D2.4. Policy Recommendations (II)

WP2: Learner Centric Advanced Manufacturi

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EXECUTIVE SUMMARY

The goal of the D2.4 Policy Recommendations is to inform policy makers at local/regional/national/and European levels about our developments. This information might be useful for them to design their policies..

The second policy recommendation shares the key findings of our research on the set up, implementation, applications, and international collaboration in Learning Factories in VET, and provides recommendations for policymakers. These recommendations are aimed at the EU level, but they can also be relevant at the national, regional, and local levels and are based on three assumptions:

- Relevance of a skilled workforce. Having the right skills is a vehicle for employability (at the individual level), prosperity (at the individual, company, and economic level), and innovation (both at the company and social level).
- Relevance of good quality and technologically up-to-date labs and training facilities to ensure vocational education and training students are used to operate in highly digitalised factory-like settings before their entrance in the labour market.
- Relevance of active learning and hands-on learning methodologies for vocational education and training students to become highly skilled. This includes a combination of job specific, transversal and digital skills, as well as a combination of practical (hands on) and theoretical knowledge.

This Policy Brief is based on the research of the LCAMP under its sixth work package. For the relevant reports, please look on the website or check the section “further reading” below. Please note that the following key findings and recommendations are aimed at vocational education and training between levels three and six of the European Qualifications Framework.

The document is composed by:

- A definition of Learning Factory, with a subsection on Collaborative Learning Factories.
- Reasons to support the implementation of learning factories in vocational education and training.
- Five Key findings and six recommendations that follow from them.
- A summary of all the recommendations for faster reading.
- A general description of LCAMP.
- References.

1. HOW DOES LCAMP DEFINE THE CONCEPT OF THE LEARNING FACTORY”

Before we start with the recommendations, it is important to clarify what LCAMP refers to with the expression “Learning Factory”.

Learning Factories are specialised, high-tech educational environments that replicate real-world industrial settings, offering students immersive, hands-on learning experiences. These simulated workplaces are equipped with advanced technologies such as robots, computer-controlled machinery, and other automated systems, enabling students to apply theoretical knowledge in realistic contexts while developing technical and practical abilities, as well as critical thinking and problem-solving skills (Abele, 2015). By emulating actual industrial processes, Learning Factories help students gain a deeper understanding of specific industries and the tasks, processes, and technologies involved. The International Association of Learning Factories (IALF) defines them as follows (Abele E., 2015) (IALF, 2021):

> A Learning Factory is a learning environment where processes and technologies are based on a real industrial site which allows a direct approach to product creation process (product development, manufacturing, quality-management, logistics). 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.”

See also: D6.1-PartI-Role-of-LFs-in-VET-1.pdf pages 13-16.

1.1. THE COLLABORATIVE LEARNING FACTORY

A Learning Factory is defined as "a close-to-reality factory environment for education, training, and research purposes, which enables experiential learning in a realistic industrial setting" (Abele et al., 2017). In this context, the **LCAMP Collaborative Learning Factory** represents a physical environment designed for educational purposes that replicates the entire value chain required to produce a product, with a strong emphasis on realism and features that promote collaboration (LCAMP, 2023).

This semi-industrial learning environment is specifically designed to support the integration of Industry 4.0 technologies and infrastructures within educational settings. It encourages interdisciplinary cooperation, allowing multiple disciplines to work together within the same Learning Factory. Additionally, it facilitates collaboration between geographically separated vocational education and training (VET) centers, enhancing the learning experience through connectivity and shared innovation (LCAMP, 2023b).

Figure 1. Assembly cell within the CLF at Miguel Altuna LHII's facility. Source: LCAMP

The difference between a learning factory in a narrow sense (Abele et al., 2017) and a collaborative learning factory is that summarised in the table 1 below:

Table 1 Comparison between Learning Factory and Collaborative Learning Factory

Learning factory (in a narrow sense (Abele, 2016))	**Collaborative learning factory**
Reproduce a production process of a real factory.	Reproduce a production process of a real factory.
Located in a single geographical location.	It is geographically distributed in various location where the different learning factories are located. The CLF interconnect LFs.
Does not involve an international element.	Optionally, student are required to collaborate with students from other countries because each learning factory is producing a part that will then be assembled in an assembly line, which will also be located in one of the learning factories.
The full production process takes place in a single learning factory.	The production process can be either fully implemented or subdivided among various learning factories.

2. WHY SUPPORT THE IMPLEMENTATION OF LEARNING FACTORIES IN VET?

Our research on the effects of the digital and green transition on a selection of manufacturing jobs showed that companies look for a workforce with the following characteristics in relation to skills:

- Holistic approach to digitalisation: The levels of digitalisation and automation are heterogeneous, with higher digitalisation levels in bigger companies. In general, digital technologies are not simply new tools to perform old tasks. Digital technologies change the way workers relate to each other, the way they relate to their work, the way they work and, of course, some of the tasks (or a lot, or all, depending on the job and the company) they perform. In this sense, digital skills are important but complex and not exclusively technology dependent. We have to approach the digitalisation of work in a holistic manner.
- Technological non-determinism: Technology trends are important but are not determinant, there are important non-technological elements (organisational practices, types of companies, sector, etc.) that influence the way jobs are affected by technology.
- Relevance of new technologies: Most companies are aware of their need to introduce new technologies, digital and others, to continue being competitive, attractive for the new generations and more sustainable.
- Basic skills to do the job: Companies seek workers with a solid understanding of the fundamental technical aspects of the job. Each company, after hiring a person with the basic knowledge, invests a considerable amount of time in training, in most cases within the company, until they have an autonomous and productive worker. In addition to a solid fundamental base, companies seek highly specialized profiles. The more specialisation we can achieve while maintaining a strong base and the inclusion of soft skills, the better.
- Soft skills: Transversal or soft skills, such as communication, interest in learning, flexible mindset towards change, or problem-solving, are very valued but only when they come as an addition to technical skills. Despite all the rhetoric in favour of soft skills and predicting the obsolescence of technical skills, despite the “humans should focus on human tasks while machines should focus on technical tasks” rhetoric, companies value soft skills if and only if they come together with technical skills.
- Foreign languages: Companies value workers who can speak other languages apart from their mother tongue. The language of preference varies from one company to the other.

These findings about the needs of companies create challenges for vocational education and training providers which should, ideally, be capable of meeting them. The table 2 shows how LCAMP’s Collaborative Learning Factory potentially addresses the challenges and meets the needs of companies:

Table 2 Challenges addresses by the Collaborative Learning Factory

Challenge/ company need	LCAMP Collaborative Learning Factory

Holistic approach to digitalisation	In the collaborative learning factory, digital technologies are introduced as part of a production process and not as an end in themselves. The CLF reproduces the whole value chain of the production process. This is useful to ensure vocational education and training students are aware of the whole value chain while they are used to work in highly digitalised production lines and understand digitalisation as applied to production.
Technological non-determinism	In the collaborative learning factory many non-technological decisions have to be taken to design and carry out the distributed production process that will lead to the final product (which is a technological product produced with the use of technology). This creates the need to combine the use of technology with the need to organise work, to divide tasks, to make decisions, and to solve problems. As a result, students acquire an understanding of technology which is close to the real world, instead of learning to use gadgets without any context or in highly artificial situations designed for learning purposes. Furthermore, learning factories allows the replication of the organizational aspects that influence the functioning of operation in production lines, allowing for the development of different perspectives on the use of technology.
Relevance of technologies	Companies are (they have probably always been) introducing technologies with various aims (being more competitive, more attractive, safer, more efficient, save energy, reduce error, automate manual tasks, etc.). The nature of the technologies introduced and the way that those technologies are implemented within the production processes, jobs and tasks are bringing changes, in many cases substantial changes, on the skills of the workforce. If vocational education and training providers are to be a relevant partner of companies, they also have to adopt those technologies to prepare students for modern industrial needs. Vocational education and training students and teachers should be familiar with the newest technologies. LCAMP collaborative learning factory provides a pathway with assistance tools, a network of practitioners,

	theoretical knowledge, conferences, and real-life examples to support vocational education and training providers in the implementation of new technologies in their labs.
Basic skills to do the job	In the collaborative learning factory students learn by doing. Students who are able to pass a course in the collaborative learning factory setting, are very likely to have acquired the basic skills needed by a company. In addition, the collaborative learning factory is an appropriate environment to acquire specialised skills.
Soft skills	The (active) learning methodologies adopted in the learning factories, facilitate addressing several transversal skills. Learning factories are prepared even to assess those skills when the appropriate skills frameworks are in place. The nature of the collaborative learning factory where students from different countries co-work designing and manufacturing a product make the approach an excellent way to develop soft skills.. In more advanced set ups, where interdisciplinar learnings are introduced, students carry out cross speciality projects within the collaborative learning factory, by working in interdisciplinar teams.
Foreign languages	In the collaborative learning factory students from one place will work with students from other places. If the vocational education and training providers are located in countries with different languages, students will develop their capacity to communicate with people from other nationalities. This is a skill that will be highly valued in the labour market.

Learning factories are, therefore, a promising tool to address the needs of companies and to help vocational education and training students in acquiring relevant competences. Things being so, what could be done to support their implementation?

3. KEY FINDINGS AND RECOMMENDATIONS

The successful implementation of a learning factory (a pre-requisite for the collaborative learning factory) should consider five elements. The first three elements are necessary conditions, the next two are important but not indispensable:

- Funding: the setting up of a learning factory requires the implementation of technology in the facilities of a vocational education and training provider. This can only be done through a solid funding programme.
- Knowledge: funding is necessary to buy equipment, but its successful implementation to replicate a factory-like setting and its meaningful use with students will also depend on the knowledge of the staff involved in setting the learning factory up and in using it with students in a meaningful manner.
- Mindset for learning factories. Setting up a learning factory and making it available across various specialization areas in a school requires the involvement of several members of the organization. In many cases, this will call for changes in teaching methodologies and organizational structures, bringing shifts to the daily routines and habits of various teachers. To make all this possible, a 'learning factory' mindset is essential, as is the support of pedagogical leaders and school's managers.
- Support tools: there are tools that can support the (competent) staff using the funding to establish learning factories. These tools are not sufficient in themselves, but their success depends on the competence of the people using them and the availability of funds to carry out the actions envisaged.
- Internationalisation: perhaps the most dispensable element of the list, but helpful to connect with other vocational education and training providers and work in collaborative learning factory activities. It is

The next subsections will delve deeper into these elements and provide policy makers with specific recommendations, but let us summarise this introduction by saying that the successful implementation of a learning factory, or collaborative learning factory, depends on having enough funds to be invested under the guidance of persons who have a knowledge of the topic and an engaged team and that this implementation could be supported by different tools and international options.

3.1. FUNDING

The successful implementation of a learning factory requires funding. On the one hand, vocational education and training providers should have funds available to be invested in technology. On the other hand, vocational education and training providers should have enough staff to carry out these implementations. As a consequence, our first recommendation for policy makers is:

Recommendation 1: Create a targeted funding mechanism to finance (or co-finance) the implementation of technology in vocational education and training provider facilities.

This first recommendation can be further developed at different levels:

Recommendation 1a for the European Union: create a targeted EU funding mechanism to co-finance the implementation of technology in vocational education and training provider facilities. Erasmus+ and Horizon Europe would be the programmes in which it makes most sense.

Recommendation 1b for national, regional, and local policy makers: finance the implementation of technology in vocational education and training making use of the available mechanisms.

3.2. KNOWLEDGE

The successful implementation of a learning factory requires people with knowledge of the topic. The value chains reproduced within learning factories can reach levels of sophistication comparable to those found in industrial enterprises. These environments integrate, or have the potential to integrate, a wide array of technologies, making expertise across various disciplines and domains a fundamental requirement. It is not only knowledge of specific technologies that is required, but also the ability to integrate diverse technologies, ensure the effective functioning of the production chain, and embed learning activities within it. Furthermore, given that the primary objective is people training, the relationship between people and technology must be carefully addressed, and the impact of seemingly revolutionary technologies—such as artificial intelligence—must be critically assessed.

Developing this knowledge depends on three things:

- Having a strong knowledge base on which the understanding about learning factories can be built. The people (from diverse background) involved in these activities should have a strong technological base on their fields and then learn about its implementation in learning factories. They should also have a solid understanding of the curricular and pedagogical aspects of his/her region, as well as experience in working with students.
- Being encouraged to learn and having time for it. From an educational perspective, getting involved in learning factories requires stepping outside our comfort zones, moving beyond the areas in which we may already be experts, and engaging in collaborative work with specialists from other fields.
- To get access to the knowledge. The availability of learning resources, be it courses, books, publications, videos, etc, the availability of communities of experts (i.e the international association of learning factories) and their open communities.

For developing knowledge on the topic, LCAMP has developed (and is still doing so) publications, courses, pilots, and tools. All of them are available through our webpage. There are other interesting knowledge sources that can be found in different EU funded projects (check the references section of the document) or in international networks (check the references section).

To better understand our approach to technological knowledge, it may be useful to recall 3 of the 10 principles of our strategic plan (pages 9-15):

- Principle 3: against technological determinism, that we can summarise as follows:
    - Technology and society are not independent. They shape each other in a process of co-construction
    - The “big-bang” type of invention, if it exists at all, is very rare. Most new technologies appear as a result of a long process of small changes in which several actors participate.
    - It is important to acknowledge the relevance of other stakeholders (apart from the builders of technology) in the creation of new technologies. In this sense, the

role of users has been researched in the last few years (von Hippel 2006, Oudshoorn and Pinch 2005; Oldenziel and Hard 2013)

- Principle 5: Principle 5: Digitalisation goes beyond introducing new tools in our work, that we can summarise as follows:
  - Digitalisation modifies how we work, how we communicate and how we live. An approach to digitalisation that considers questions such as “what skills do our students need to handle digital technology A and B? What skills do workers need to use digital technology C? ” do not grasp the complexity of the issue. The adoption of most new technologies literally changes our lives and we should address digitalisation with this broad mindset.

- Principle 7: Broad conception of technology and knowledge:
  - We adopt a wide definition of technology. For us technology will mean (Bijker 1995):
    - The knowledge required to handle a specific technology, or artifact, or a group of them.
    - The artifacts themselves, like a computer, a robot, or a pencil.
    - The reflection about the previous two, as in reflecting about I4.0, I5.0, digitalisation or advanced manufacturing.

  - As for knowledge, there are different types that are relevant to our field of activities (Jensen et al. 2007): knowledge-what, knowledge-why, knowledge-who, and knowledge-how. All of them are important, but we are aware that VET is related to knowing how to do things, more than to knowing why or what.
    - Know-how will typically be learnt in apprenticeship-relations where the apprentice follows his master, studies his ‘body language’ as well as his spoken language and relies upon his authority. Know-how is what characterizes a skilled worker and artisan but it is also something that distinguishes the first-rate from the average manager and scientist. (cited from Jensen et a. 2007)

Our second and third recommendations are

Recommendation 2: support research and hands on activities about learning factories to ensure that a solid knowledge is being generated and disseminated.

This recommendation can be developed in further levels:

Recommendation 2a for the European Union: include learning factories as a topic for research or to develop activities in the funding programmes to support the generation and the diffusion of knowledge about learning factories in Europe.

Recommendation 2b for national, regional, and local policy makers: support the generation and diffusion of knowledge about learning factories by creating schemes for developing focused research, development or testing activities.

Recommendation 3 for the European Union: encourage teachers (or other staff) to develop their knowledge about learning factories and national, regional, and local policy makers to support the implementation of learning factories by showcasing good examples, case studies, or inviting speakers to conferences.

3.3. MINDSETS FOR LEARNING FACTORIES

The implementation of learning factories will influence on the pedagogical aspects of the teaching and learning processes. Switching from traditional teaching methods to active methodologies such the introduction of a learning factory for hands on learning activities requires a transformation process of the way that the learning processes takes place. To update pedagogic schemes certain aspects must be reviewed:

- Teaching delivery methods.
- Assessment frameworks and methods.
- Definition of learning KPIs linked to the learning factory processes
- Coordination of teachers, spaces, schedules and timetables
- Inclusion of interdisciplinary learning activities

The adoption of learning factory will call for changes in teaching methodologies and organizational structures, bringing shifts to the daily routines and habits of various teachers. To make all this possible, a 'learning factory' mindset is essential, as is the support of pedagogical leaders and school's managers. Setting up a learning factory and making it available across various specialization areas in schools requires the involvement of several members of the organization.

Our fourth recommendation is

Recommendation 4 Promoting research on the pedagogy related to learning factories for vocational education and training.

- Encouraging research on the adaptation pedagogy of learning factories to regional VET systems.
- Fostering initiatives to adapt learning factory pedagogies and/or to develop corresponding mindsets.
- Disseminating best practices in learning factory pedagogies.

3.4. SUPPORT TOOLS

The discourses about technology and pedagogy are complex. Vocational education and training providers need approaches that they can realistically implement in their context and use with their students. There is an overload of available technologies and uncertainty about what to choose, when, and why. This is especially challenging for vocational education and training providers, which tend to have limited time, expertise, or budgets. LCAMP has developed some tools for those VET centres in the process of creating a learning factory: the Learning Factories. Self-Assessment Tool, LF-SAT. This tool aims to support teachers in the process of building a learning factory, addressing, pedagogy, value chain reproducibility, equipment and technology and training delivery. Moreover, relevant support documents are available in the LCAMP website with information on the morphology of the collaborative learning factory and guidelines to create a learning factory in HVET centres. In addition to the material created by LCAMP, the International Association of Learning Factories also offers various publications on their website. Among them is a tool for evaluating already operational learning factories: the Maturity Model for Learning Factories. https://ialf-online.com/publications.html

Our fifth recommendation is aimed at vocational education and training providers.

Recommendation 5 for vocational education and training providers: make use of the tools available at the LCAMP platform.

3.5. INTERNATIONALISATION

Knowledge and technology are (to some extent) universal: a knowledge generated in a region can be useful for others. Collaborative learning factories show their real strength for the development of students' competences when the international collaboration layer is added to the learning factory. LCAMP can support vocational education and training providers in connecting with others by providing networking opportunities, contacts, and joint development opportunities. Apart from that, LCAMP has created an Open Innovation Community, defined as:

> A group of people who share a passion for technological innovation in line with the LCAMP collaborative learning factory model and the ADMA model and we aim to learn how to do it better as we interact regularly

This allows any vocational education and training provider to have access to an assistance network composed of knowledgeable peers who can assist them in solving the challenges related to the implementation of (collaborative) learning factories.

Our fifth recommendation, aimed at regional and local policy makers and at vocational education and training providers is:

Recommendation 6 for regional and local policy makers and vocational education and training providers: join the LCAMP alliance to have access to a network of peers who can assist you and with whom you can connect for further developments.

4. SUMMARY

This policy brief provides insights from the LCAMP project on implementing Learning Factories in Vocational Education and Training across Europe. It offers recommendations for policymakers at local, regional, national, and EU levels, as well as for vocational education and training providers grounded in research from Work Package 6.

What is a Learning Factory?

- A Learning Factory is a high-tech, hands-on educational environment that replicates real industrial settings, helping vocational education and training students gain both technical and transversal skills.
- A Collaborative Learning Factory goes further—different parts of a product are produced across LFs in different countries and assembled in a final location, promoting international collaboration and soft skills like communication and teamwork.

Why Support Learning Factories in vocational education and training?

Learning Factories respond directly to the skills needs of industry, including:

- Holistic digitalisation awareness
- Real-world technology use (not only theoretical)

- Strong technical and soft skill development
- Exposure to international teamwork and foreign languages

Learning Factories help bridge the gap between what Vocational education and training providers teach and what companies need in their workers.

Key Success Factors & Policy Recommendations

Funding

LFs require significant investment in technology and staffing.

Recommendation 1: Create a targeted funding mechanism to finance (or co-finance) the implementation of technology in vocational education and training provider facilities.

Knowledge

Successful Learning Factory implementation relies on knowledgeable staff.

Recommendation 2: Support research and hands on activities about learning factories to ensure that a solid knowledge is being generated and disseminated.

Recommendation 3: Encourage teachers (or other staff) to develop their knowledge about learning factories and national, regional, and local policy makers to support the implementation of learning factories by showcasing good examples, case studies, or inviting speakers to conferences.

Mindsets

Recommendation 4: Promoting research on the pedagogy related to learning factories for vocational education and training.

Support Tools

VET providers face tech overload and need guidance on tools and strategies.

Recommendation 5: Use LCAMP-developed tools (self-assessment, maturity models) to guide Learning factories setup and use.

Internationalisation

Cross-border collaboration enhances student skills and institutional innovation.

Recommendation 6: Join the LCAMP Alliance and its Open Innovation Community to access peer networks and collaborative opportunities.

Final Takeaway

The LCAMP collaborative learning factory model:

- Aligns well with industry needs for digital, job specific, and soft skills.
- Supports internationalisation and modernisation of Vocational education and training.
- Requires investment, training, and shared tools to succeed.

Successful implementation = Funds + Knowledge + Mindset + Tools + Collaboration

5. ABOUT LCAMP

The LCAMP project aims to support and empower regional Advanced Manufacturing Centres of Vocational Excellence (CoVE) to become more resilient, innovative and better equipped to

train, upskill, and reskill young and adult students to successfully face the digital and green transitions.

In the context of LCAMP, you will find from the development of skills and competences to their provision; in addition to the design of learning pathways, micro-credentials, active methodological approaches, articulation of services and innovation for SMEs.

The fifth industrial revolution is built upon the technologies of the fourth, with an increased emphasis on a human-centric, sustainable and resilient industrial base, emphasising the digital and green transitions. A key pillar of this economic transformation is the role played by Advanced Manufacturing systems such as Robotics, 3D & 4D printing, artificial intelligence and high-performance computing.

Industry 5.0 requires Vocational Education and Training to develop 'learning-centric approaches' that focus on the holistic competences of humans that plan, manage, oversee or operate technologies. By collaborating across borders, the LCAMP alliance's goal is to support and empower regional Advanced Manufacturing Centers of Vocational Excellence to become more resilient, innovative, and better equipped to train, upskill, and reskill young and adult students to successfully face the digital and green transitions. The alliance will help regions grow and be more competitive through their Vocational Education and Training

To do so, the LCAMP project will develop activities in three main strands:

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
The LCAMP consortium is composed of 20 full partners from 10 countries, of which 9 are educational organisations, 7 are industrial companies and 4 are VET and industrial associations. The consortium is also supported by 60 associated partners.

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