emotional intelligence.

9 Elaborating the Strategy for a CoVE Platform Development in Advanced Manufacturing

9.1. Introduction

A CoVE Advanced Manufacturing Platform should build a strategic alliance around the three stakeholder groups – VET/HEVT institutions, the world of work and the learners. The Strategic Alliance is service-oriented, planning to establish permanent structures for:

- **Teaching & Learning:** establishing AM skills frameworks and curricula; launching or revising AM programmes (including micro-credentials); creating or capacity building learning factories (special AM labs, jointly run by VET and industry)
- **Cooperation and Partnerships:** launching a skills & jobs observatory for advanced manufacturing; accelerating industry/VET/region cooperation ideas via an open innovation community and providing consultancy to SMEs on integrating SME/VET connections.
- **Governance & Funding:** creating a one-stop-shop portal for all our services; ensuring a business case for continuing services to stakeholders in the long-term, while enhancing participation.

Centres of Vocational Excellence (CoVEs) in Europe and abroad, understood as VET /HVET providers that follow learner centred approaches, will provide several services in addition to initial training (training for workers, training for the unemployed, consultancy services, entrepreneurship services, etc.). The service will be work aligned with regional Smart Specialisation Strategies, and collaborate with the key agents at regional level (companies, R&D, authorities, etc.). They can and should play a major role at regional level to address the challenges of the twin transitions in AM. CoVEs work at local/regional level, with students and companies from their areas, and they should be encouraged to continue doing it.

The strategic goal of the AM platform to be designed is to support and empower regional AM CoVEs to become more resilient, innovative, and better equipped to train, upskill, and reskill young and adult students to successfully face the twin transitions and their effects on AM. The AM platform will help regions to grow and be more competitive through their VET systems.

An AM platform will bring together a large group of organisations from European and non-European regions where AM is a priority. These organisations should represent different agents of the strategic triangle: VET/HVET centres, companies, regional government, R&D centres, associations of companies, clusters, and a European association of regional governments.

Each partner, and the organisations that will join the Alliance on the AM platform, will work in alignment with their regional policies, collaborate with the key agents and provide services for their areas.

9.2. Our strategy: What are we planning to do?

The EXAM 4.0 Strategy is defined **HERE**.

(https://examhub.eu/wp-content/uploads/2021/06/3_1_P08_Strategic_Plan_of_the_Platform.pdf)

Our vision: We want to become a European reference platform for knowledge generation and exchange, collaboration, and service provision for Advanced Manufacturing VET/H-VET centres and companies.

The main target of the platform is to create an easy-to-use digital tool beneficial to the different stakeholder groups. **This objective is divided into smaller strategic objectives related to key initiatives to achieve them:**

1. To submit a project to fund creation of the platform
2. To create the platform
3. To create/provide the services of the platform
4. To position the platform in Europe
5. To make the platform self-sustainable

The overall strategic objectives developing an AM platform are:

Offering services and opportunities for:

- AM VET/HVET centres to network with national and international institutions, exchange micro-credentials, innovate learning methods in work-based education with, e.g., collaborative learning factories, work in Applied Research, provide services for SMEs, improve skills assessment for course development etc.
- AM VET/HVET students to find career guidance and skills profiler and specialized training offers.
- AM VET/HVET teachers to network, learn, share knowledge, and co-develop customized micro-credentials

- Adult learners to be informed by possible learning pathways using the skills profiler and studying best practice cases from other learners
- AM SMEs to receive guidance on I 4.0 change programmes and find Applied Research collaboration options and upskilling for their workers.
- Regional governments to have high quality information to improve the design of regional policies and initiatives.
- Citizens to form a skilled workforce which support sustainable regional policies and practices.

9.3. ERASMUS+ in the 2021-2027 funding period

We wrote the EXAM4.0 project proposal between 2018 and 2019. At that time, the initiative on platforms of centres of vocational excellence was still a pilot and the European Commission included it in the Sector Skills Alliance action of the Erasmus+ programme. They created a specific Lot1 for it. We did not know how the initiative was going to evolve and we could have never imagined how relevant it would become in the next few years.

For this reason, when we wrote the proposal, it made full sense to us to think about going on in the next Lots, 2 and 3, of the Sector Skills Alliance action.

One year later, in 2020, the European Commission created an action inside the third Key Action of the Erasmus+ programme. This means that in 2020, the initiative on platforms of centres of vocational excellence, in which EXAM4.0 was one of the pioneer projects, was separated from Sector Skills Alliances.

The 2014-2020 funding period ended in 2020 and with it the Erasmus+ programme in which the EXAM4.0 project was funded.

The new Erasmus+ programme for the 2021-2027 funding period was published in March 2021 with this structure:

1. **Key Action 1:** Learning mobility of individuals
2. **Key Action 2:** Cooperation among organisations and institutions
3. **Key Action 3:** Support to policy development and cooperation

While the structure of the programme, divided in three Key Actions, is the same as the previous one of the 2014-2020 programme, the content of each Key Action has changed.

The initiative on Platforms of Centres of Vocational excellence, that was first included as a Sector Skills Alliances sub-action and then under the third Key Action, is now included in an action called "partnerships for excellence" and the lot2 and lot3 actions of the sector skills alliances action of the previous programme are now under "alliances for innovation" action. The following table shows the changes of the last three years in a more visual way:

2019 (ERASMUS+ 2014-2020)	2020 (ERASMUS+ 2014-2020)	2021 (ERASMUS+ 2021-2027)
Initiative on Platforms of vocational excellence as the Lot1 of Sector Skills Alliances (KA2)	Initiative on Platforms of vocational excellence under Key Action 3	Initiative on Platforms of vocational excellence as "centres of vocational excellence" of the action "partnerships for excellence" (KA2)
Lot 2 of the Sectors Skills Alliances (KA2)	Continues under Sector Skills Alliances (KA2)	Alliances for innovation Lot1
Lot 3 "Sectoral blueprints" of the Sector Skills Alliances (KA2)	Continues under Sector Skills Alliances (KA2)	Alliances for innovation Lot2

Table 7: Erasmus+ Lots Source: EU Commission

Considering these changes, the next sections will outline how we plan to continue in the Alliances for innovation and in the centres of vocational excellence of the new Erasmus+.

9.4. Continuation of EXAM 4.0 as an Alliance for Innovation

The Alliances for innovation action includes two lots:

1. Alliances for Education and Enterprises
2. Alliances for Sectoral Cooperation on Skills (Implementing the blueprint)

EXAM 4.0 has a lot of potential to continue under these lots.

EXAM 4.0- Alliance for Education and Enterprises (Lot1: Alliances for Innovation KA2)

On the one hand, Alliances for Education and Enterprises promote the work between Higher Education, VET and companies, which has a perfect fit with our partnership (we include all of these agents) and with our intentions. In our strategy we stated that:

> *The EXAM 4.0 platform aims at becoming the European reference platform for knowledge generation and exchange, collaboration and service provision for VET/HVET centres and companies working in the Advanced Manufacturing sector.*

Which goes in line with the goals of this Lot.

On the other hand, the type of actions they encourage are:

1. Fostering new, innovative and multidisciplinary approaches to teaching and learning: fostering innovation in education design and delivery, teaching methods, assessment techniques, learning environments and/or developing new skills;
2. Fostering corporate social responsibility (e.g. equity, inclusion, climate change, environmental protection and sustainable development);
3. Stimulating a sense of initiative and entrepreneurial attitudes, mind-sets and skills in learners, educational staff and other workers, in line with the Entrepreneurship Competence Framework (EntreComp);
4. Improving the quality and relevance of skills developed and certified through education and training systems (including new skills and tackling skills mismatches);
5. Facilitating the flow and co-creation of knowledge between higher education and vocational education and training, research, public sector and the business sector;
6. Building and supporting effective and efficient higher education and vocational education and training systems, which are connected and inclusive, and contribute to innovation.

At EXAM 4.0, the things we did and the ones we plan to do, are very aligned to them.

The following table describes the activities and related actions

ACTIVITIES ENCOURAGED BY THE ACTION	ACTIVITIES OF EXAM 4.0 RELATED TO THEM
Fostering new, innovative and multidisciplinary approaches to teaching and learning: fostering innovation in education design and delivery, teaching methods, assessment techniques, learning environments and/or developing new skills;	The EXAM 4.0 Competence Framework. The EXAM 4.0 Collaborative Learning Factory Model.
Fostering corporate social responsibility (e.g. equity, inclusion, climate change, environmental protection and sustainable development);	The EXAM 4.0 Competence Framework.
Stimulating a sense of initiative and entrepreneurial attitudes, mind-sets and skills in learners, educational staff and other workers, in line with the Entrepreneurship Competence Framework (EntreComp);	The EXAM 4.0 Competence Framework. The Protocol of exploitation by entrepreneurs of the EXAM 4.0 Collaborative Learning Factory.
Improving the quality and relevance of skills developed and certified through education and training systems (including new skills and tackling skills mismatches);	The EXAM 4.0 Competence Framework. The EXAM 4.0 Collaborative Learning Factory
Improving the quality and relevance of skills developed and certified through education and training systems (including new skills and tackling skills mismatches);	The EXAM 4.0 Competence Framework.
Facilitating the flow and co-creation of knowledge between higher education and vocational education and training, research, the public sector and the business sector;	The EXAM 4.0 community and platform.
Building and supporting effective and efficient higher education and vocational education and training systems, which are connected and inclusive, and contribute to innovation.	The EXAM 4.0 community and platform.

Table 8: Strategic initiatives of Exam 4.0 Source: Exam 4.0 2021

Therefore, EXAM 4.0 has potential to continue in the Lot1 of this action.

EXAM 4.0 as an Alliance for Sector Cooperation on Skills (blueprint)
In contrast with the first lot, EXAM 4.0 does not fit into the blueprint, Lot2, as it is defined right now. The same as in the previous funding period, the European Commission decides on the sectors for these blueprints.

At this moment, following the New Industrial Strategy, they want projects on the following sectors:

- **Tourism:** Passenger transport and travel; Hotels, short term accommodation; Restaurants and catering; Events, theme parks etc.
- **Mobility-Transport-Automobile:** Production of motor vehicles, ships and trains, and accessories; Their repair and maintenance; Freight Transport etc.
- **Aerospace and defence:** Aircraft and spacecraft production; Military and weapons; Satellites etc.
- **Construction:** Building of residential and non-residential estates; Building of roads and railways; Building of utilities and civil engineering; Associated activities etc.
- **Agri-food:** Building of residential and non-residential estates; Building of roads and railways; Building of utilities and civil engineering; Associated activities etc.
- **Low carbon energy intensive industries:** Extraction of fossil fuels; Refining; Manufacturing of products with high environmental impact: plastics, chemicals, fertilisers, iron and steel, forest-based products, cement, rubber, non-ferrous metals, etc.
- **Textile:** Production of textiles, wearing apparel, footwear, leather and jewellery etc
- **Creative and cultural industries:** Newspapers, books and periodicals; Motion picture, video and television; Radio and music etc.
- **Digital:** Telecommunications; Software and programming; Web portals; Manufacturing of computers and equipment etc.
- **Renewable energy:** Telecommunications; Software and programming; Web portals; Manufacturing of computers and equipment etc.
- **Electronics:** Production of electronics etc.
- **Retail:** Retail sales; Wholesale connected to consumers etc.
- **Proximity and social economy:** Social enterprises, associations and cooperatives aiming at generating a social impact etc
- **Health:** Pharmaceutical products and equipment; Hospitals, nursing homes, residential care etc

However, being a platform of vocational excellence in Advanced Manufacturing, we should keep an eye on the evolution of the blueprint. It is possible that in further modifications of the current Erasmus programme, actions related to Advanced Manufacturing are included. In this case, the blueprint will be considered as an interesting continuation for our project.

9.5. Continuation of EXAM 4.0 as a partnership for excellence

This is where we consider to have the most "natural" continuation, as a platform of centres of vocational excellence.

Our Vision and Mission state that:

- **VISION:** The EXAM 4.0 platform aims at becoming the European reference platform for knowledge generation and exchange, collaboration and service provision for VET/H-VET centres and companies working in the Advanced Manufacturing sector.

- **MISSION:** Collaboration and networking between VET/HVET centres and companies/-company associations working in the Advanced Manufacturing sector to reduce skills gaps in the industry and to transfer knowledge between VET centres and companies.

And this seems to find the most convenient place under this action of the new Erasmus+ programme.

But why do we consider having our "natural" continuation there?

Around 2017, the European Commission started looking for VET excellence: What makes a VET centre to be excellent? They concluded that, although there were many differences, whenever they found a VET centre were Staff was satisfied, Students were highly employable when they finished their education and Companies were satisfied with the competences of students there were some common elements:

1. Learner centred approaches.
2. Provision of several services in addition to initial training: training for workers, training for the unemployed, consultancy services, entrepreneurship services, etc.
3. Alignment with regional strategies. RIS3 is mentioned several times.
4. Collaboration with the key agents at regional level: companies, R&D, authorities, etc.

These centres work at local/regional level, with students and companies from their areas, and they should continue doing so. However, the EC was afraid of not having some form of connection among these centres.

The idea of connecting CoVEs through transnational platforms led the EC to launch a pilot call for proposals to explore the possibility of establishing European Platforms of Centres of Vocational Excellence. The call was launched under Lot1 of the Sector Skills Alliances Action of the Erasmus+ programme in 2018.

The Commission funded 5 pilot projects focused, each one, in a sector. EXAM 4.0 was among them.

In 2020, the project coordinators of the 5 pilot CoVEs started meeting and working in a team. Then, some months later and with the support of the European Commission, the European Training Foundation and the Joint Research Centre of the European Commission, project coordinators formed a Community of Practices. Katapult, in the Netherlands, and Tknika, in the Basque Country, are leading the community. It's kick off meeting took place at Tknika on November 8 and 9 2021 and it's official launch was at the International Basque VET Congress organised by the Basque VET Vice-ministry of the *Department of Education of the Basque Government* [1].

The EC will also organise a support service for the CoVEs. We took part in some meetings with the EC and the JRC to discuss the utility of them. The scoping report Support Services for Centres of Vocational Excellence of the Joint Research Centre of the EC explains it better but, in a nutshell, these services will be grouped in three pillars: knowledge sharing, networking and collaboration, and information and support.

The fact that we were running one of the five pilot projects of the very first pilot call and that we have been involved in all the coordination activities with the rest of the projects and institutions, places us in a privileged position to carry out a successful project: our ideas and the initiative EC initiative on CoVEs have been growing together and feeding each other.

The project EXAM4.0 fixed the foundations of the platform for AM as a starting point for its development and we were one of the key agents in making the initiative as famous and relevant as it is today.

1. *https://www.youtube.com/watch?v=Pl2FoRiu-NE*
https://www.youtube.com/watch?v=P3spyogd5Qc

Have we done something or are we just fantasizing?

As our approach is very practice oriented and we are very committed to our vision and mission, we have already submitted a proposal to the call of centres of vocational excellence, in September 2021, to scale up our activities.

If this proposal gets granted we will have 4 millions of Euros and a strong partnership to come closer to our vision of becoming the European reference platform in Advanced Manufacturing for VET/HVET centres and companies.

9.6. Conclusion

One of our prospective long-term strategic outcomes of an AM collaboration platform and its activities is to set up the first Strategic Alliance from members of the three stakeholder groups, learners, institutions and the world of work facing the challenges of I 4.0.

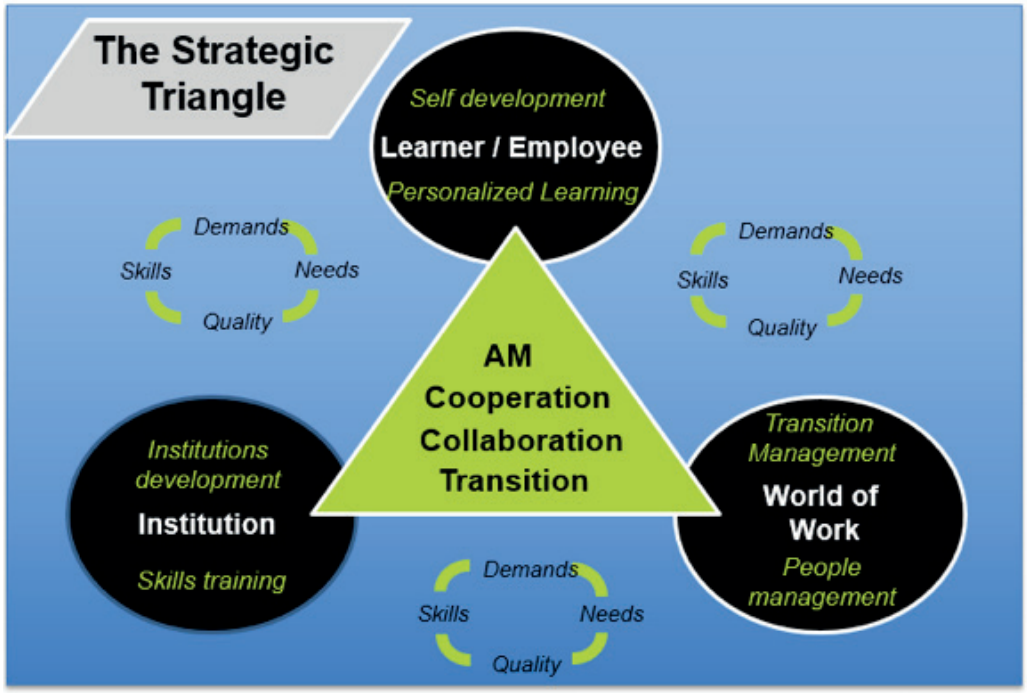


Figure 25: The Strategic Triangle Source: Project BEEHiVES DHBW 2018

With its services, analysis tools and rich set of data coming from all three groups benefiting each other, the AM collaboration platform will deliver hands-on working solutions, not just mere proofs of concepts. This will allow to grow the AM collaboration platform memberships organically, inviting new adopters to use the tools and services and further develop a sustainable and expanding network of students and adult learners, VET institutions and companies in Europe and abroad.

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EXAM 4.0

THE EXCELLENT ADVANCED MANUFACTURING 4.0