EXAM 4.0

THE EXCELLENT ADVANCED MANUFACTURING 4.0

A VET centre 4.0: Action Plan draft

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VET 4.0 for Advanced Manufacturing

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EXAM 4.0 partners:

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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 EXAM 4.0 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 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/VET providers, AM companies and Employers Association, Networks) on how to face the challenge of Industry 4.0. Chapter 5 will give an outlook to VET4.0 describing future design plans. Chapter 6 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.

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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

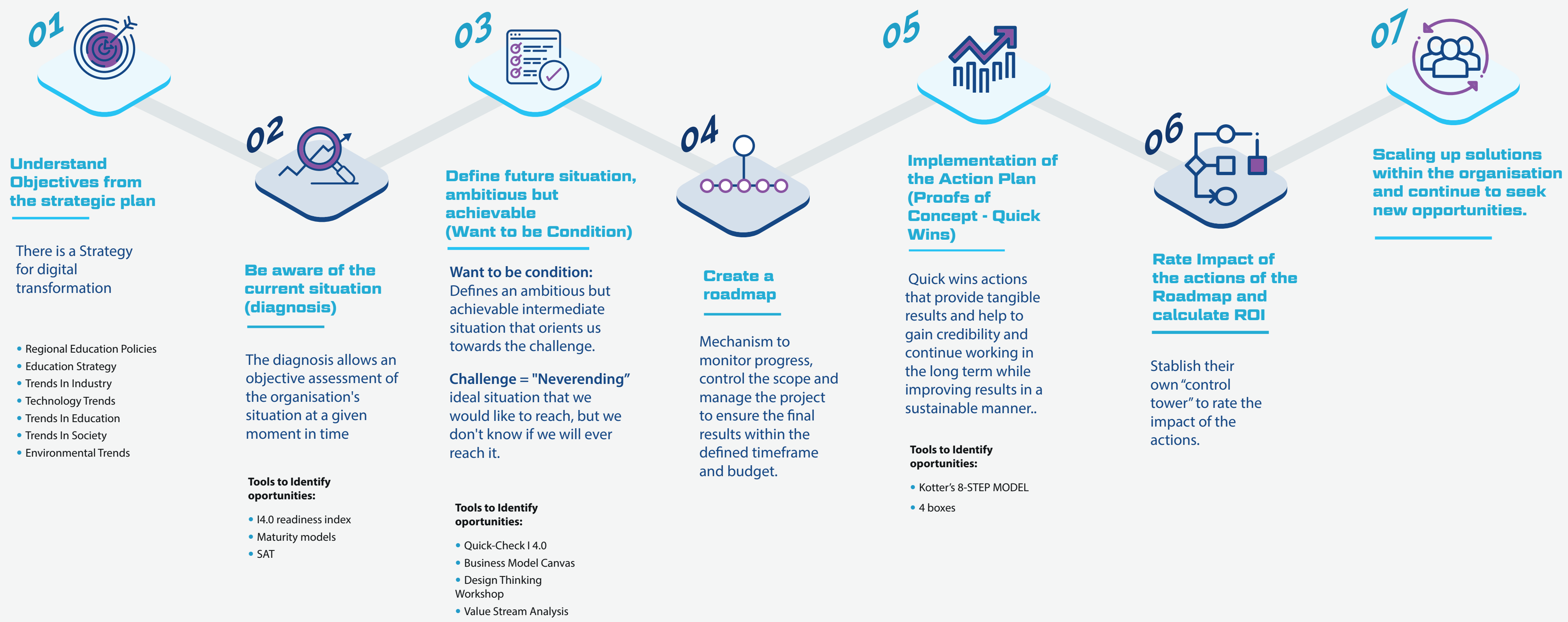


Figure 1. Guide for implement Advanced Manufacturing labs in VET/HVET centres Source: Exam 4.0

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)**

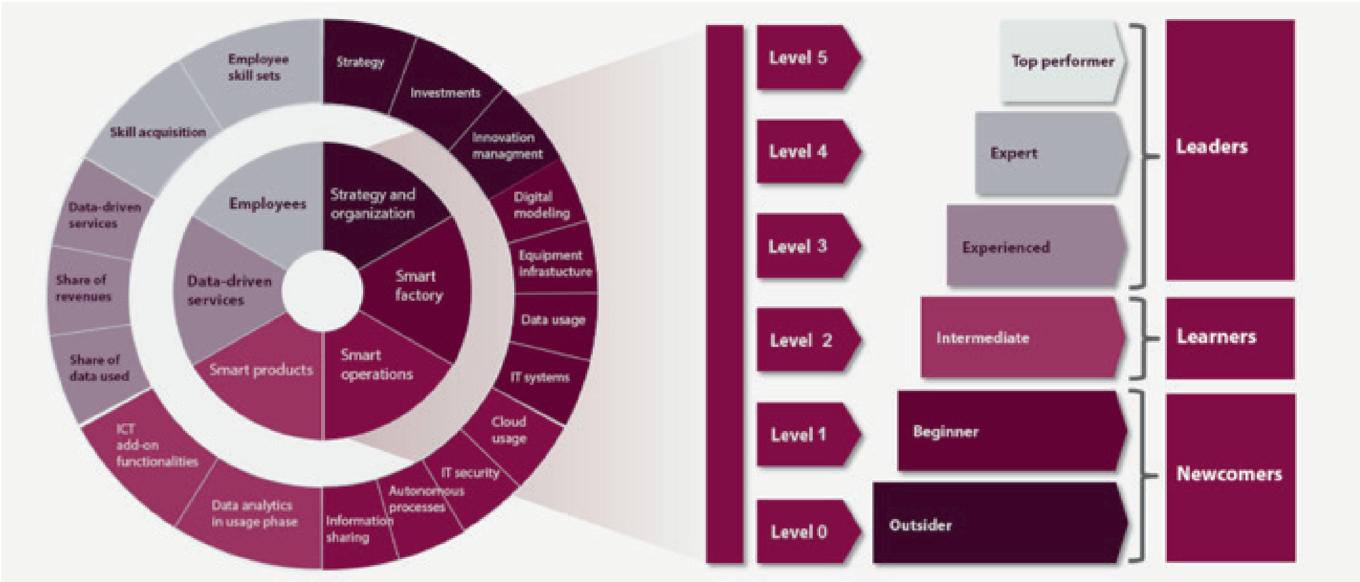


Figure 2. Industry 4.0 readiness Source:IMPULS

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

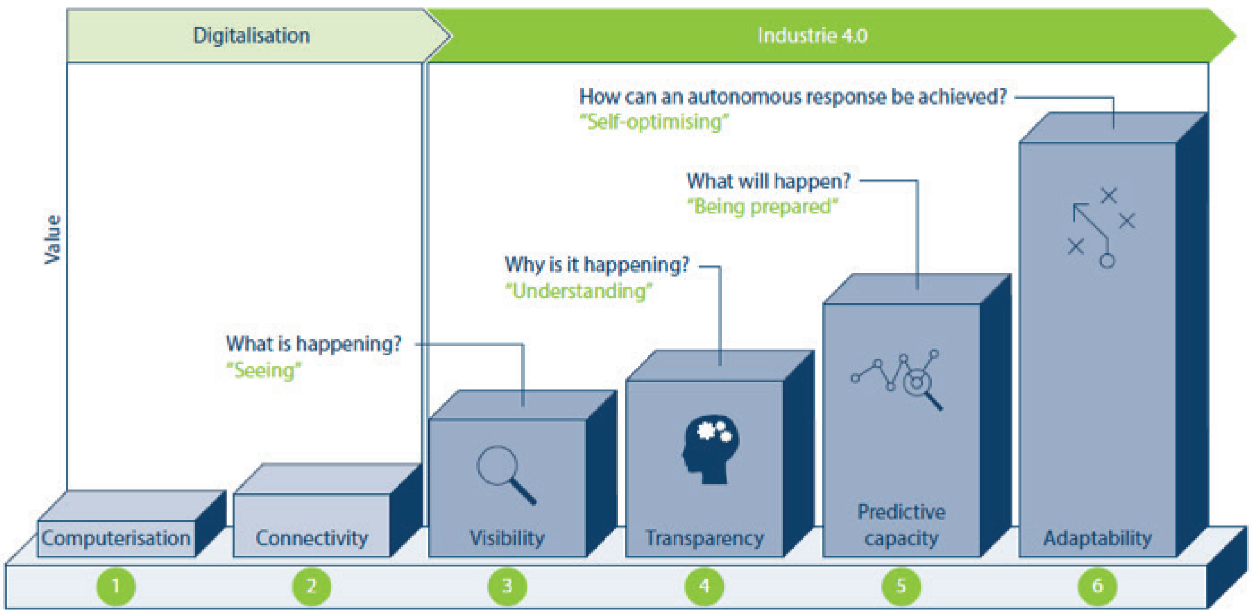


Figure 3. Stages in the Industry 4.0 development path Source: FIR e. V. at RWTH Aachen University

- **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)**

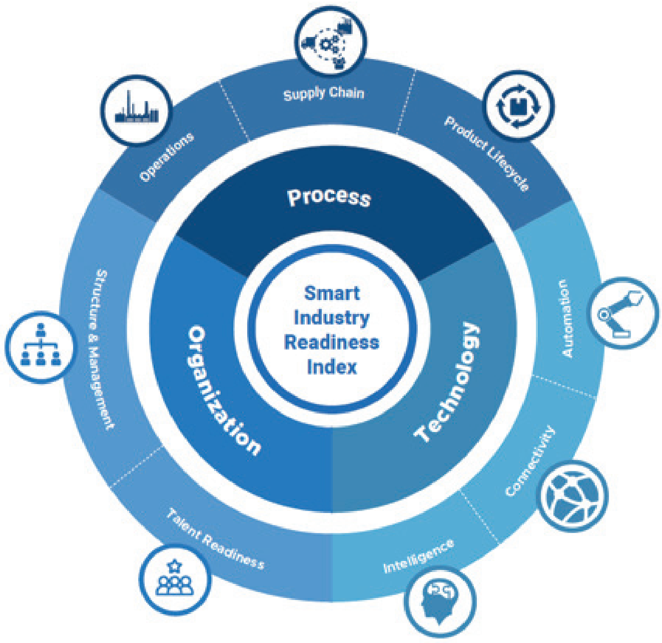


Figure 4. The 3 building blocks and the 8 pillars of the SIRI model. Source: Singapore Economic Development Board SEDB 2021

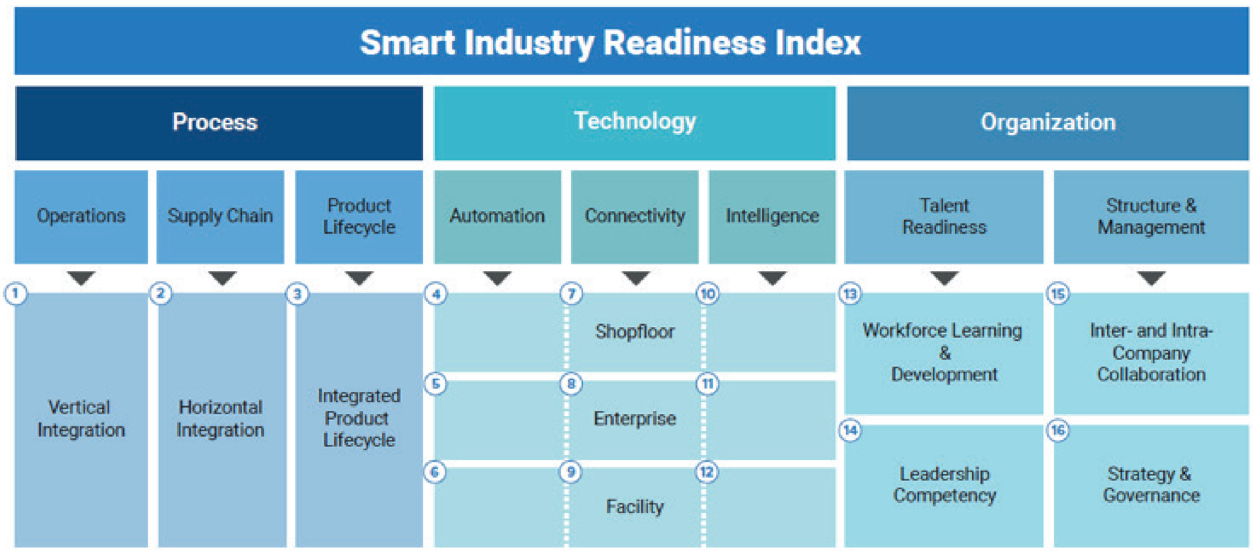


Figure 5. The 16 dimensions of assessment Source: Singapore Economic Development Board

• **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)**

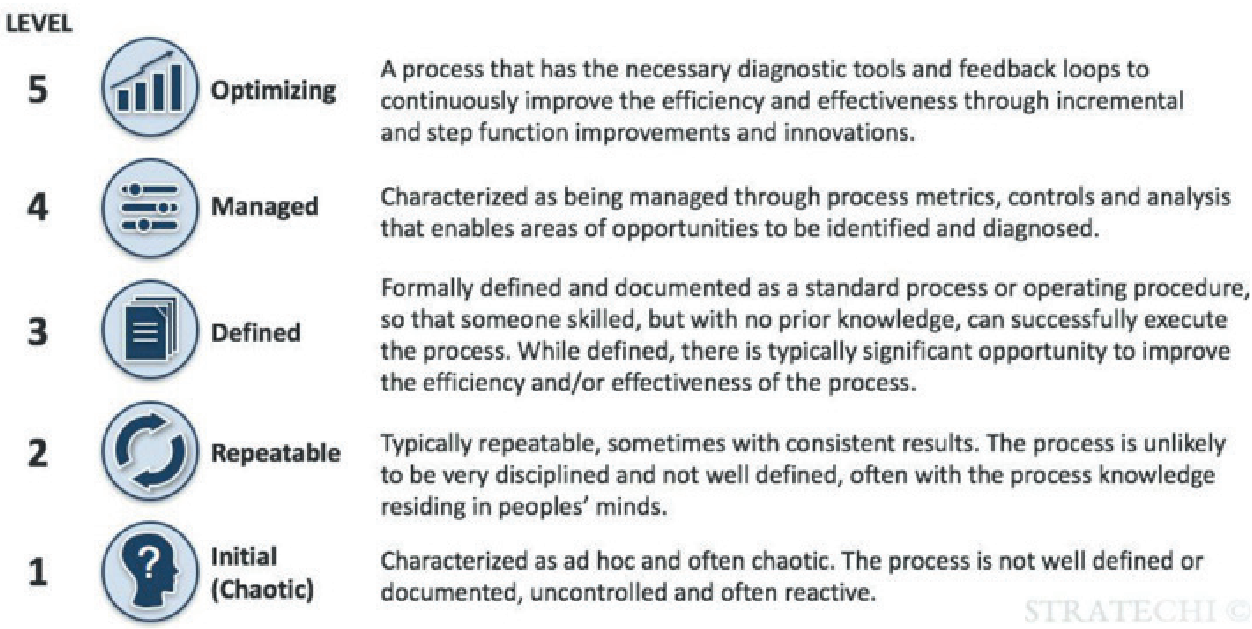


Figure 7. Process maturity levels – Source: Stratechi

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)

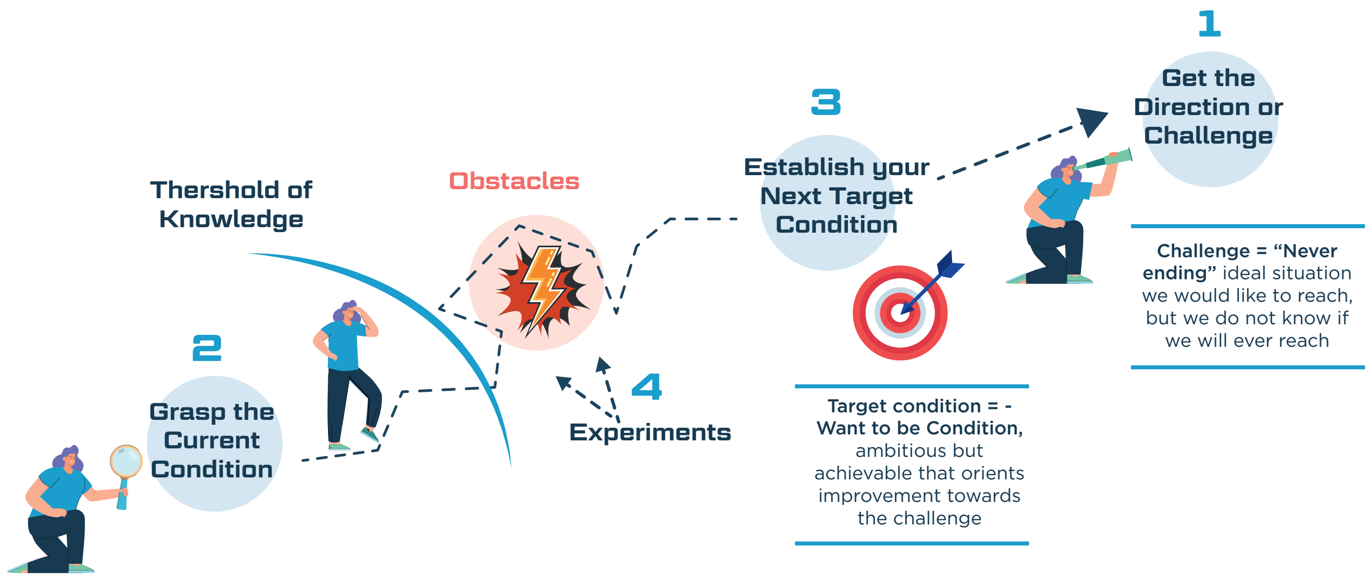


Figure 8. The improvement Kata pattern
Source: Exam 4.0

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.

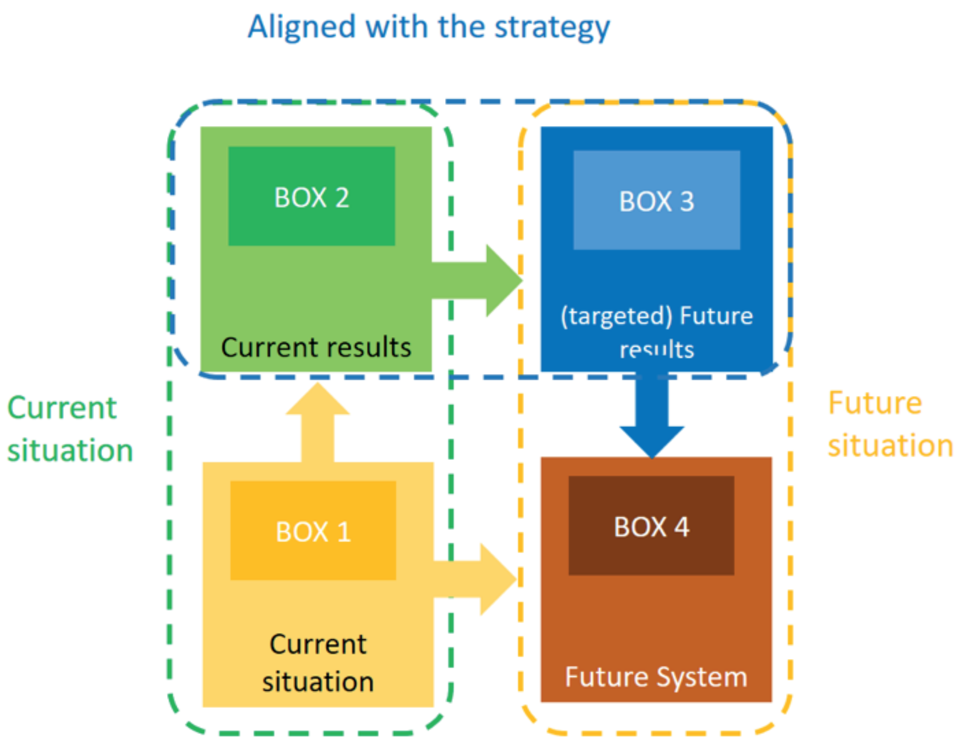


Figure 9. 4 boxes, a tool to guide improvement in the medium-long term. Source: Renault Consulting

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:

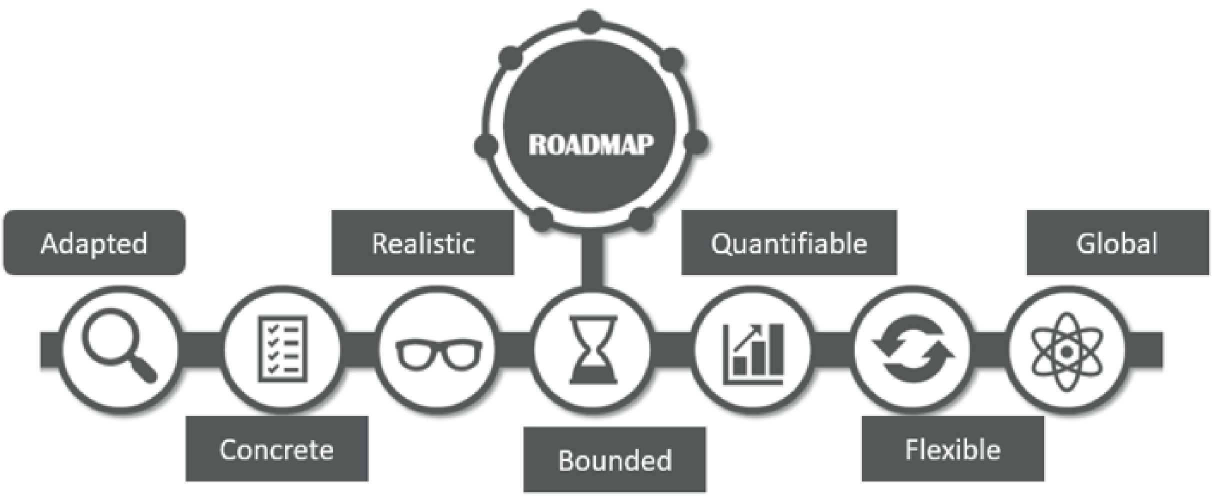


Figure 11. Features of a roadmap Source: Renault Consulting

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

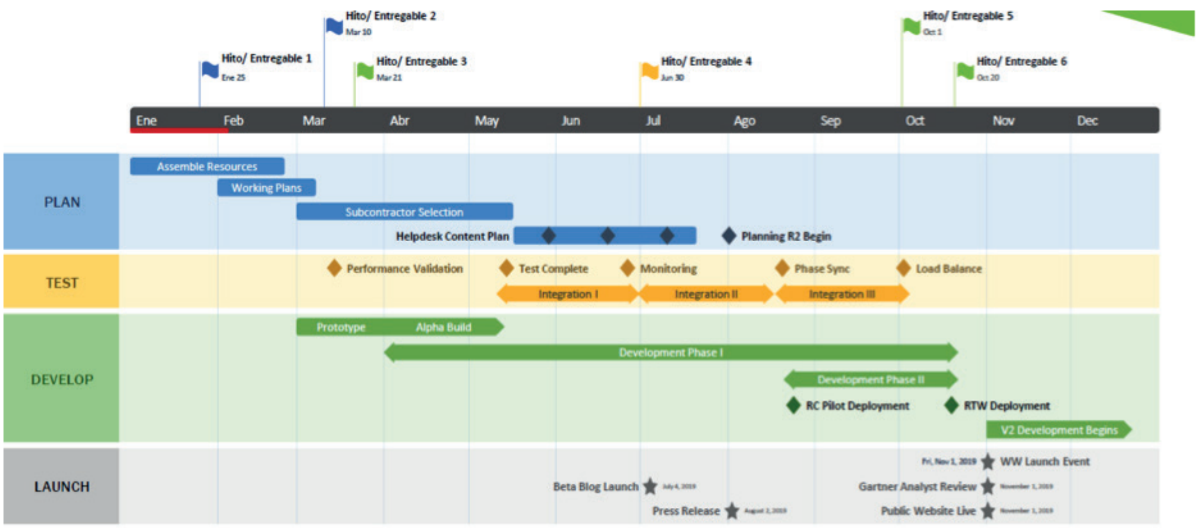


Figure 12. Example of roadmaps Source: Renault consulting

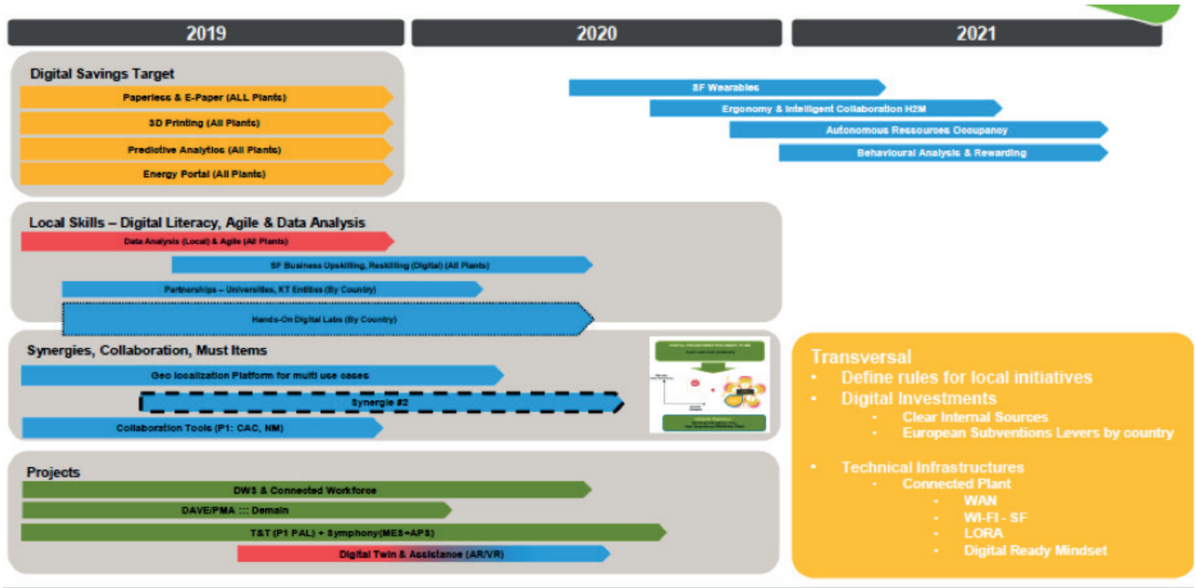


Figure 13. Example of roadmaps Source: Renault consulting

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 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.

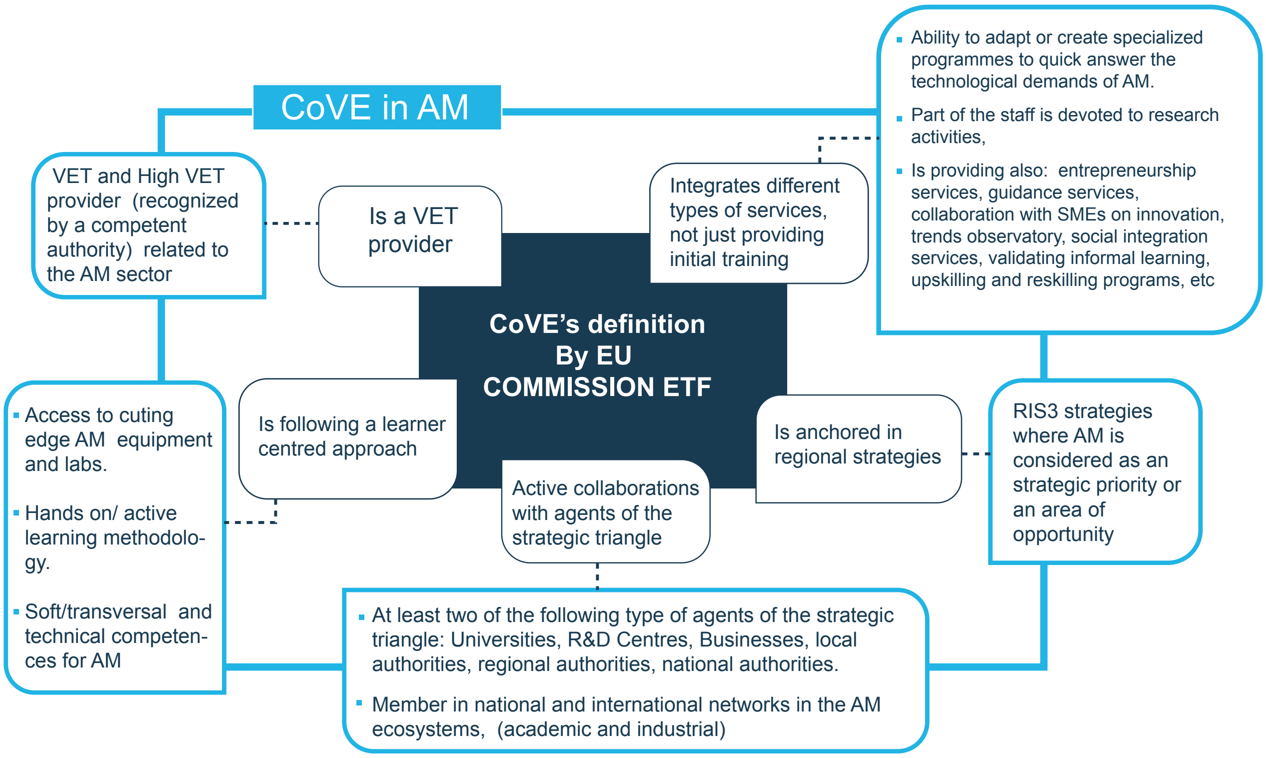


Figure 17: Features of CoVE's for Advanced Manufacturing .Source: EXAM4.0

5.1. 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.

5.2. 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

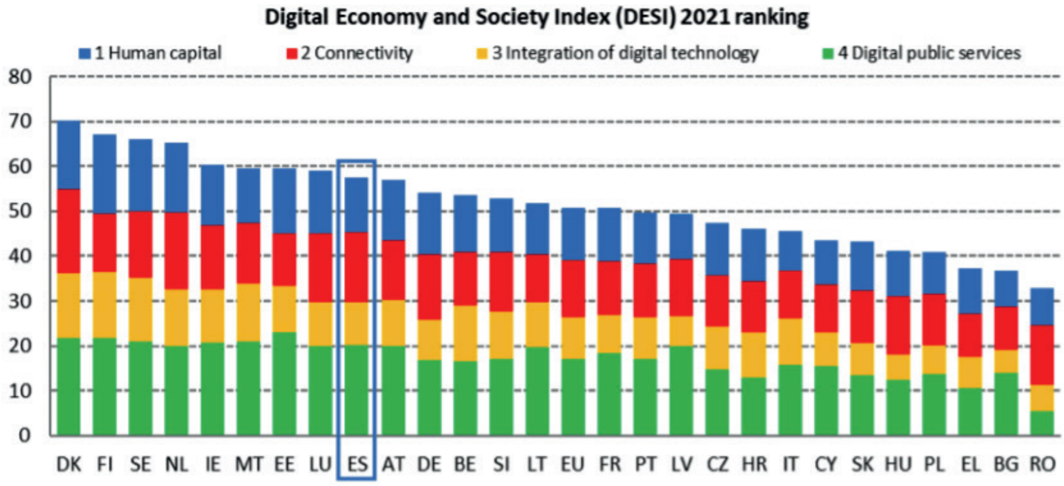


Figure 18: Economy and Society Index Source: DESI Index

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.

5.3. 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.

5.4. 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

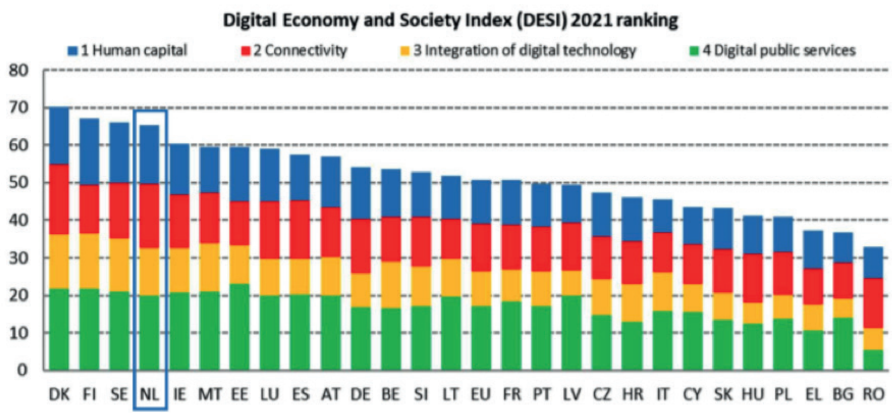


Figure 19: Economy and Society Index Source: DESI Index

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.

5.5. 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 unemployment 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.

5.6. 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.

6 Design Plans Proposal for the VET centre 4.0

6.1. 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

6.2. 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.

6.3.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.

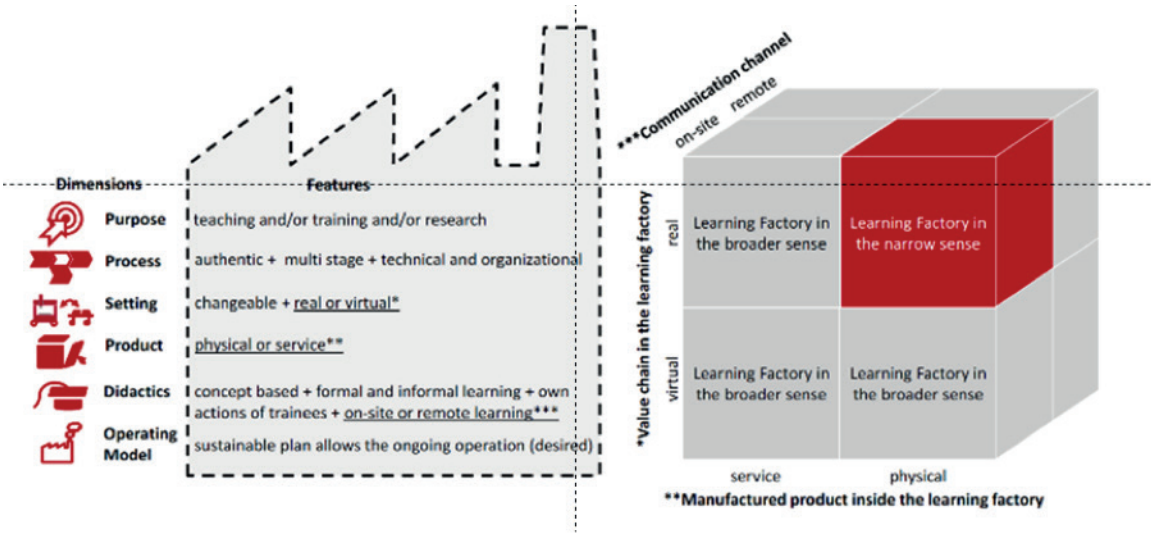


Figure 20: Key features and variants of Learning Factories – Source Abele 2015 at all.

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.

6.4. 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.

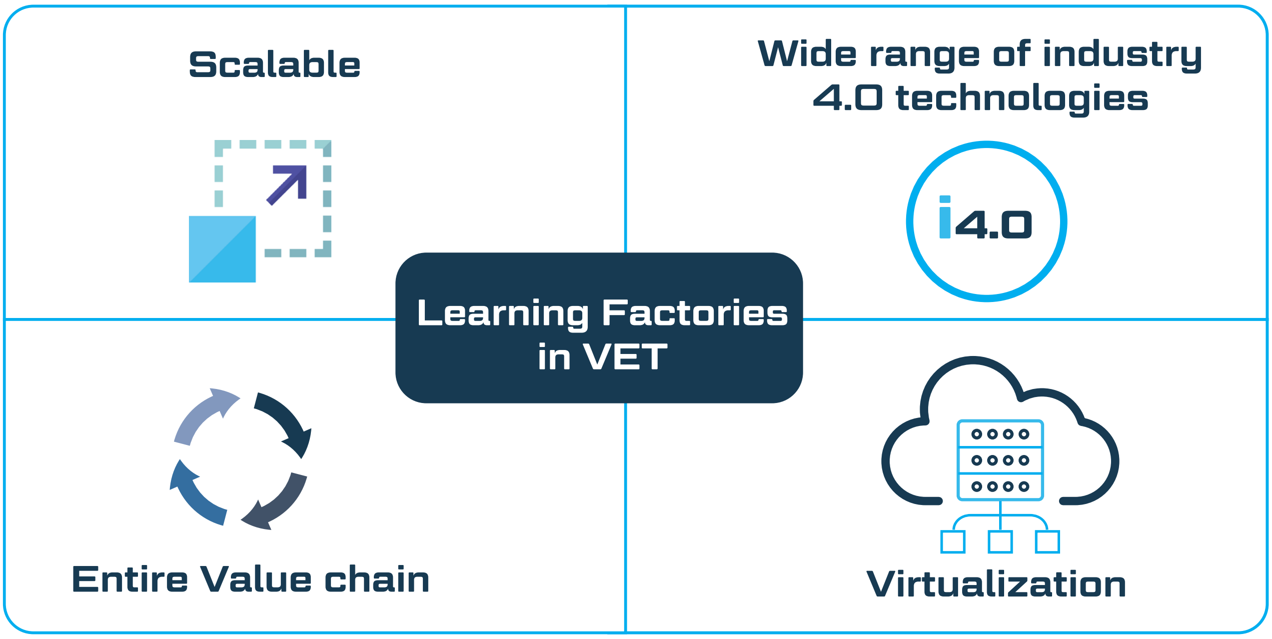


Figure 21: Image of Advantages of LFs: Source Exam4.0

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.

6.5. 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.

6.6. EXAM 4.0 Collaborative Learning Factory

6.6.1. 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.

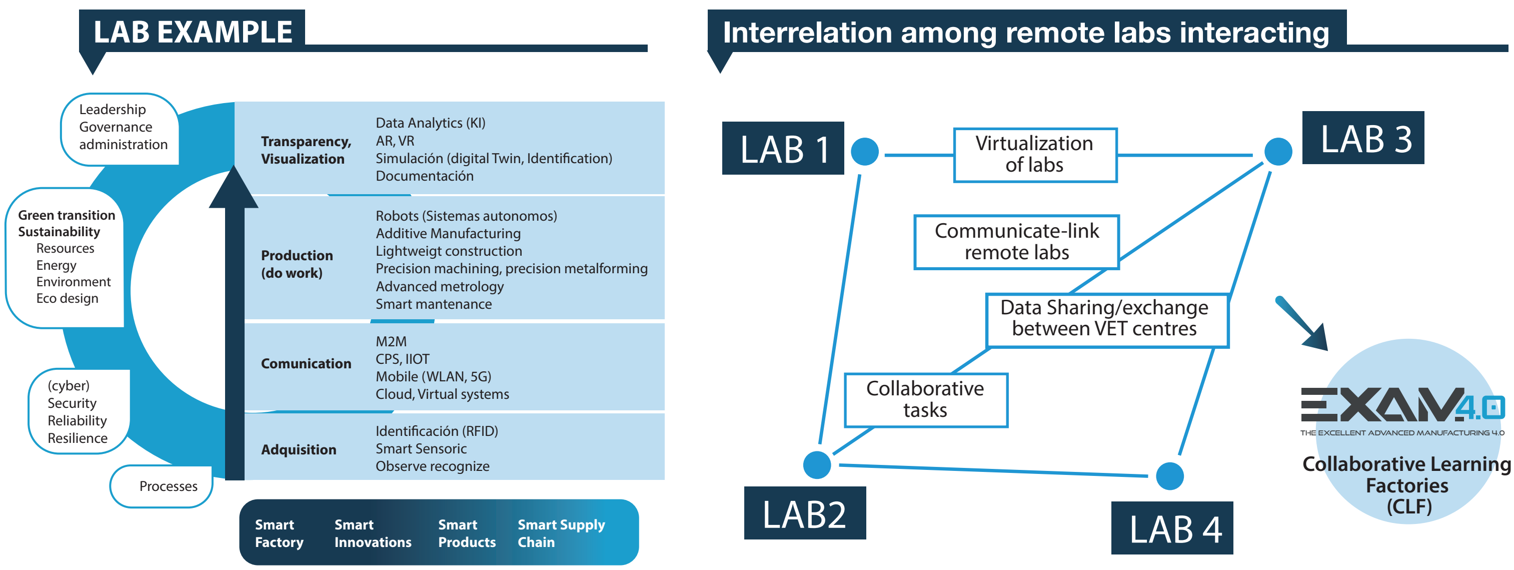


Figure 22 Image of the schematic interrelation among remote labs interacting in the CLF: Source Exam4.0

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

6.6.2. 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

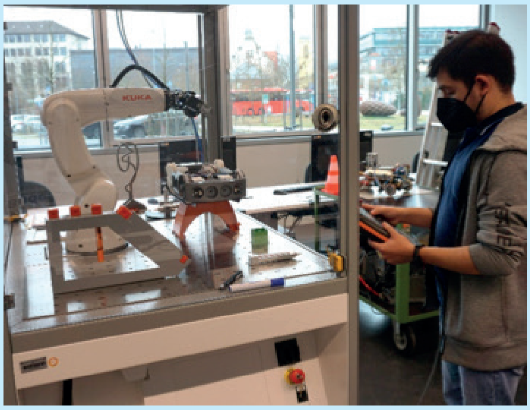
In order to use a established and easy to compare system to categorize de CLF, we describe our proposed CLF using the LF morphology proposed by the AILF: in this model the LF morphology is described by 7 dimensions: 1) Operational model, 2) Targets and purpose 3) Process 4) Settings 5) Product 6) Didactic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

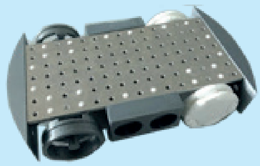
The CLF has been carried out by joining several independent LFs. The sum of the contributions of each LF makes up the final result, i.e. the product generated in collaboration: the EXAM4.0 autonomous educational robot.

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

<table>
<tr><th>DIMENSION</th><th>EXAM4.0 CLF</th><th>ASPECTS CONSIDERED IN THIS DIMENSION:</th></tr>
<tr><td>3.- PROCESS</td><td>Sum of the involved LF’s processes</td><td rowspan="2">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
</td></tr>
<tr><td>4.- SETTINGS</td><td>Sum of 4 involved LF’s settings</td></tr>
<tr><td>4.- PRODUCT</td><td>Autonomous mobile educational robot</td><td>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,).
</td></tr>
</table>

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

6.6.3. 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.

6.6.4. 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

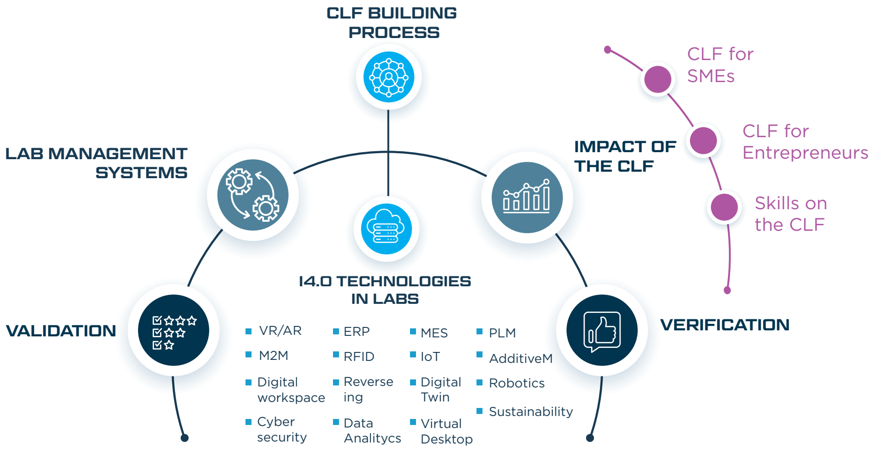


Figure 24: Reports on the influence of a CLF implementation on VET side programs; Source EMAM4.0

6.6.5. 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.

6.7. 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.

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