Learner Centric Advanced Manufacturing Platform

RESEARCH ON THE ROLE OF LEARNING FACTORIES IN VET EDUCATION

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Project summary	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. I5.0, requires VET to develop 'learning centric approaches' that focus on the holistic competences of humans that plan, manage, oversee or operate technologies. LCAMP will tackle this by incorporating a permanent European Platform of Vocational Excellence for Advanced Manufacturing, seeded from a consortium of 20 partners and over 50 associate organisations including leading VET/HVET centres, companies, regional government, R&D centres, associations of companies and clusters. By collaborating across borders, LCAMP's goal is to support and empower regional AM CoVEs to become more resilient, innovative, and better equipped to train, upskill, and reskill young and adult students to successfully face the digital and green transitions. We will help regions grow and be more competitive through their VET systems. The Alliance is service-oriented, planning to establish permanent structures for:

	• Teaching & Learning: establishing AM skills frameworks and curricula; launching or revising AM programmes (including micro-credentials); creating or capacity building learning factories (special AM labs, jointly run by VET and industry) • Cooperation and Partnerships: launching a skills & jobs observatory for advanced manufacturing; accelerating industry/VET/region cooperation ideas via an open innovation community and providing consultancy to SMEs on integrating SME/VET connections. • Governance & Funding: creating a one-stop-shop portal for all our services; ensuring a business case for continuing services to stakeholders in the long-term, while enhancing participation
Work Packages	WP01: Project management and coordination. WP02: Learner Centric Advanced Manufacturing CoVEs Alliance. WP03: Observatory. WP04: Open Innovation Community. WP05: Human-Centric Learning for Advanced Manufacturing. WP06: Industry 4.0 technology absorption through the Collaborative Learning Factory. WP07: SME-VET connection. WP08: Advanced Manufacturing Excellence Discovery Platform. WP09: Dissemination. WP10: Roadmap for Continued Development Learner Centric Advanced Manufacturing CoVEs Alliance.

Glossary and acronyms

Acronyms

AI - Artificial Intelligence

AM - Advanced Manufacturing

CLF Collaborative Learning Factory

CoVE - Centres of Vocational Excellence

EXAM4.0 Excellence Advanced Manufacturing 4.0

EC European Commission

EQF European Qualifications Framework

EU European Union

HE Higher Education

HVET Higher Vocational Education and Training

I4.0 Industry 4.0

IALF International Association of LFs

IoT Internet of Things

LCAMP Learner Centric Advanced Manufacturing Platform

LF Learning Factory

LF4.0 Learning Factories 4.0

OECD Organisation for Economic Cooperation and Development

SDLF 4.0 Scale-Down Learning Factories 4.0

SIF Smart Innovative Factory

TVET Technical and Vocational Education and Training

VET Vocational Education and Training

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EXECUTIVE SUMMARY

This document analyses the use of Learning Factories in Vocational Education and Training (VET) centres providing technical study programs related to Advanced Manufacturing and Industry 4.0. The countries included in the study are France, Germany, Italy, Netherlands, Slovenia, Spain, Sweden, Türkiye, and Canada.

Overview

The report examines the various approaches to the setting up of Learning Factories (LF) in VET centres, their different contexts, and the challenges they face in different countries. It also provides a brief overview of the current state of Learning Factories in each country, highlighting key trends and initiatives.

Learning Factories in VET centres

"Learning Factories are a practical way of teaching in a hands-on environment, specialized learning environments that replicate real-world industrial settings and provide hands-on learning experiences for students." (E. Abele, 2015). In recent years, the trend of creating LF in the educational field has emerged. This fact is due to the positive contributions that this type of work-based learning offers in learning environments. The benefits of LFs at university level are well documented in literature. The approach is likewise useful for VET study programs.

However, the use of LFs in VET is not very popular. The research carried out in 9 countries shows that with very few exceptions, the variation of LFs denominated Scale Down Learning Factories (SDLF) are the most common type of LFs used in VET. These modular sized LFs, normally commercially supplied with didactic purposes, use equipment with reduced size compared with industrial equipment. Those SDLF are equipped with state-of-the-art digital technologies used in Industry 4.0 environments but they work on elements with smaller dimensions. Their didactic function makes them appropriate to address not only technical competences but also transversal ones. On the other hand, the SDLF lack the potential of working in the manufacturing of real products for which life size are needed. In that respect, the pedagogical approaches of SDLFs are more limited.

The core LFs, meaning life size environment with industrial equipment and lay out, are not common in VET centres. This publication reports on the pilot Collaborative Learning Factory concept which was followed up by the LCAMP project and is being approached as a joint Learning Factory.

Main findings

The use of LFs in Vocational Education and Training Centres is less common that the SDLF. The research found 175 VET centres using such facilities, most of them in Germany (39%) followed by Spain (including Basque Country) 25%.

A general finding in all the studied regions is that different types of active methodologies are widely implemented in VET schools, usually including the participation of industry partners. The use of active methodologies is common, independently of the use of LFs or SDLFs. In certain cases, similar learning methods to LFs are being used but with different/alternative denominations. Indeed, in some of the studied countries the term Learning Factory does not appear to be commonly used.

For the competences addresses in SDLFs, study programs and configurations used in the countries studied have many agreements. Their applications are usually for advanced manufacturing and industry 4.0 related VET study programs where they mostly address technical competences. Programs such as industrial automation, robotics, mechatronics, maintenance, advanced manufacturing, mechanical engineering, manufacturing production, control engineering and similar are using those pieces of equipment. These SDLF give certain space to develop many transversal skills, although they are also more limited than life size LFs to create interdisciplinary environments where more options are available.

Potential of life size LFs in VET

The study concludes that training in advanced manufacturing carried out in real environments and using active teaching methodologies provides great benefits.

It, moreover, suggests that VET centres are working with active teaching methodologies and that, in some cases, they also work with SDLFs.

If we furthermore take into account that LFs work well at university level, we can infer that the implementation of LFs in VET makes sense as a means of reinforcing training in advanced manufacturing.

1 INTRODUCTION

1.1 Objectives

This report analyses the use of Learning Factories (LF) in Vocational Education and Training (VET) and Higher Vocational and Training (HVET) centres providing technical study programs (EQF 3-6) in the countries represented by the LCAMP consortium, which are France, Germany, Italy, Netherlands, Slovenia, Spain, Sweden, Türkiye and Canada.

The report examines the various approaches to the setting up of LFs in VET centres, their different contexts, and the challenges they face in different countries. It also provides a brief overview of the current state of LFs in each country, highlighting key trends and initiatives.

In section 2 a mapping of LFs in those countries is shown. The mapping covers the main characteristics of the analysed LFs and a general overview of the competences and skills commonly addressed by the analysed LFs.

1.2 Research Methodology

The report is based on studies and desk research carried out by the partners involved: Miguel Altuna, Tknika, DHBW; VSS, CMQ, DVC, CNG, MADE; KPDONE, Camosun.

The studied European regions or countries are; Basque Country, Spain, Baden Wurttemberg (Germany), Slovenia, France, The Netherlands, the Västra Götaland region (Sweden), Italy, Kocaeli (Türkiye).

The methodology used has been direct interviews and structured surveys in regional VET networks conducted by partner organizations. A total number of **163 VET centres** and **53 other organizations in 9 countries** were included in the analysis.

COUNTRIES/REGIONS	NUMBER OF VET CENTRES ADDRESSED	NUMBER OF VET CENTRE INCLUDED IN THE STUDY	NUMBER OF UNIVERSITIES, RTO, COMPETENCE CENTRES
Basque Country	16	12	4
France	45	2	0
Germany	68	68	28
Italy	Not applicable (1)	0	8
Netherlands	13	13	0
Slovenia	10	5	1
Spain	29	21	8
Sweden	11	1	0
Türkiye	23	23	0
Canada	18	18	4
TOTAL	**233**	**163**	**53**

(1) Only in Lobardy there are 900 VET centres and there is no official data available as to whether those VET centres are using LFs or not.

➢ *Table 1 Scope of the study*

The second source of information have been the suppliers of commercial SDLFs. The 2 main suppliers are SMC International Training and Festo Didactics. In this case, the information may not be accurate enough in some of the covered regions due to the difficulties in contacting the regional distributors.

Thirdly, we have relied on publications of the International Association of Learning Factories to reinforce the analysis.

2 IDENTICATION OF LFS IN VET CENTRES

2.1 Definition of a Learning Factory

"Learning Factories (LF) are a practical way of teaching in a hands-on environment, specialized learning environments that replicate real-world industrial settings and provide hands-on learning experiences for students. These LFs are designed to simulate industrial processes and allow students to apply the knowledge they have acquired in the classroom to a real-world environment. They are typically a simulated work environment, complete with tools, machines, and materials, where students can practice and apply the skills and knowledge they are learning in a real-world setting. They can also be used to introduce students to a particular industry or field, allowing them to gain a better understanding of the types of tasks, processes, and technologies associated with the field" (Abele E., 2015)

In a high-tech educational environment such as LFs, students can gain practical experience in a simulated industrial environment. They are equipped with advanced technology, including robots, computer-controlled machines, and other automated systems, which allow students to learn in a realistic and immersive way. The LF model has been shown to be effective in supporting the learning of technical and practical skills (E. Abele, 2015), as well as problem-solving and critical thinking.

In recent years, the trend of creating LF in the educational field has emerged. This fact is due to the positive contributions that this type of work-based learning offers in learning environments. In order to improve or acquire technical skills, self-explanatory and easy to use tools can be used in the area of work-based learning. On the one hand, these tools allow the employee to manage complex situations, while at the same time, making the process more efficient (Adolph, Tisch, & Metternich, 2014).

2.2 Types of Learning Factories

The reference model used in this report to describe the LFs is the Learning Factory Morphology given by the International Association of Learning Factories (IALF): *"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."* (Abele E., 2015) (IALF, 2021)

Under the IALF definition a lot of different configurations of LFs are possible. The IALF describes the variety of the LF concept diversity along seven dimensions as show in **Figure 1**. (Abele E., 2015) (Tisch, 2019)

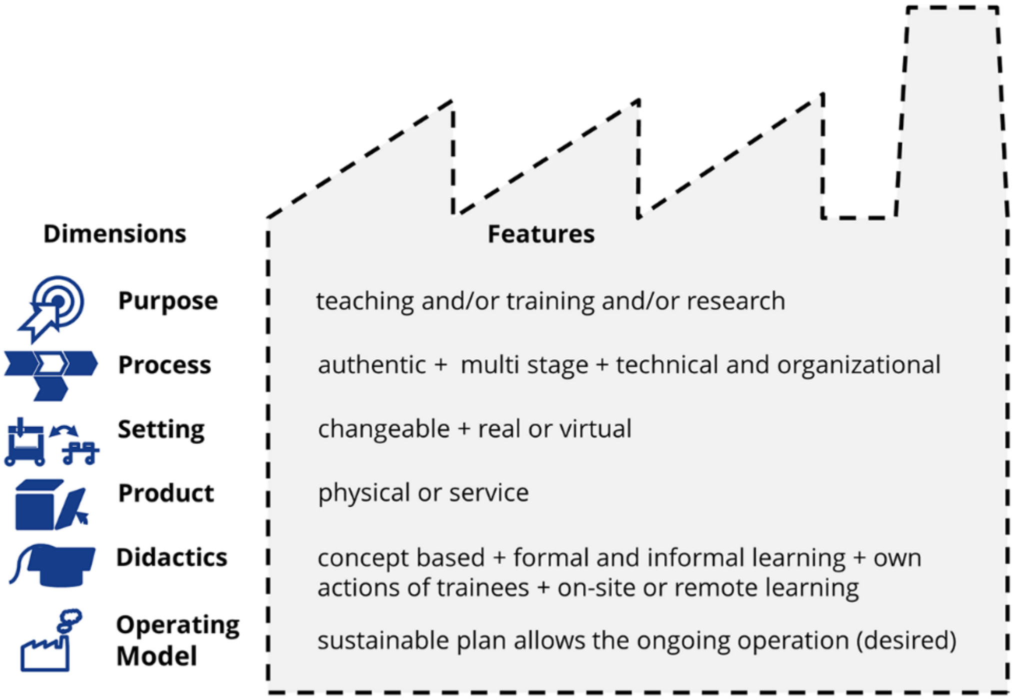

Figure 1 *Dimension of a LF Source: (Abele E., 2015)*

The description of those dimension makes it possible to compare LFs along the mentioned 7 dimensions.

- Operational model
- Purpose and targets
- Process
- Setting
- Product
- Didactics
- Metrics

For Each of the 7 dimensions there are multiple variants, therefore an exhaustive comparative analysis requires all those details for all the described LFs.

The target of the current study are LFs established in VET and HVET centres, study programs for students of EQF levels 3-6. In some cases, the purpose of the LFs covered in this study will also be ongoing worker training.

Taking as a reference the guidelines established by the IALF, the core concept of the LF consists of a realistic, **physical life-size factory environment** in which a physical product is created that learners can experience directly on site (Abele E., 2015). However, there can be some variations to that concept that are also considered as LFs, which are:

- Scale Down Learning Factories or model scale Learning Factories (SDLF)
- physical mobile LFs,
- low-cost LFs,
- digitally and virtually supported LFs
- producing LFs.

Considering the competences addressed in VET centres and taking into account the presence of SDLF in VET schools, we have included 2 main groups of LFs in this study:

- **Standard Learning factories:** Following the core concept of LFs: "a realistic, physical **life-size factory** environment in which a physical product is created that learners can experience directly on site (Abele E., 2015) Some examples are shown in **Figure 2** and **Figure 3**.
- **Scale Down LFs**, modular sized LFs, normally commercially supplied with didactic purposes. "Scaled or model scale LFs do not use original factory equipment but smaller equivalents, which should differ as little as possible from the original factory equipment except for the smaller dimensions" (Abele E., 2015). (Examples show in section 9.1).

Whatever the configuration of the LF is, they offer a prominent action oriented pedagogical approaches which are aligned with the competence building methods generally used in European VET systems. The pedagogical approaches enhancing experiential learning and project-based learning help to develop new ways to work simultaneously on job specific and transversal competences (OECD, 2021).

Figure 2 *The IIoT LF in TU Darmstadt. Source: TU Darmstadt*

Figure 3 *Smart Production Lab. Source: FH Johanneum*

2.3 Presence of LFs in VET centres

The reference model used in this report to describe the LFs is the Learning Factory Morphology given by the International Association of Learning Factories (IALF): *"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."* (Abele E., 2015) (IALF, 2021)

Under the IALF definition a lot of different configurations of LFs are possible. The IALF describes the variety of the LF concept diversity along seven dimensions as show in **Figure 1**. (Abele E., 2015) (Tisch, 2019)

2.4 Competences and Skills

The competences and skills that can be trained in LFs are varied and cover a wide range of disciplines and industries. These can include technical skills such as automation, operating machinery, programming, robotics, as well as transversal skills like communication, teamwork, critical thinking and problem-solving.

One of the main advantages of LFs is that they provide an immersive and experiential learning environment, which can help to bridge the gap between theory and practice. By simulating real-world scenarios and challenges, learners can develop the confidence and competence needed to succeed in their chosen profession.

Furthermore, LFs can be tailored to meet the needs of different learners and industries, making them a flexible and adaptable approach to vocational and educational training. Whether someone is looking to develop a specific technical skill or to build their soft skills and professional competences, a LF can provide an effective and engaging learning experience. Furthermore, the LFs are configurations to fulfil users need which will determinate the purpose of the LF. Therefore, depending on the desired competences and skills the configuration of the LF may change.

Concerning the SDLF 4.0 for advanced manufacturing and industry 4.0 they are designed mostly to address technical competences of industry 4.0. Depending on the modules purchased and their set up, the competences will vary. In the case of Germany, the methodologies of the LFs aims to link competences of mechanical engineering, electrical engineering an IT with professional production management systems' competences.

Taking as example the stationary LF by SMC International Training (SMC International Training, 2023) the competences and skills obtained by learners would be the following.

- Technical skills: the assembly, testing, and maintenance of sensors and measurement systems. This includes the use of specialized tools and equipment, such as soldering irons, oscilloscopes, and multimeters. They could include 3D printing, CNC machining, and robotic assembly.
- Quality control: Learners can develop competences related to quality control processes and procedures. This includes the ability to identify defects and implement corrective actions to ensure that products meet the required specifications.
- Lean manufacturing: Learners can develop competences related to lean manufacturing principles and techniques. This includes the ability to identify and eliminate waste, optimize production processes, and improve efficiency.
- Collaboration and teamwork: Learners can develop competences related to collaboration and teamwork. This includes the ability to work effectively in a team environment, communicate with colleagues, and contribute to the achievement of common goals.
- Problem-solving: Learners can develop competences related to problem-solving. This includes the ability to identify and analyse problems, develop and evaluate alternative solutions, and implement effective solutions.

Another example of competences addressed by SDLFs can be found hereafter: the learning goals of the MPS 404-1 model by FESTO Didactics (Festo Didactics, 2023):

- Networking of multiple stations, controllers and I/O units with an MES-centred software environment via network-based protocols (OPC UA, IO-Link, PROFINET, TCP-IP, Node-RED).
- Programming of industrial touch panel and getting to know modern human-machine interfaces such as augmented reality and web interfaces.
- Getting to know RFID and network technology and intelligent sensors based on IO-Link.
- Getting to know new business models through IIoT retrofitting using webcam and small computers as well as application of algorithms from the field of machine learning.
- Manufacturing of customised products through Webshop-induced manufacturing orders.
- Vacuum and parallel gripper technology and conversion of production systems.

2.5 Collaborative Learning Factory

The Collaborative Learning Factory (CLF) is a concept that brings together the principles of collaborative learning and the structure of a factory-like environment to enhance the learning experience. It is a model that promotes active participation, teamwork, and practical application of knowledge. By combining hands-on activities with group collaboration, the CLF fosters a dynamic and engaging learning environment.

The key idea behind the CLF is to simulate real-world scenarios and challenges within an educational setting. It aims to bridge the gap between theoretical knowledge and practical skills by providing students with opportunities to work together, solve problems, and apply their learning in a realistic and meaningful way. The factory-like environment offers a structured framework that allows students to experience the entire process of a project, from conception to completion.

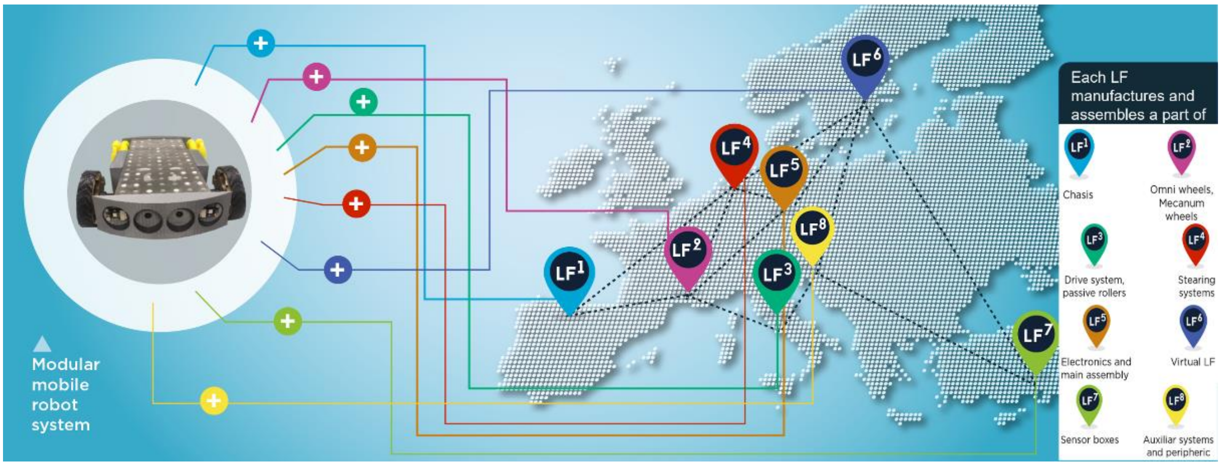

Figure 4 CLF, network of LFs Source: LCAMP

LFs or manufacturing labs to set up a common infrastructure to design, manufacture, and assemble products in collaboration The CLF is a part of the Learning Centric Advanced Manufacturing Platform (LCAMP), an international network of VET providers that have linked their regional autonomous (EXAM4.0, 2019). In the CLF, the product is subdivided into sub-products and each subproduct is produced in independent LFs located in different regions (see **Figure 4**). The final assembly of all the subproducts is carried out in CLF's final assembly line, located in a partner's lab (EXAM 4.0 (b), 2021) (EXAM4.0 (a), 2021).

This international consortium aims to enrich local independent LFs and/or manufacturing labs by fostering international collaboration. Currently 8 organizations, VET centres, a competence centre and a university of applied science are involved in the initiative.

2.6 International Association of Learning Factories

The International Association of Learning Factories (IALF) is a global organization dedicated to promoting and advancing the concept of LFs in education, research, and industry. Its mission is to foster collaboration, knowledge exchange, and innovation in order to enhance the effectiveness of LFs worldwide. The emphasis is in the relevance of improving technical skills and competences, as well as efficient capacity in newer processes. (IALF, 2021)

These are the LFs that are registered in the IALF.

EUROPE, MIDDLE EAST AND AFRICA	UNIVERSITY	LFs NAME
Austria	Vienna University of Technology	**Pilot Factory Industrie 4.0**
Greece	University of Patras	**LMS Learning Factory**
Germany	RWTH Aachen University	**DCC Aachen**
Germany	Braunschweig Institute of Technology	**Die Lernfabrik**
Germany	Reutlingen	**Werk150**
Hungary	Hungarian Academy of Sciences	**Centre of Excellence in Production Informatics and Control**
Germany	Ruhr University Bochum	**LPS Learning Factory**
Germany	Karlsruhe Institute of Technology	**Learning Factory Global Production**
Sweden	KTH Royal Institute of Technology	**XPRES real lab**
South Africa	Stellenbosch University	**Stellenbosch Learning Factory (SLF)**
Italy	Free University of Bolzano	**Smart Mini Factory**
Germany	Technische Universität Darmstadt	**Prozesslernfabrik - Center for industrial Productivity (CiP)**
Luxembourg	University of Luxembourg	**Operational Excellence Laboratory**
Austria	Graz University of Technology	**LEAD Factory**
Bosnia & Herzegovina	University of Mostar	**FSRE Learning Factory**
The Neatherlands	University of Twente	
Croatia	University of Split	**Lean Learning Factory**
Finland	Aalto University	**Aalto Factory of the Future**
Germany	Technical University of Munich	**Learning Factory for optimal machining (LOZ)**

AMERICAS	UNIVERSITY	LFs NAME
Canada	University of Alberta	**ALLFactory**
USA	Purdue University	**Intelligent Learning Factory (ILF)**
Canada	McMaster University	**SEPT Learning Factory**
Brazil	Universidade de São Paulo	**Fábrica do Futuro**
ASIA-PACIFIC	**UNIVERSITY**	**LFs NAME**
Malaysia	Universiti Malaysia Pahang	**FIM Smart Learning Factory**
Singapore	Agency for Science, Technology and Research	**Model Factory@SIMTech**
China	Tongji University	**LFF for 5G and AI Technology Application**

➢ ***Table 2*** *LFs registered in the International Association of Learning Factories (IALF)*

The Conference in LFs is organized every year in different places. (IALF, 2021)

3 FINDINGS

3.1 Overall Findings

The VET systems in the studied countries have some remarkable differences. Among those differences, the equipment and machinery in advanced manufacturing, mechatronics and robotics labs varies from region to region, even between regions in same member states. In regions where the investment in VET education is high, we can find very well-equipped labs with state-of-the-art machinery. The setting up of LFs, not only involves pedagogic challenges but also high investments are also needed. It is not surprising that those regions where VET schools are better equipped are also the regions where LFs, more precisely SDLFs, have been found.

A remarkable finding is that independently of the investments on equipment and therefore the presence of SDLFs, the active methodologies are well spread in all the VET systems; We have found examples of problem-based learnings, work-based learnings, training based on collaborations with companies and similar in all the studied regions.

Standard LFs with life size factory approaches are not commonly used as such among the studied VET centres.

However, the SDLF concept, also known as training systems for Industry 4.0 (SMC International Training, 2023) and Modular Production Systems (Festo Didactics, 2023) are becoming rather common in VET school. These modular pieces of equipment are commercially available and configurable. Users acquire the modules appropriate for their training purposes based on their investment capacity. It is possible to start for the simplest (and cheapest) 1-2 modules configuration and scale it up to 10-14 modules' set ups where rather high investments are needed.

The SDLF are usually designed to address technical competences of industry 4.0. The identified SLDF are use in study programs such as automation, industrial robotics, mechatronics and other Industry 4.0 related courses. Some examples of Industry 4.0 logistics have also been found. Usually there are not interdisciplinary training courses involved. That is, students in one program do not interact with students from another program.

In all the countries included in this research there are several VET schools where they have already implemented such equipment. This SDLF are also used in engineering studies at universities. **Table 3** shows the figures.

COUNTRIES/ REGIONS	NUMBER OF VET CENTRES INCLUDED IN THE STUDY	NUMBER OF LF FOUND (LIFE SIZE)	NUMBER OF SDLF FOUND	NUMBER OF LABS CLOSE TO LF CONCEPT (USING PBL, PIECED LFS, ACTIVE METHODOLOGIES ETC.	NUMBER OF LF IN UNIVERSITIES, RTOS (LIFE SIZE + SDLF)
Basque Country	31	2	14	31	4
France	45	0	2	Not included [1]	Not included
Germany	68	0	68	Not included	28
Italy	0	0	0	8	8
Netherlands	13	0	Not included	13	Not included
Slovenia	5	0	4	5	1
Spain	55	0	35	1 (Not exhaustive) [2]	5
Sweden	1	0	0	11	0
Türkiye	23	0	7	23	0
Canada	18	2	8	18	4

(1) Individualized study of the VET centres using active methodologies in their courses was not included.
(2) There could be more centres using active methodologies.

➢ ***Table 3*** *Number of SDLFs found in the studied EU regions.*

In the annexes 1-10 the detailed information per country is given.

3.2 Findings by countries

3.2.1 Overview

The results of the study show that the presence of LFs in the different countries is not homogeneous. **Figure 5** shows the distribution of the identified SDLF in VET centres and universities. The reasons for the differences are various:

- Difficulties to access to official data in some countries.
- The term Learning Factory, Scale Down Learning Factory or LF 4.0 are not widely used in all the regions to refer to the training equipment commercialized by SMC International Training and FESTO Didactics. It is possible that more VET centres have them but use another denomination.
- Different public policies and funding to invest in SDLFs.

Figure 5 *Identified centres with SDLFs, SDLF and LF in Universities and CLF partners in Europe. Source: Author's creation*

In the following sections the main conclusions of the regional analysis displayed. For the full regional analyses refer to annexes 9.2 to 9.10

3.2.2 Findings in France

The study has not yet found LFs in France. However, the research shows that project-based learning is quite common in France as it is implemented in every professional high school through the manufactured object initiative. For these project-based learning initiatives to be LFs, students would need to work on the entirety of the project from start to end and not only for a few steps of the project.

It is likely that despite our findings there are LFs in France. However, as they do not use that term, they are difficult to identify.

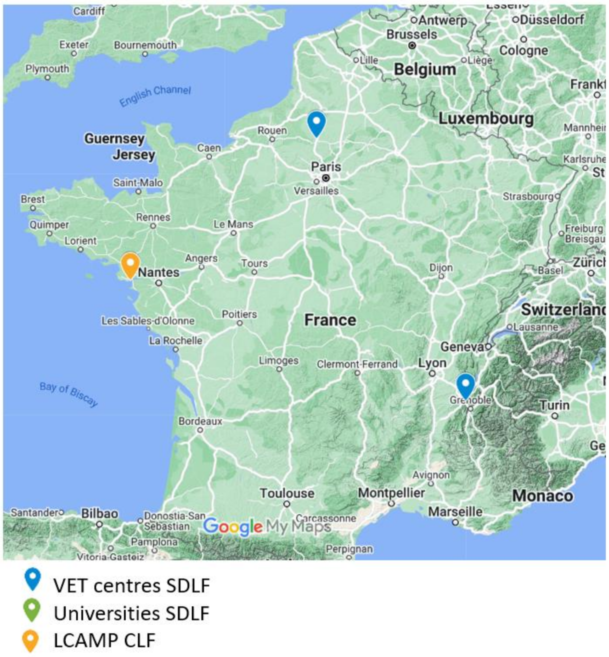

Figure 6 *Identified centres with ScLFs, SDLF in universities and CLF partners in France. Source: Author's creation*

Full report about France is available in the annex, section 9.2

3.2.3 Findings in Germany

The concept of SDLF is rather established at the VET centres level. There are specific regional policies and funding to foster such methodologies. In Baden Wurttemberg we have identified 68 VET centres with such equipment. In particular trainees in technical apprenticeships such as mechatronics, machining mechanics or industrial mechanics do receive instruction and application of new technologies in the LFs. Furthermore, various VET centres collaborate with other schools and universities of applied science e.g., teacher training colleges and universities, to train and prepare teachers and trainers for I4.0 and appliance of new technologies. In some LFs, trainees are given the opportunity to contribute to production in small projects in collaboration with industrial companies.

Concerning Life Size Learning Factories (LSLF), they are usually used in universities of applied sciences (Hoschule für angewandte Wissenschaften (HAW)). The concept of LSLF at HAWs usually includes a project-based approach. LSLF enable students to gain an insight into processes and further production processes in semester projects where among technical competences soft skills referring to team competences and acting in groups can be acquired. In fact, the concept of LF was developed in Darmstadt University (Abele E M. J., 2015)

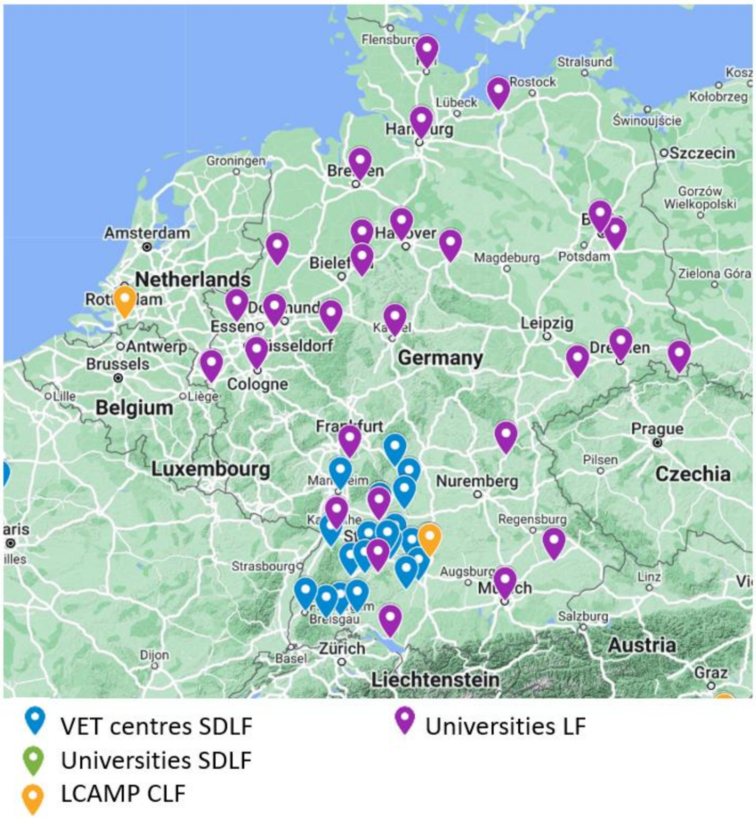

Figure 7 *Identified centres with Scale Down LFs, LF in universities and CLF partners in Germany. Source: Author's creation*

Full report about Germany is available in the annex, section 9.3.

3.2.4 Findings in Italy

The VET centres in Italy currently do not use LFs as a methodology for training in industry 4.0 related competences. No evidence has been found about the use of scale down LFs, although it is possible such pieces of equipment are already present in some HVET centres.

Concerning the Competence Centres spread in the national territory, they are pioneering at different level and speed Learning factories for training purposes, mostly for continuous training for industry and VET/HVET centres. Some LFs have a focus on creating technology knowledge, i.e., illustrating and showing how to use a digital technology in different industry rather than have a process perspective. This means there is not yet a widespread application of "connected LFs" aiming at upskilling digital competence of the manufacturing industry in a value chain perspective. The risk is that the highest technology focus might affect the practical approach or application into process manufacturing systems, thus making TFs difficult to adapt to different sector and leading to "technology silos".

However, MADE Competence Centre is the most advanced LF in Lombardy and Italy, pioneering the implementation of such approach also in international R&D project consortia (e.g., EIT Manufacturing).

Full report about Italy is available in the annex, section 9.4

3.2.5 Findings in the Netherlands

Although all VET centres have different Industry 4.0 facilities, they are focused on learning approaches and do not have defined products. All labs have their own unique approach based on the specific regional industries involved, but they have in common that all have a mix of the following elements: Access to state-of-the-art facilities, Project-based learning, Collaboration with industry partners, Entrepreneurship focus and Career guidance and support.

The centres have facilities and equipment to rather easy set up LF configurations. They are already using a very valuable features that enrich those labs as mentioned before. Based on this situation it is expected that most centres could set up a LF, with an entire production value chain to manufacture a product.

Full report about the Netherlands is available in the annex, section 9.5

3.2.6 Findings in Slovenia

In Slovenia we have not found VET schools with established LFs, following the definition of IALF in section 2.1. There is another initiative such as Inter-enterprise Training Centres, which has similar aims to LFs but whose methodology is rather different.

Full report about Slovenia is available in the annex, section 9.6

3.2.7 Findings in Spain

The use of life size LFs in Spain is not common. However, the SDLFs have emerged as a valuable approach to VET in Spain, particularly in the field of mechatronics and industrial automation and robotics.

The study identifies 27 VET centres out of the 214 centres in Spain (12%) using Industry 4.0 SDLFs. These figures are taken for the program *Industrial automation and robotics*. In the Basque Country 9 VET centres out 25 (36%) have stablished SDLF for Industry 4.0 for the same program. The establishment of the Spanish network of VET excellence centres would also foster this tendency. Currently 4%1 of those excellence centres operating in the mentioned fields are using SDLFs for Industry 4.0.

The term LF is not well known and there is certain confusion using it. LFs are, to a certain extent, linked to the modules commercialized by SMC International Training and FESTO Didactics whereas the core LF approach, using life size equipment is not widely known. 17% of the SDLF users do not use the term LF and they are not aware of the life size LF approaches.

Concerning the core LF approaches, the study identifies very few examples. The Collaborative Learning Factory (CLF) piloted in the EXAM4.0 initiative and currently followed up in LCAMP is one of those. In the Basque region CIFP Miguel Altuna LHII VET Centre established the Collaborative Learning CLF concept in their advanced manufacturing lab. Although the lay out of the equipment used in the LF is not exclusive, the disposition in manufacturing cells makes it possible to use life size equipment in the LF.

It is remarkable that the use of active methodologies is the standard in the Basque Country. VET centres work within the ETHAZI framework where the entire learning model is connected in a collaborative learning method based on challenges. The scheme used is very often close to the LF approach although this term is not commonly used. In other regions of Spain similar approaches are also becoming the norm.

The fact that frameworks such as ETHAZI are successfully implemented shows a clear strategy to foster methodologies where transversal skills are enriched. In that sense, the use of LFs, offers a wide range of possibilities to create new opportunities in this direction.

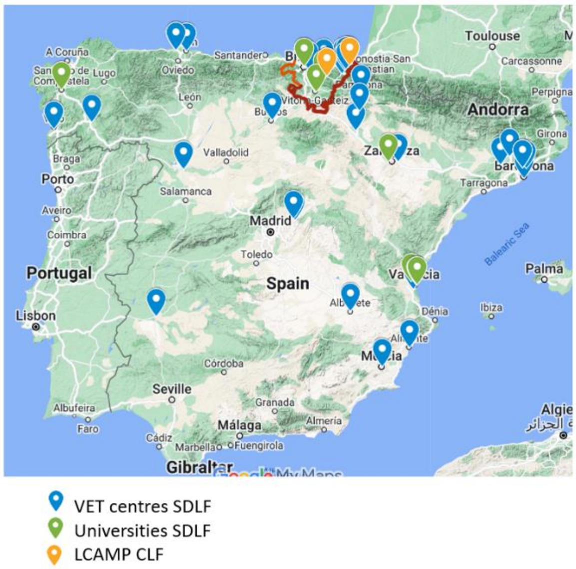

Figure 8 *Identified centres with SDLFs, SDLF in universities and CLF partners in Spain. Source: Author's creation*

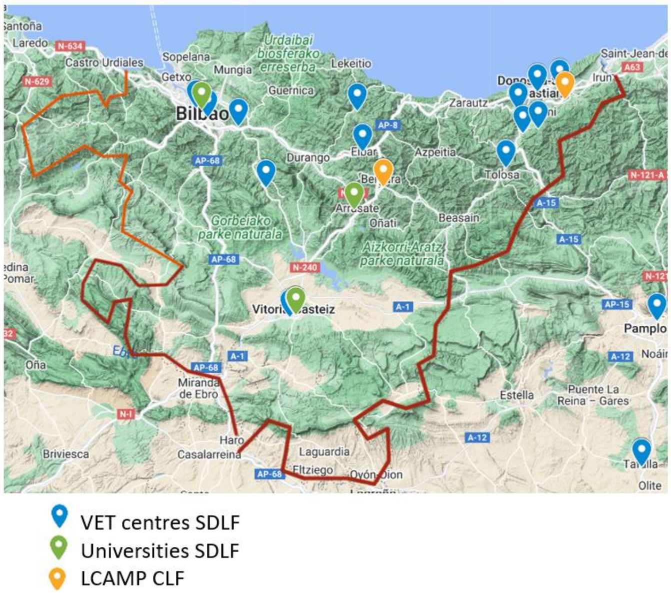

Figure 9 *Identified centres with SDLFs in VET, SDLF in universities and CLF partners in the Basque Country. Source: Author's creation*

Full report about Spain available i in the annex, section 9.7

3.2.8 Findings in Sweden

The conclusion of the research carried out in Sweden is that there are a variety of VET centers using LABS close to the LF concept. Life sized LF and SDLF are usually implemented in universities and HVET centres. Schools and companies are not eager to hand out too much information about equipment and educational methods. This may have been due to a lack of time and interest on their side.

On the other hand, there is a network of open innovation enviroment operating in Sweden with good examples of training facilities for life long learning on advanced manufacturing. The 12 organisations are public private partesrhip involving uninversities, research centres, large companies. Furthermore, some of those large companies have VET centres integrated. These open innovation enviroments operate LFs or SDLFs for their training and research activities.

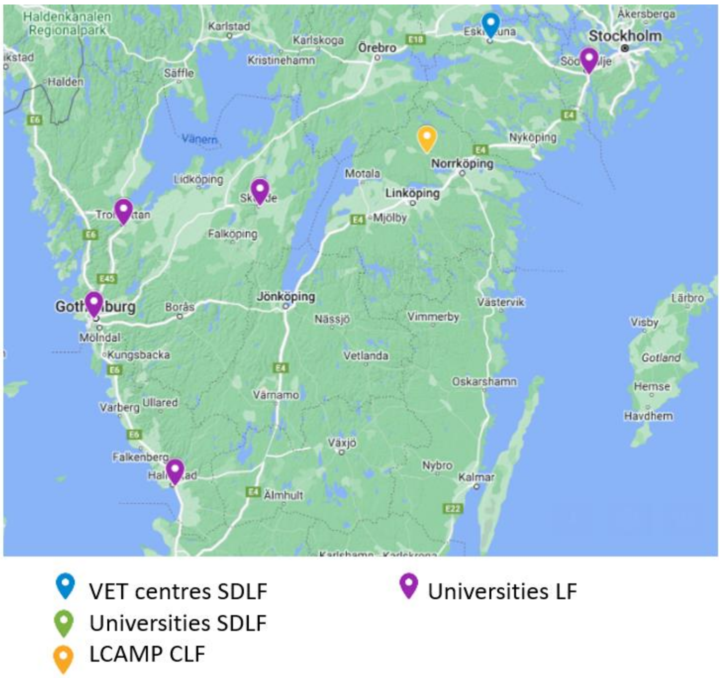

Figure 10: SDLF, CLF and LFs in Sweden. Source: Author's creation

Full report about Sweden is available in the annex, section 9.8.

3.2.9 Findings in Türkiye

In Türkiye, the use of LFs for advanced production techniques courses in VET schools is limited to a small number of schools. However, in the Kocaeli region, only 12 out of 80 vocational high schools have training workshops/labs including pieced LFs where production can take place. These facilities do not simulate an entire factory but include specific sections such as production and packaging. 4 of these 12 VET schools have dedicated training classrooms where advanced manufacturing techniques, such as SDLFs can be taught. In the engineering departments of three universities located in Kocaeli, SDLFs are widely used for engineering education.

On the other hand, in Türkiye, various efforts have been made to enable businesses to benefit from lean production and digital transformation processes, including training personnel and interns. One such initiative is the establishment of the Applied SME Competence Centres (Model Factories) in collaboration between the Ministry of Industry and Technology of the Republic of Türkiye and the United Nations Development Programme (UNDP), which have the concept of standard LFs.

In some VET schools in Türkiye, SLDF have been established with the support of the central government and local development agencies at various levels. However, the general approach is to establish learning environments such as life-size factories or SDLFs (Model Factories) in industrial organizations, Industrial Zones (OIZ), or institutions coordinated by Industrial Chambers. This is because these training environments, which are established at high costs, have high sustainability costs such as basic maintenance, calibration, and renovation. Since it is not feasible for VET schools to consistently meet these costs, these training facilities eventually become idle. Therefore, Model Factories are established under the coordination of industrial institutions. The established model factories are associated with VET schools in the region.

The primary purpose of Model Factories is to provide training and consultancy services in lean transformation (aimed at improving operational efficiency) and digital transformation (implementing the principles of the Fourth Industrial Revolution) to small and medium-sized enterprises. Moreover, through the protocols established between Model Factories and VET schools, students enrolled in the 12th grade of VET schools can carry out their internship training in these facilities. Additionally, some courses are conducted in these facilities to enhance the practical skills and competences of VET schools.

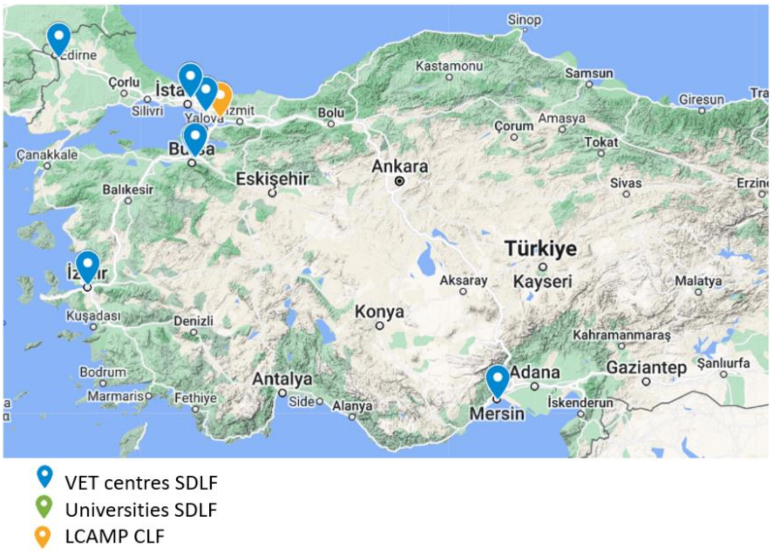

__Figure 11__ Identified centres with Scale Down LFs, SDLF in universities and CLF partners in Spain. Source: Author's creation

Full report about the Türkiye is available in the annex, section 9.9

3.2.10 Findings in Canada

The nature of Canada's development of LFs is intrinsically tied to the nature of federal and provincial educational funding and oversight. While a few Canadian universities have successfully drawn on federal and provincial funding to create fully realized LFs, most LF-like environments in the country are piecemeal, providing factory-like modules, often specialized to particular industries or methodologies, within academic contexts serving both educational and production goals. These modular facilities, organized across regional and national networks, provide students and industry professionals with applied research environments in which to develop their skills and learn upcoming industry standards.

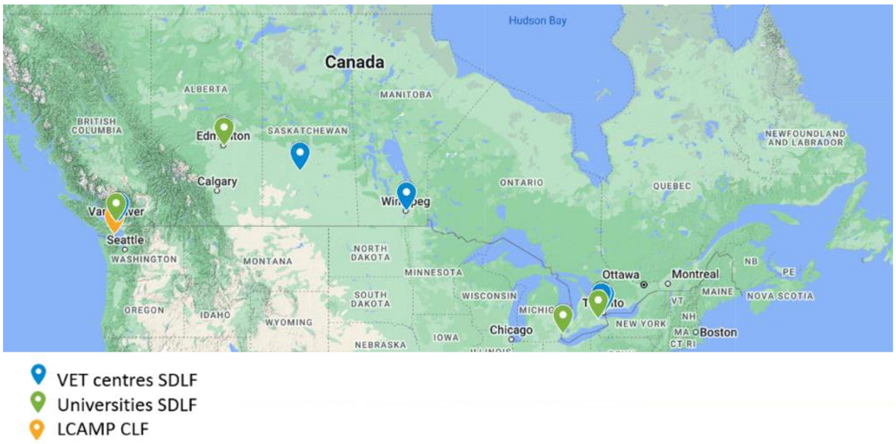

***Figure 12** Identified centres with Scale Down LFs, SDLF in universities and CLF partners in Canada. Source: Author's creation*

Full report about Canada is available in annexes, section 9.10

4 CONCLUSIONS

LFs in universities

LFs run in several universities in Europe as an approach to enhance skills and competences for advanced manufacturing and industry 4.0. Many of the features of the LFs, i.e., practical ways of teaching in hands on environments, replicas of real-world industrial settings, full value chains of manufacturing processes, opportunities to apply skills and knowledge in a real-world setting, make the LF concept very appropriate also for VET environments.

Furthermore, LFs with its understanding of links between technologies-tasks -jobs, an even the links between different stages in a production chain make it possible to directly address many transversal skills, to create interdisciplinary work scenarios and other attributes that are not always easy to reproduce in more traditional learning methodologies.

Outside Europe, the overview carried out in Canada shows that a few Canadian universities have also successfully created fully realized LFs.

SDLFs in VET centres

The study founds very few examples of life size LFs within the VET schools covered in EU countries and also in Canada.

The LF type of scenarios that are currently used in VET centres in the studied countries are the Scale Down Learning Factories (SDLF). These type of LFs are commercially available in modular configurations. They are normally turn-key solutions.

The use of SDLFs is not homogeneous in all the countries. In regions like Baden-Wurttemberg or the Basque Country many VET centres are equipped with SDLF 4.0. The public policies and funding opportunities in those regions are a decisive lever to spread such approaches. In other regions the presence of LFs or even SDLFs in not so obvious. Deeper research would be needed to find the reason behind that.

In any case, the competences, study programs and configurations worked out in the studied SDLFs have many concordances. Their applications are usually for advanced manufacturing and industry 4.0 related VET study programs where they mostly address technical competences. Programs such as industrial automation, robotics, mechatronics, maintenance, advanced manufacturing, mechanical engineering, manufacturing production, control engineering and similar are using those pieces of equipment. Concerning transversal skills, these SDLF give certain space to develop many transversal skills, although they are also more limited than life size LFs to create interdisciplinary environments where more options are available.

Likewise, in the studied VET centres, the results and impact of such SLDF in students' competences are very promising. Therefore, the SDLFs approach has very good acceptance in VET. Looking at the growth in the establishment of SDLF in the last 5 years, there is a trend to invest in such equipment.

Active methodologies in VET centres and Innovation Ecosystems

A general finding in all the studied regions is that different types of active methodologies are widely implemented in VET schools, usually including the participation of industry. The use of active methodologies is common, independently of the use of LFs. In certain cases, similar learning methods to those of LFs are being used but name differently. Some examples found in the study are: Manufactured object initiative and Technology platforms in France, Public Private partnerships in the Netherlands, Inter-enterprise Training Centres in Slovenia, Network of Vocational excellence in Spain, and ETHAZI framework in the Basque Country. Besides the active methodologies used, many of those VET schools are well equipped, using industry-like machinery for the trainings.

Other regional strategies found are the innovation ecosystems where the development of talent is included with upskilling/reskilling programs. In those ecosystems the collaboration with the regional education organizations either universities or VET centres is established. In the examples of the Competence centres for Industry 4.0 in Italy or the Model Factories in Türkiye they are using Teaching Factories approaches and active methodologies like LFs for the development of talent.

For the Canadian case, the idiosyncrasy of Canada is tied to the nature of federal and provincial educational funding and oversight: most LF-like environments in VET centres in the country are piecemeal, providing factory-like modules, often adapted to particular industries or methodologies.

The CLF defined in EXAM4.0 (EXAM4.0, 2019) and scaled up in LCAMP CoVE (LCAMP, 2022) is an example of the use of equipment of VET labs to establish LF schemes to enhance collaboration, interdisciplinary and other transversal skills.

All these active methodologies and innovation strategies are tightly related to the foundations of the LFs. The need to address simultaneously job-related skills, digital skills, personal and social skills make it necessary to look for appropriate methodologies to foster the development of the mentioned competences and skills.

Potential of life size LFs in VET

As we have seen throughout the document, training in advanced manufacturing carried out in real environments and using active teaching methodologies provides great benefits.

The study we have carried out shows us, moreover, that VET centres are working with active teaching methodologies and that, in some cases, they also operate with SDLFs.

If we add to this the fact that LFs work well at university level, we can infer that the implementation of LFs in VET makes sense as a means of reinforcing training in advanced manufacturing.

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8 ACKNOWLEDGMENTS

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- SMC International Training Spain,
- FESTO Didactics Spain

9 ANNEXES

9.1 Scale Down Learning Factories

In this report the term **Scale Down Learning Factory (SDLF**) is used for modular sized LFs, normally commercially supplied with didactic purposes. “Scaled or model scale LFs do not use original factory equipment but smaller equivalents, which should differ as little as possible from the original factory equipment except for the smaller dimensions” (Abele E., 2015).

In Europe there are 2 major suppliers for SDLFs that are SMC International Training and FESTO Didactic. In this section one example from each of them is given to illustrate the type of equipment we are referring to

9.1.1 SDLF 4.0 by SMC International Training

SMC International Training's systems for Industry 4.0 are designed to equip organizations with the knowledge and skills necessary to thrive in the era of advanced manufacturing.

Depending on the training needs, SMC International Training has many types of learning systems based on Industry 4.0. Some of them focused on advanced manufacturing and Industry 4.0 concepts and others in mechatronics and Industry 4.0. Based on the type of system, there will be a variation of factors, such as the technologies used, the product obtained, competences and skills achieved...

Figure 13 *SMC Assembly’s; training system for Industry 4.0, SIF-400 and mechatronics training equipment, M&I-400. Source: SMC International Training*

These systems incorporate various technologies that enable the digital transformation of industrial processes, for instance; Internet of Things (IoT), Data Analitics, artificial Intelligence (AI), Cloud Computing, Augmented Reality (AR) and Virtual Reality (VR), Cybersecurity, Human-Machine Interface (HMI). (SMC International Training, 2023)

These technologies are integrated into SMC International Training's systems to enable the seamless integration of data, connectivity, and automation, driving the transition towards smarter, more efficient, and connected manufacturing processes in the context of Industry 4.0.

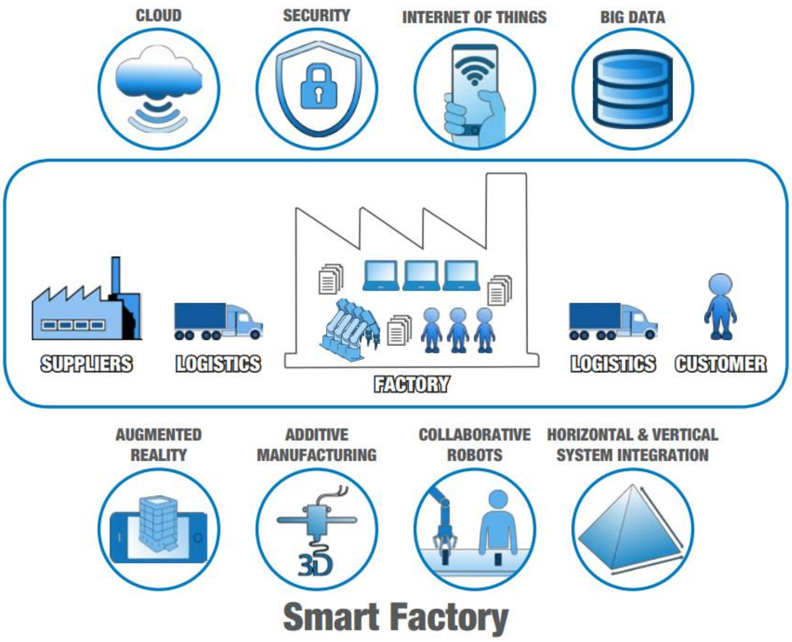


Figure 14. *Technology at the service of the business. Source: SMC International Training*

9.1.2 SDLF 4.0 by FESTO Didactics

These factories are designed to be highly modular, allowing them to be configured to meet the specific needs of a facility. The factories are designed to be highly automated and feature intelligent components, such as robots, to assist in the manufacturing process. These factories also feature a range of sensors, enabling them to monitor and adjust their environment in real-time. Additionally, they are equipped with cloud-based analytics and artificial intelligence technologies to support data-driven decision making. Finally, the factories can be connected to other industrial systems, allowing for the sharing of data and information. All these features allow for a highly optimized and efficient manufacturing process.

Overall, FESTO SDLF 4.0 are designed to be highly automated, efficient and feature intelligent components to ensure optimal performance. They also feature cloud-based analytics and artificial intelligence technologies to support data-driven decision making. Apart from that, they can be connected to other industrial systems to enable the sharing of data and information.

Figure 15. Festo CP Lab 410-1 model . Source: Festo Didactics

9.2 FRANCE

In France it appears to be very difficult to find LFs. None of the studied VET schools have LFs. However, they use a similar approach through project-based learning. That is the case of the manufactured objects and the technological platform initiatives (see section 9.2.2).

Nonetheless, the main suppliers of training equipment that are operating in France such as SMC International Training and FESTO Didactics, have equipped VET centres across Europe with equipment to considered SDLF for Industry 4.0.

9.2.1 Scaled Down Learning Factories

Concerning SDLF, we have identified such Industry 4.0 equipment in a small number of schools which teach both, students and employees. Among the commercial machines identified, there are what the supplier calls “factory schools”. This equipment is meant to hold an entire chain value. For instance, the CP Factory (Cyber-Physical Factory) is a modular LF meant to teach about the production of phones. According to the supplier, there are at least 2 VET that have a CP Factory: UIMM Pôle Formation Isère Moirans and Promeo Formation Beauvais. Through this equipment, students or employees can learn about cyber security, digital twin, and more.

Figure 16 UIMM Pôle Formation Isère Moirans centres SDLF. Source : UIMM Pôle Formation Isère Moirans (https://www.formation-industries-isere.fr/l-industrie-4-0)

Figure 17 *Promeo Formation Beauvais centres Industry 4.0 lab working. Source: Promeo Formation Beauvais (https://www.promeo-formation.fr/nos-centres/beauvais)*

9.2.2 Manufactured Objects

Every professional and technological high school in France is part of the “objets confectionnés” (manufactured objects) initiative. It allows students to work on real projects. It is a cheaper option for companies. Furthermore, by working on these concrete projects, students avoid wasting material by working on projects that would otherwise be of no use and thus thrown away once the assignment is done.

The first goal of this initiative is to train students. As such any and every student of a professional or technological high school can take part in a project, from first years to post-secondary students. Depending on their age and expertise their projects will be more or less difficult, and they will be more or less autonomous. The projects are assigned by the coordinator (the high school’s Director of Vocational and Technological Training) in concertation with the teachers.

The students’ projects vary a lot. While this initiative is meant for companies to entrust students with projects concerning their business, public entities (city councils, city halls, etc.) and individuals can also contact high schools for projects.

As the main goal of this initiative is to train students, students’ curriculum, as well as the high school’s equipment need to be considered when receiving project offers. That means that projects usually need to be adapted before being accepted so that students can do the project in its entirety. As the projects are done by students during class, it takes them longer to complete it. As such, companies need to wait longer for the final product than if they had asked another company. However, while the wait is longer, it is much cheaper for companies to confide their work to students as they usually only pay for the raw material and the use of equipment, and not for the students’ service.

The variety of the students’ projects and opportunities depend on the variety of their high school’s equipment.

9.2.2.1 *La Découverte High School in Decazeville*

La Découverte high school is a high school offering general, professional, and technological courses for students enrolled in secondary or tertiary education. Regarding the manufacturing sector, it offers training on plastics and composites, on mechanical product manufacturing, on industrial boiler making, and on product manufacturing. About 250 students every year are eligible to work on concrete projects.

La Découverte high school's strength is the variety of training it offers as well as the various equipment it possesses. As such the high school can accept a variety of projects. Their projects take between 2 weeks to 18 months and can involve from 2 to around 10-15 students. (Le Bras, 2023)

9.2.3 *Technological Platform*

Another type of methodology like the LF concept was created through the **"**platforme technologique" (technological platform) initiative (Les structures de diffusion de technologies, 2022). Though the intent of this initiative was not to teach students it has grown in some places to include a pedagogical aspect.

The goal of this initiative is to strengthen France's industrial network. As equipment prices are an important obstacle to SMEs' economic development, through this initiative companies can access VET´s' equipment at a much lower price.

As of January 2022, there are 45 technological platforms in France (**Figure 18**). The technological platforms have different specialities such as wood, electronics, solar panels, etc. As such, not every one of these technological platforms work on projects related to the advanced manufacturing sector.

***Figure 18** French regions and the number of technological platforms Source: Author's creation.*

Among these technological platforms, some expanded to offer project-based learning opportunities. These technological platforms not only share equipment, but their students take an active part in companies' projects.

9.2.3.1 The Conpim technological platform

This technological platform puts together the equipment of 5 different locations to help local and very small companies. This 5-location technological platform also allows the cooperation between 5 high schools' training offers and very small companies on projects.

This technological platform is an initiative with multiple locations: La Découverte high school of Decazeville and Monteil high school of Rodez are the main actors. There are 3 additional locations: G. Monnervile high school of Cahors, Jean-Jaurès high school of Saint-Affrique, and P.P Riquet high school of Saint-Orens.

This technological platform puts together the equipment of 5 different locations to help local and very small companies. This 5-location technological platform also allows the cooperation between 5 high schools' training offers and very small companies on projects.

When companies come forward with projects for this technological platform, the managers of the platform decide if it is doable and if there are students that can benefit from it. To make this decision they mostly consider students in higher education using that equipment and enrolled either in technician training, or in a professional licence course. Among these there are currently 3 technician training courses/groups and 1 professional licence course/group at La Découverte high school of Decazeville and 2 technician training courses/groups at Monteil high school in Rodez that can be involved in various projects with SMEs. These trainings are about machining, composite plastics, and design and production of industrial boiler work for instance.

Companies come to an agreement with a coordinator of the technological platform on the deadlines, the fee, and the expected results.

Though selected projects are meant to allow students to train, students do not always directly take part in the project while it is ongoing. If the de are too short or the work too complicated, coordinators may decide that they or the teachers will do the project themselves and use it afterward as a teaching tool.

Projects vary greatly: differing in length and difficulty, involving different skills and steps. For instance, a project could be only about product development and design or only about prototyping, manufacturing and recycling, or everything all at once. The number of students can also vary, from 5 to 20 students, and the project usually requires 1 to 2 days of work. As there are numerous projects throughout the year, at the end of the year about 50 students take part in one of the projects.

Despite the training aspect of this initiative, the main goal of this technological platform is to help very small and local companies to develop and to strengthen the local industrial network. The training aspect is secondary.

This technological platform is part of a network to make its existence known in the area, such as the industrial cluster Mecanic Vallée, AD'OCC (Occitania's economic development agency), as well as other high schools. The platform is also represented at industrial fairs.

9.2.3.2 The department of Mechanical engineering and computer-integrated manufacturing from the University Institute Technology of Limousin

This University Institute of Technology of Limousin has multiple training opportunities in different departments. One of those is the Mechanical engineering and computer-integrated manufacturing department. It offers 3 types of training: Quality and Methods, Digital Engineering for Additive Manufacturing, and Digital Engineering for Agile Manufacturing. These are all professional licenses aimed at giving vocational training and professional experience.

This VET's department used to work with students on professional projects through the Ramsei's technological platform initiative. However, this initiative is currently suspended since December 2022.

This department has however found other ways to have students work on real professional projects. Instead of going through the technical initiative it now goes through the AVRUL incubator. Thanks to this entity they can keep working with companies on concrete projects like before.

They have found working through AVRUL easier than working through the technological platform as the administrative process for them has become is much faster. Thus, they can work more easily on more projects.

They also use these projects and partnerships to find internships and apprenticeships for students in these companies to work on specific projects that can last up to three years and involving up to ten students.

The way this initiative operates is like the technological platform: companies come forward with projects and they discuss with the departments' coordinators regarding the fees and the expectations.

This department not only trains students but also offers training opportunities to businesses' employees to develop their competences.

9.2.4 Conclusions

Only 2 SDLF have been found in VET/HVET schools in France. These are VET equipped with FESTO's CP Factory.

However, this research shows that project-based learning is quite common in France as it is implemented in every professional high school through the Manufactured Object initiative.

It is likely that despite these findings there are more LFs in France. However, as they do not use that term, they are difficult to identify.

9.3 GERMANY

9.3.1 Overview

Since 2016 the Ministry of Economics, Labor, and Housing of Baden-Württemberg has been funding the establishment of 16 LFs 4.0 at vocational schools. In 2023, there are 68 LF at VET schools distributed all over Baden-Württemberg, partially funded by the state of Baden-Württemberg. The ministry pursues the objective to prepare current and future skilled workers, experts and trainees in the LFs for the requirements of digitization. Therefore, the facilities are equipped with modern industrial automation solutions to provide learners with the basics for application-oriented processed learning. The methodologies of the LFs link mechanical engineering, electrical engineering an IT with professional production management systems (Ministerium für Wirtschaft, Arbeit und Wohnungsbau Baden-Württemberg (b), 2022).

The map in **Figure 19** shows the distribution of LFs at VETs in Baden-Wurttemberg.

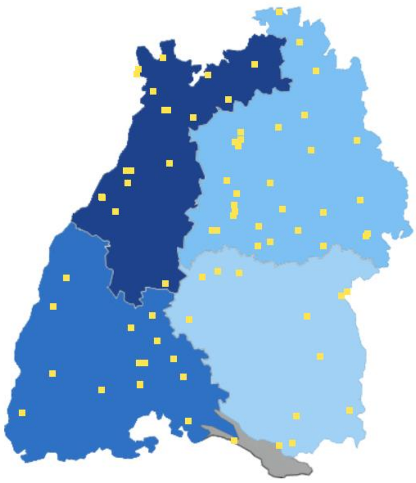


Figure 19 *Map of LFs in Baden-Wurttemberg*
Source: https://lernfabrik.kultus bw.de/,Lde/Startseite/Lernfabriken

Furthermore, there are 28 LF at universities for applied science as well as 23 LF at scientific universities distributed all over Germany as shown in **Figure 20**. The LFs at HVETs and universities primarily present topics referring to engineering especially regarding topics such as “optimizing production processes” and “digitization”. Among engineering topics there is also an increasing amount of LFs at HVETs teaching topics referring to economic and sciences, such as “management and organization” and “occupational health and work safety” (Rolf G. Heinze, 2021)

***Figure 20** Locations with LFs at German universities Source: (Rolf G. Heinze, 2021)*

The table below shows a list of VET centres where SDLF 4.0 are set up.

NAME OF CENTRE	REGION	TYPO OF CENTRE	EQF Level	LINK	PHOTO
Andreas-Schneider-Schule Heilbronn	Baden-Württemberg - Stuttgart	VET	3-4	www.ass-hn.com	
Berufliches Schulzentrum Wertheim	Baden-Württemberg - Stuttgart	VET	3-4	www.bsz-wertheim.de	
Christian Schmidt-Schule Neckarsulm	Baden-Württemberg - Stuttgart	VET	3-4	www.css-nsu.de	
Friedrich-Ebert-Schule Esslingen	Baden-Württemberg - Stuttgart	VET	3-4	www.fes-es.de	
Gewerbliche Schule Backnang	Baden-Württemberg - Stuttgart	VET	3-5	www.gs-bk.de	
Gewerbliche-Schule Bad Mergentheim	Baden-Württemberg - Stuttgart	VET	3-6	www.gsmgh.de	
Gewerbliche Schule Craislheim	Baden-Württemberg - Stuttgart	VET	3-4	www.gscr.de	
Gewerbliche Schule Geislingen	Baden-Württemberg - Stuttgart	VET	3-4	www.gewerblichesc hule.de	
Gewerbliche Schule Göppingen	Baden-Württemberg - Stuttgart	VET	3-4	www.gs-gp.eu	
Gewerbliche Schule Künzelsau	Baden-Württemberg - Stuttgart	VET	3-6	www.gwkuen.de	

Gewerbliche Schule Schwäbisch Gmünd	Baden-Württemberg - Stuttgart	VET	3-4	www.gs-gd.de	
Gewerbliche Schule Schwäbisch Hall	Baden-Württemberg - Stuttgart	VET	3-4	gbs-sha.de	
Gewerbliche Schule Tauberbischofsheim	Baden-Württemberg - Stuttgart	VET	3-4	www.gstbb.de	
Gewerbliche und Kaufmännische Schule Bietigheim-Bissingen	Baden-Württemberg - Stuttgart	VET	3-6	www.bsz-bietigheim.de	
Gottlieb-Daimler-Schule 1 Sindelfingen	Baden-Württemberg - Stuttgart	VET	3-4	www.gds1.de	
Gottlieb-Daimler-Schule 2 Abteilung Akademie für Datenverarbeitung	Baden-Württemberg - Stuttgart	VET	3-4	www.gds2.de	
Grafenbergschule Schorndorf	Baden-Württemberg - Stuttgart	VET	3-6	www.gsso.de	
Gustav-von-Schmoller-Schule Heilbronn	Baden-Württemberg - Stuttgart	VET	3-4	www.gvss.de	
Kaufmännische Schule Geislingen	Baden-Württemberg - Stuttgart	VET	3-4	www.lernfabrik-geislingen.de	
Max-Eyth-Schule Kirchheim	Baden-Württemberg - Stuttgart	VET	3-5	www.mesk.de	
Max-Eyth-Schule Stuttgart	Baden-Württemberg - Stuttgart	VEt	3-5	www.lernfabrik-stuttgart.de	
Philipp-Matthäus-Hahn-Schule Nürtingen	Baden-Württemberg - Stuttgart	VET	3-4	www.pmhs.de	
Robert-Bosch-Schule Stuttgart	Baden-Württemberg - Stuttgart	VEt	3-4	www.lernfabrik-stuttgart.de	
Technische Schule Aalen	Baden-Württemberg - Stuttgart	VET	3-6	smartfactory.tsaalen.de	
Technische Schule Heidenheim	Baden-Württemberg - Stuttgart	VET	3-5	www.heid-tech.de	
Werner-Siemens-Schule Stuttgart	Baden-Württemberg - Stuttgart	VET	3-4	www.lernfabrik-stuttgart.de	
Wilhelm-Maybach-Schule Heilbronn	Baden-Württemberg - Stuttgart	VET	3-6	www.gvvss.de	

Albert-Einstein-Schule Ettlingen	Baden-Württemberg - Karlsruhe	VET	3-4	www.aesettlingen.de	
Berufliche Schulen Bretten	Baden-Württemberg - Karlsruhe	VET	3-4	www.bsb-bretten.de	
Carl-Benz-Schule Gaggenai	Baden-Württemberg - Karlsruhe	VET	3-4	www.carl-benz-schule-gaggenau.de/besonderheiten/lernfabrik-4-0	
Carl-Benz-Schule Karlsruhe	Baden-Württemberg - Karlsruhe	VET	3-4	www.lernfarbrik.karlsruhe.de	
Erhart-Schott-Schule Schwetzingen	Baden-Württemberg - Karlsruhe	VET	3-5	lernfabrik.rhein-neckar-kreis.de	
Friedrich-Hecker-Schule Sinsheim	Baden-Württemberg - Karlsruhe	VET	3-4	lernfabrik.rhein-neckar-kreis.de	
Gewerbliche und Hauswirtschaftliche Schule Horb	Baden-Württemberg - Karlsruhe	VET	3-4	www.neckarfab.de	
Hans-Freudenberg-Schule Weinheim	Baden-Württemberg - Karlsruhe	VET	3-4	lernfabrik.rhein-neckar-kreis.de	
Heinrich-Hertz-Schule Karlsruhe	Baden-Württemberg - Karlsruhe	VET	3-6	lernfabrik.rhein-neckar-kreis.de	
Hubert-Sternberg-Schule Wiesloch	Baden-Württemberg - Karlsruhe	VET	3-4	lernfabrik.rhein-neckar-kreis.de	
Johann-Philipp-Bronner Wiesloch	Baden-Württemberg - Karlsruhe	VET	3-4	lernfabrik.rhein-neckar-kreis.de	
Josef-Durler-Schule Rastatt	Baden-Württemberg - Karlsruhe	VET	3-5	www.jdsr.de/lernwelt-4-0	
Theodor-Frey-Schule Eberbach	Baden-Württemberg - Karlsruhe	VET	3-4	lernfabrik.rhein-neckar-kreis.de	
Werner-von-Siemens-Schule Mannheim	Baden-Württemberg - Karlsruhe	VET	3-4	wvss-mannheim.de	
Zentralgewerbeschule Buchen	Baden-Württemberg - Karlsruhe	VET	3-4	www.zgb-buchen.de/lernfabrik.html	
Berufliche Schulen Oberndorf-Sulz	Baden-Württemberg - Freiburg	VET	3-5	www.bos-schule.de	

Berufliche Schulen Schramberg	Baden-Württemberg - Freiburg	VET	3-4	www.bs-schramberg.de	
Erich-Hauser-Gewerbeschule Rottweil	Baden-Württemberg - Freiburg	VET	3-4	www.ehg-rottweil.de	
Erwin Teufel Schule Spaiching	Baden-Württemberg - Freiburg	VET	3-4	www.ets-spaichingen.de	
Ferdinand-von-Steinbeis-Schule Tuttlingen	Baden-Württemberg - Freiburg	VET	3-4	www.steinbeisschule.de	
Gewerbeschule Villingen-Schwenningen	Baden-Württemberg - Freiburg	VET	3-4	www.gewerbeschule-vs.de	
Gewerbliche Schule Lahr	Baden-Württemberg - Freiburg	VET	3-6	www.gs-lahr.de	
Gewerbliche Schulen Donaueschingen	Baden-Württemberg - Freiburg	VET	3-5	www.tg-donaueschingen.de	
Gewerbliche und Kaufmännische Schulen Müllheim	Baden-Württemberg - Freiburg	VET	3-4	www.gks-muellheim.de	
Hans-Thoma-Schule Titisee-Neustadt	Baden-Württemberg - Freiburg	VET	3-4	www.hans-thoma-schule.de	
Hohentwiel-Gewerbeschule Singen	Baden-Württemberg - Freiburg	VET	3-4	www.hgs-singen.de	
Richard-Fehrenbach-Gewerbeschule Freiburg	Baden-Württemberg - Freiburg	VET	3-6	www.rfgs.de	
Staatliche Feintechnikschule Villingen-Schwenningen	Baden-Württemberg - Freiburg	VET	3-6	www.feintechnikschule.de/entwicklungsstand-lernfabrik-industrie-40	
Walther-Rathenau-Gewerbeschule Freiburg	Baden-Württemberg - Freiburg	VET	3-4	www.wara.de	
Zeppelin-Gewerbeschule Konstanz	Baden-Württemberg - Freiburg	VET	3-4	www.zgk-konstanz.de	
Berufliche Schule Rottenburg	Baden-Württemberg - Tübingen	VET	3-4	www.bsrottenburg.de	
Elektronikerschule Tettnang	Baden-Württemberg - Tübingen	VET	3-4	www.elektronikschule.de	

Ferdinand-von-Steinbeis-Schule Reutlingen	Baden-Württemberg - Tübingen	VET	3-4	www.steinbeisschule-reutlingen.de	
Geschwister-Scholl-Schule Leutkirch	Baden-Württemberg - Tübingen	VET	3-4	www.gss-leutkirch.de	
Gewerbliche Schule Ehingen	Baden-Württemberg - Tübingen	VET	3-6	www.gbs-ehingen.de	
Gewerbliche Schule Tübingen	Baden-Württemberg - Tübingen	VET	3-4	www.gs-tuebingen.de	
Humpis-Schule Ravensburg	Baden-Württemberg - Tübingen	VET	3-4	www.humpis-schule.de	
Karl-Arnold-Schule Bierach	Baden-Württemberg - Tübingen	VET	3-4	www.kas-bc.de	
Philipü-Matthäus-Hahn Schule Balingen	Baden-Württemberg - Tübingen	VET	3-4	www.gsz-zak.de/wp/category/lernfabrik	
Robert-Bosch-Schule Ulm	Baden-Württemberg - Tübingen	VET	3-4	www.rbs-ulm.de	
Wilhelm-Schickard-Schule Tübingen	Baden-Württemberg - Tübingen	VET	3-4	www.wilhelm-schickard-schule.de	
Hochschule für Technik und Wirtschaft Aalen	Baden-Württemberg	HVET	6-7	https://www.tpbw-i40.de/	
Pädagogische Hochschule Schwäbisch Gmünd	Baden-Württemberg	HVET	6-8	https://www.ph-gmuend.de/einrichtungen/fakultaet-i/institut-fuer-bildung-beruf-technik/berufspaedagogik/didaktik-40	
Hochschule Heilbronn	Baden-Württemberg	HVET	6-7	https://www.hs-heilbronn.de/de/lernfabrik	

➢ ***Table 4*** *List VET centres in Baden Wurttemberg with SDLF*

9.3.2 DHBW – Duale Hochschule Baden-Württemberg

The DHBW is a university of its own type that is exclusively dedicated to dual academic education. The DHBW Heidenheim is focused on providing the regional demands of the East Württemberg region for skilled workers and executives in the region. DHBW Heidenheim has various laboratories that support teaching on the one hand, but also research, innovation and transfer in the other hand. In addition, research projects can be implemented together with companies and institutions.

The automation laboratory at DHBW Heidenheim contains two sections: Firstly, two model systems of automated production lines from FESTO Didactic and, secondly, three robot training cells from Kuka company. The automation laboratory is equipped with a FESTO Didactic SDLF model system in which students learn how to use robot programming, PC and tablet-supported process visualisation for monitoring and operating manufacturing equipment, production data acquisition and production data analysis. Furthermore, the FabLab is an open workshop and offers production equipment and modern industrial production processes for the manufacture of individual pieces. With equipment such as 3D printers, laser cutters, soldering technology and many other machines and tools, a large number of different materials can be processed (DHBW Heidenheim, 2023)

9.3.3 Pädagogische Hochschule Schwäbisch Gmünd

The smart Factory Didaktik4.0 is a collaboration between the HVET centre of the PH Schwäbisch Gmünd and the local vocational training institutions. Within the Didactic 4.0 vocational teachers and training staff can be qualified according to requirements of the digital work environment. The Smart Factory provides didactic learning materials and concepts for different vocational occupations such as mechatronics technician, electronics technician for automation technology and industrial mechanic.

With its Smart Factory, PH Schwäbisch Gmünd pursues the objectives to develop and test didactically prepared teaching materials and learning situations, if necessary, using digital media, to strengthen vocational action skills by implementing work-process-related teaching concepts and strengthen the cooperation between VETs and dual partner companies, to present linking opportunities with further LFs and vocational institutions.

The learning outcomes of the Smart Factory Didactic 4.0 imply the understanding of retrofitting, maintenance, maintenance methods and networking, as well as operating data, process and condition values, monitor, evaluate and interpret operating data and to plan, visualize and implement maintenance measures. Furthermore, the methodological approach of the Smart Factory imparts competences referring to problem solving and team spirit.

The Smart Factory includes a problem-based and group-based approach. The participants are divided into small groups according to their training profession and work on a project-related basis. Participants work on various tasks in their groups, from calculating the sensor technology, cost calculations to tasks on predictive management, and jointly develop final presentations on the respective project (PH Schwäbisch Gmünd, 2022)

9.3.4 Hochschule Heilbronn – jumpING

jumpING is a problem- and project-based LF of Hochschule Heilbronn for students in their 6th semester. In this LF, the students' own initiative and networking and self-organisation skills are challenged and promoted in a special way. The aim for students is to experience the entire product development process of a manufacturing company with its manifold interconnections and to experience it practically. jumpING implies milling as well as lathes, injector blasting unit and an engraving laser. The methodological approach implies a project- and problem-oriented learning in collaborating small groups, presentations, regular coaching sessions with topic mentors and written assignments (Balve P, 2019)

The LF simulates a real production company that consists of different departments. For the duration of the semester, the students decide on a specialisation such as product development, production planning or quality management. The LF has been in operation since the winter semester 2011/12 (HS-Heilbronn, 2023)

The task for students is to create a fully documented and ready-to-ship series product at competitive cost within four months. To do so, students work together in teams according to their subjects and will collaboratively exercise all core processes of a real production company, such as product development, operative manufacturing as well as quality assurance. Each team is assisted by a professor with whom the participants can consult on technical and methodological matters. At the end of the semester, students and participants of the LF organise a student fair and present their produced small-scale series. The LF jumpING does present the prerequisite of a completed internship semester.

The imparted learning outcomes include methodological competences such as, problem-solving abilities, material science, manufacturing, assembly, project management and quality control, as well as social competences such as team ability, collaboration, self-organisation, self-reflection, presentation skills, verbal and written communication and reasoning. Furthermore, students participating in the LF of Hochschule Heilbronn acquire personal competences referring to independence, willingness to perform, reflection ability, responsibility and accountability (HS-Heilbronn, 2023) (Festo Didactics, 2017)

Figure 21 *Learning factory 4.0, Philipp-Matthäus-Hahn-Schule. Balingen Source: Project Global Project Solutions.*

9.3.5 Conclusions

The concept of SDLF is rather established at VET centres level. There are specific regional policies and funding to foster such methodologies. In Baden Wurttemberg we have identified 68 VET centres with such equipment. In particular trainees in technical apprenticeships such as mechatronics, machining mechanics or industrial mechanics receive instruction and application of new technologies in the LFs. Furthermore, various VET centres collaborate with other schools and universities of applied science e.g. teacher training colleges and universities, to train and prepare teachers and trainers for I4.0 and appliance of new technologies. In some LFs, trainees are given the opportunity to contribute to production in small projects in collaboration with industrial companies.

Concerning Life Size Learning Factories (LSLF), they are usually used in universities of applied sciences (Hoschule für angewandte Wissenschaften (HAW)). The concept of LSLF at HAWs usually includes a project-based approach. LSLF enable students to gain an insight into processes and further production processes in semester projects where among technical competences soft skills referring to team competences and acting in groups can be acquired. In fact, the concept of LF was developed in Darmstadt University (Abele E., 2015)

9.4 ITALY

9.4.1 Overview

VET Centres are indeed very rooted in the territory and only Lombardy alone has more than 900 VET accredited centres, counting from the only official regional source (Regione Lombardia, 2023) as indicated in **Figure 22**.

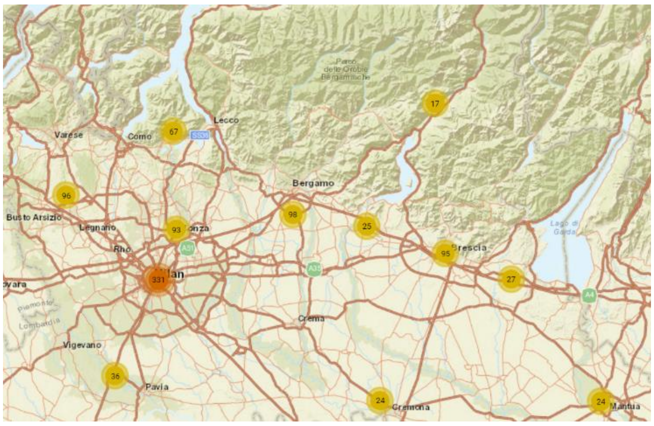


Figure 22 *Lombardy VET centre (Source: Lombardy Region Data - www.dati.lombardia.it)*

To the best of our knowledge, there is no official data available as to whether those VET centres are using Scale Down Learning Factories or not.

The upskilling of digital competence, especially in manufacturing industry, remains a big challenge for VET system and for the overall Italian education system. In this sense, in 2019, Italian Plan Industry 4.0, identified eight Italian Competence Centres and since 2019 they constitute, together with the Digital Innovation Hub, one of the central points of the Industry 4.0 strategy. The competence centres are public-private partnerships aiming at providing guidance and training activities for companies on Industry 4.0 issues as well as support in the implementation of innovation, industrial research and experimental development projects to be carried out, for end users (SMEs), new products, processes or services (or their improvement) through advanced technologies in the Industry 4.0 field. For this reason, they simulate a pre-industrial scenario with state of the art technology (TRL 6-8).

The national competence centres were selected in 2018 through a public tender.

They are based in Bologna (BI-REX), Genoa (Start 4.0), Milan (Made 4.0), Naples (MediTech), Padua (SMACT), Pisa (ARTES 4.0), Rome (Cyber 4.0), and Turin (CIM 4.0) and described in the following paragraphs.

This research explores, we explored some of the most important potential LFs (Chryssolourisa G., 2016) that are growing in Italy along with some that are just starting.

9.4.2 BI-REX – Bologna: Big data Innovation-Research Excellence

BI-REX - Is one of the 8 Italian Competence Centres with a specific focus on Big Data and supports SMEs, in their digitalization and innovation processes and in the adoption of enabling technologies, with business perspective. BI-REX is a public-private consortium, born in 2018 and based in Bologna, which brings together 57 players in partnership between universities, research centres and companies of excellence to assist companies, and in particular SMEs, through a varied series of services: from consultancy to technology evaluation, from design to validation of innovative solutions, from orientation to training up to the Pilot Line.

9.4.3 Start 4.0 Genoa: Security and Optimization of Strategic Infrastructures I4.0

The Security and Optimization of Strategic Infrastructures Industry 4.0, The composition of the public/private partnership, which was established as an Association on 21 January 2019, involves 6 public entities (CNR, IIT Foundation, Port System Authority of the Western Ligurian Sea, Port System Authority of the Eastern Ligurian Sea, INAIL and the Chamber of Commerce of Genoa) and 33 companies.

The latter were selected through the response to a public notice for expression of interest based on an evaluation process of specific technical characteristics and aspects of economic solidity consistent with the programmatic aims of the Centre.

The presence of large companies with an international reference market, the IIT, the CNR, the collaboration with the University of Genoa and in consideration of their participation in initiatives and projects strongly connected to the areas of reference, allows the CdC to benefit from an extremely extensive network of relationships with companies and other research organizations currently not directly involved in the partnership.

The role of SMEs involved in the partnership is fundamental, which, together with large companies, represent the entire production chain in the application domains of reference.

The great involvement of SMEs in the activities of the Centre also makes it possible to effectively seize the opportunity to activate, within the SMEs themselves, a process of technological strengthening and consolidation with consequent direct benefits on the activities of the Centre for the development of services, projects and technology transfer initiatives that will take into account the very large number of SMEs active on the regional and national territory in the reference domains.

9.4.4 MADE 4.0 – Milan: Competence Centre Industry 4.0

MADE is a Competence Centre for Industry 4.0 created to implement Orientation, Training, and Finalization activities for technology transfer projects with companies on Industry 4.0 issues.

A technical interlocutor that companies can turn to for support during the digital transition to a Smart Factory. The first contact with companies that are not aware of the Competence Centre's offerings is that of orientation during which we engage companies to increase their awareness on Industry 4.0 issues with the aim of developing training paths dedicated to technicians, but also to the strategic profiles of companies and carry out technology transfer projects.

The ultimate goal of the Competence Centre is to keep the profile of companies high, competitive, and sustainable. In this sense MADE leverages a testing facility of over 2000 mq, organised in 6 manufacturing scenarios(**Figure 23**) and 25 technology use cases (**Figure 24**)

Figure 23 *MADE Competence Centre Testing Facilities Source: MADE*

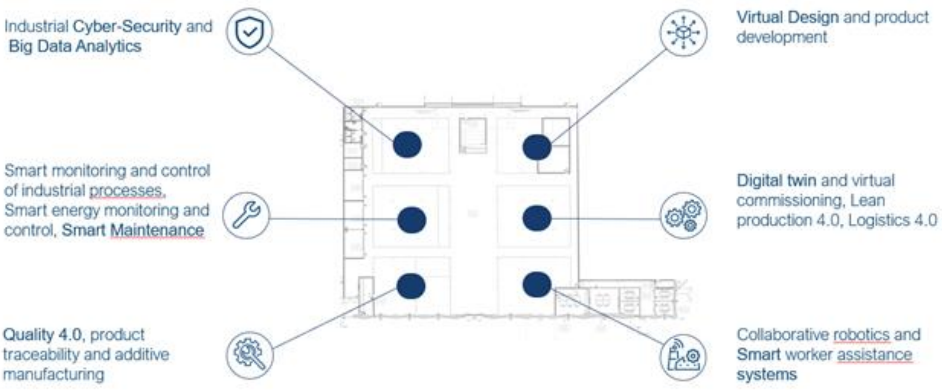


Figure 24 *MADE technology use cases: example Source: MADE*

MADE supports manufacturing companies on the path of digital transformation. It guarantees a broad panorama of knowledge, methods, and tools in the area of digital technologies. From design to product engineering, production management, logistics, and end-of-life management, MADE provides its space and expertise to serve businesses.

MADE Competence Centre is pioneering the implementation of LF methodology both at National and European level, due to participation in EU projects.

9.4.5 MediTech – Naples: Competence Centre I4.0

Mediterranean Competence Centre 4 Innovation is the multi-regional Competence Centre, active in Puglia and Campania, born as a facilitator of the adoption of the enabling technologies of Industry 4.0 by SMEs and the Public Administration and to be a tool for disseminating culture and innovation practices in the production of goods and services on the national territory, particularly on the Mediterranean basin.

The Competence Centre, selected in 2018 by the MISE among the eight centres of national importance, is a public-private partnership, which carries out orientation and training activities for companies on Industry 4.0 issues as well as support in the implementation of innovation projects, research industrial and experimental development aimed at the creation, by user companies, in particular SMEs, of new products, processes or services (or their improvement) through advanced technologies in the Industry 4.0 field. The services offered are also aimed at the Public Administration, the great protagonist of the digital transition.

Meditech counts on the collaboration of 5 universities in Campania, 3 universities in Puglia and 21 avant-garde industrial players.

9.4.6 SMACT – Padua: Competence Centre

SMACT is one of the 8 Industry 4.0 Competence Centres born in Italy on the initiative of the Ministry of Economic Development. It is a public-private partnership that brings together the 4.0 skills of research, technology providers and early adopter companies.

SMACT was born in the Triveneto by bringing together stakeholders with skills and experience in Digital Transformation, to allow the entire production and social system to face the future and create value.

9.4.7 ARTES 4.0 – Pisa: Industry 4.0 Competence Centre on Advanced Robotics and enabling digital Technologies & Systems 4.0

ARTES 4.0 was created to unite University Partners, Research Bodies, Highly Qualified Training Institutes, Foundations, Third Sector & No Profit entities, but also private Associations and

Innovative Companies in order to provide Partners and industry (in particular SMEs) technologies and services responding to their needs through guidance, training, innovation projects, industrial research and experimental development

The 114 private shareholders represent a total turnover of over 43 billion euros, equal to approximately 3% of the Italian GDP, through the participation of 17 large companies, to which one must add Companies associated to participating incubators and accelerators.

In addition, the presence of 10 Medium-sized Enterprises, 32 Small Enterprises, 35 Micro Enterprises and 17 Foundations / Third Sector Entities / Companies and Non-profit Bodies guarantees the opening of the CC skills offer thanks to the contribution of partner’s high level of dynamism.

9.4.8 Cyber 4.0 – Rome: Industry 4.0 Competence

Cyber 4.0 is the highly specialized national competence centre for cybersecurity, one of the 8 highly specialized competence centres financed by the Ministry of Economic Development.

The Centre's mission is to accompany policy makers, businesses and the PA on a growth path towards safe digitalisation, thanks to concrete, strategic and sustainable solutions based on knowledge, innovative technologies and enabling services developed with the skills of its network, which enhance the excellence of the country in the European and international context.

Guided by the same guiding principles of the Industry 4.0 Plan, the Centre therefore aims to develop the competitiveness of the country by offering companies and the Public Administration guidance and training services and financing research and innovation projects, both in the context of core cybersecurity activities, transversal to each product sector, both in specific vertical contexts, with reference to the e-Health, Automotive and Aerospace sectors. To carry out its institutional activities, the Centre can count on the collaboration of a network of over 100 experts, selected on a national basis from among its members.

In addition to institutional activities, the broad spectrum of skills covered also allows CYBER 4.0 to present itself as an entity capable of providing qualified commercial services in response to specific market needs, both in the national and international context.

Cyber 4.0 is a non-profit association made up of 43 partners: 8 public research bodies, 1 non-economic public body and 34 private entities, which include large companies, SMEs and foundations.

In addition to the members, a group of stakeholders is set up in the Cyber 4.0 ecosystem, made up of entities external to the Association who have expressed an interest in contributing to carrying out part of the program of activities.

9.4.9 CIM 4.0 – Turin: Cybersecurity Competence Centre

CIM4.0 is a network made up of Politecnico and University of Turin, together with 22 partner businesses, offering strategic and operational support within an industry 4.0 development context through technological services and advanced training courses.

With the competences of industrial leaders and the development of new business models, CIM4.0 helps companies innovating and maintaining their processes highly competitive.

CIM4.0 aims to strongly contribute to accelerating the transformation process of a wide portion of Italian companies, especially SMEs; its objective is to be at the side of businesses and support them in the digitalization process, creating a Smart Factory ecosystem.

Through two pilot lines, CIM4.0 provides a structure which allows to make the approach of new marke-ts more competitive, by carrying out new projects, processes, services and business models.

9.4.10 Conclusions

The VET centres in Italy currently do not use LFs as a methodology for training in industry 4.0 related competences. No evidence has been found of the use of scale down LFs, although it is possible such pieces of equipment are already present in some HVET centres.

Concerning the Competence Centres spread across the national territory, they are pioneering at different level and speed Learning factories for training purposes, mostly for continuous training for industry and VET/HVET centres. Some LFs have a focus on creating technology knowledge, i.e., illustrating and showing how to use a digital technology in different industries rather than have a process perspective. This means there is not yet a widespread application of “connected LFs” aiming at upskilling digital competence of the manufacturing industry in a value chain perspective. The risk is that the highest technology focus might affect the practical approach or application into process manufacturing systems, thus making TFs difficult to adapt to different sectors and leading to “technology silos”.

However, MADE Competence Centre is the most advanced LF in Lombardy and Italy, pioneering the implementation of such an approach also in international R&D project consortia (e.g., EIT Manufacturing).

9.5 NETHERLANDS

9.5.1 Analysis of Existing LFs in the Netherlands

In the Netherlands a range of VET centres make use of-Learning Factories Type of labs. These labs do not strictly follow the IALF's definition of a LF, but the VET centres have an approach close to that definition. Below a selected overview of the VET centres, with a description on the industry 4.0 elements which they are focussed on, see **Table 5** Selection of VET centres with labs for Industry 4.0 training

NAME	VET CENTRE	CITY	WEBSITE
Duurzaamheidsfabriek	Da Vinci College	Dordrecht	www.duurzaamheidsfabriek.nl
Techport	Nova College	Velsen	www.techport.nl
3D Makerszone	Nova College	Haarlem	www.3dmakerszone.com
Perron38	Deltion College	Zwolle	www.Perron38.nl
Brainport Industries Campus	Summa College	Eindhoven	www.brainportindustriescampus.com/
Fieldlab industrial Robotics	Deltion College	Harderwijk	www.fieldlabir.nl
Fieldlab Campione	ROC van Tilburg	Gilze-Rijen	www.worldclassmaintenance.com/ project/fieldlab-campione/
Smart Welding Factory	ROC van Twente	Hengelo	www.lac.nl
Spark Makers Zone	Koning Willem I College	Den Bosch	www.sparkmakerszone.nl
Make Center	ROC Midden Nederland	Nieuwegein	www.makecenter.nl
TechValley-NH	Hogeschool Inholland	Alkmaar	www.techvalley-nh.nl
5Groningen	NHL Stenden Hogeschool en de Hanze Hogeschool.	Groningen	www.5groningen.nl
Technohub Digital Twinning	Graafschap College	Doetinchem	no website

➢ ***Table 5*** *Selection of VET centres with labs for Industry 4.0 training*

9.5.2 Duurzaamheidsfabriek, Da Vinci College, Dordrecht

Duurzaamheidsfabriek Dordrecht is a Dutch innovation centre that focuses on sustainable manufacturing and Industry 4.0 technologies. The centre covers a range of Industry 4.0 subjects, including:

- Smart and connected systems: Duurzaamheidsfabriek Dordrecht supports the development of smart and connected systems that enable real-time data exchange and control of manufacturing processes.
- Digital manufacturing: The centre focuses on the use of digital technologies such as additive manufacturing, simulation, and virtual reality to improve product design, prototyping, and production.
- Robotics and automation: Duurzaamheidsfabriek Dordrecht promotes the use of robotics and automation technologies to improve production efficiency, reduce waste, and enhance worker safety.
- Sustainable materials and processes: The centre develops sustainable materials and processes that reduce environmental impact, such as the use of recycled materials and energy-efficient manufacturing methods.
- Circular economy: Duurzaamheidsfabriek Dordrecht explores the use of circular economy principles in manufacturing, such as closed-loop material cycles and product reuse.

Figure 25 *Duurzaamheidsfabriek, Dordrecht Source: www.duurzaamheidsfabriek.nl*

9.5.3 Techport, Nova College, Velsen

Techport in Velsen focuses on the development and application of Industry 4.0 technologies. The hub covers a range of Industry 4.0 subjects, including:

- Additive manufacturing and 3D printing: Techport supports research and development of additive manufacturing and 3D printing technologies, which are used in various industries for prototyping, customization, and production.
- Data analytics and artificial intelligence: Techport focuses on data analytics and artificial intelligence (AI) to enable predictive maintenance, optimize manufacturing processes, and enhance product design.
- Robotics and automation: Techport supports the development and application of robotics and automation technologies to improve productivity and efficiency in manufacturing and logistics.
- Augmented and virtual reality: Techport explores the use of augmented and virtual reality (AR/VR) technologies to enhance training, design, and visualization in various industries.
- Cybersecurity: Techport addresses cybersecurity challenges in Industry 4.0 by developing secure communication protocols, data encryption, and access control systems.
- Sustainable manufacturing: Techport promotes sustainable manufacturing practices by developing technologies that reduce waste, energy consumption, and environmental impact.

9.5.4 3D Makerszone, Nova College, Haarlem

The 3D Makerszone is a LF for Industry 4.0 in VET institutes that provides students with hands-on experience in designing and manufacturing using 3D printing technology.

3D Makerszone focuses on:

- Additive manufacturing and 3D printing: 3DMakersZone provides support for the development and application of additive manufacturing and 3D printing technologies, which are used in various industries for prototyping, customization, and production.
- Materials science: The centre focuses on the development of new materials for 3D printing, such as bioplastics, composites, and metals, as well as the testing and characterization of these materials.
- Design and prototyping: 3DMakersZone supports the use of 3D printing for rapid prototyping and design iteration, enabling faster product development cycles.

Digital manufacturing: The centre focuses on the use of digital technologies such as 3D scanning, computer-aided design (CAD), and simulation to improve product design, prototyping, and production.

Figure 26 *3D Makerszone, Haarlem Source: www.3dmakerszone.com*

9.5.5 Perron38, Deltion College, Zwolle

Perron038 focuses on Industry 4.0 technologies, entrepreneurship, and digital transformation. The centre covers a range of Industry 4.0 subjects, including:

- Internet of Things (IoT): Perron038 supports the development and application of IoT technologies to enable real-time monitoring, control, and optimization of manufacturing processes and products.
- Artificial Intelligence (AI) and Machine Learning (ML): The centre focuses on the use of AI and ML algorithms to automate decision-making processes, optimize production processes, and develop predictive maintenance solutions.
- Robotics and automation: Perron038 promotes the use of robotics and automation technologies to improve manufacturing efficiency, reduce waste, and enhance worker safety.
- Cybersecurity: The centre addresses cybersecurity challenges in Industry 4.0 by developing secure communication protocols, data encryption, and access control systems.
- Data analytics: Perron038 supports the development of data analytics solutions to extract insights from manufacturing data, improve product quality, and optimize production processes.
- Digital entrepreneurship: The centre provides support for digital entrepreneurs and start-ups to develop innovative solutions based on Industry 4.0 technologies.

9.5.6 Brainport, Summa College, Eindhoven

Brainport focuses on high-tech systems and materials, with a strong emphasis on Industry 4.0 technologies. The centre covers a wide range of Industry 4.0 subjects, including:

- Internet of Things (IoT): Brainport Eindhoven promotes the development and application of IoT technologies to enable real-time monitoring, control, and optimization of manufacturing processes and products.
- Artificial Intelligence (AI) and Machine Learning (ML): The centre focuses on the use of AI and ML algorithms to automate decision-making processes, optimize production processes, and develop predictive maintenance solutions.
- Robotics and automation: Brainport Eindhoven promotes the use of robotics and automation technologies to improve manufacturing efficiency, reduce waste, and enhance worker safety.
- Cybersecurity: The centre addresses cybersecurity challenges in Industry 4.0 by developing secure communication protocols, data encryption, and access control systems.
- Digital Twin: Brainport Eindhoven develops digital twin solutions to create a virtual representation of a physical product or process, enabling real-time optimization and predictive maintenance.
- Additive manufacturing: The centre supports the development and application of additive manufacturing technologies, such as 3D printing, to enable faster prototyping and customization, as well as more sustainable and efficient manufacturing practices.
- Sustainable manufacturing: Brainport Eindhoven focuses on developing more sustainable manufacturing practices by reducing waste, optimizing energy consumption, and developing new materials and processes.

9.5.7 Fieldlab Industrial Robotics, Deltion College, Harderwijk

Fieldlab Industrial Robotics aims to drive innovation and collaboration in the field of industrial robotics, supporting the development and implementation of cutting-edge technologies in manufacturing and other industrial sectors

- Collaborative robotics: Fieldlab Industrial Robotics focuses on the development and implementation of collaborative robot solutions (cobots) that can work alongside humans, enhancing productivity and safety in industrial environments.
- Automation and smart production: They explore automation technologies and smart production systems to optimize manufacturing processes, improve efficiency, and enable flexible and agile production.
- Digitalization and connectivity: Fieldlab Industrial Robotics emphasizes the use of digitalization and connectivity solutions, such as the Internet of Things (IoT), to enable data-driven decision-making, real-time monitoring, and control of industrial robotic systems.
- Robotics integration and control: They focus on the integration of robotics systems into existing manufacturing processes, including programming and control interfaces, to ensure seamless operation and interoperability.
- Human-robot collaboration and interaction: Fieldlab Industrial Robotics explores ways to facilitate smooth collaboration and interaction between humans and robots in the workplace, emphasizing safety, user-friendly interfaces, and intuitive interaction.
- Artificial Intelligence (AI) in robotics: They investigate the use of AI algorithms and machine learning techniques to enhance robot capabilities, such as perception, decision-making, and adaptive behaviour, enabling robots to handle complex tasks and environments.

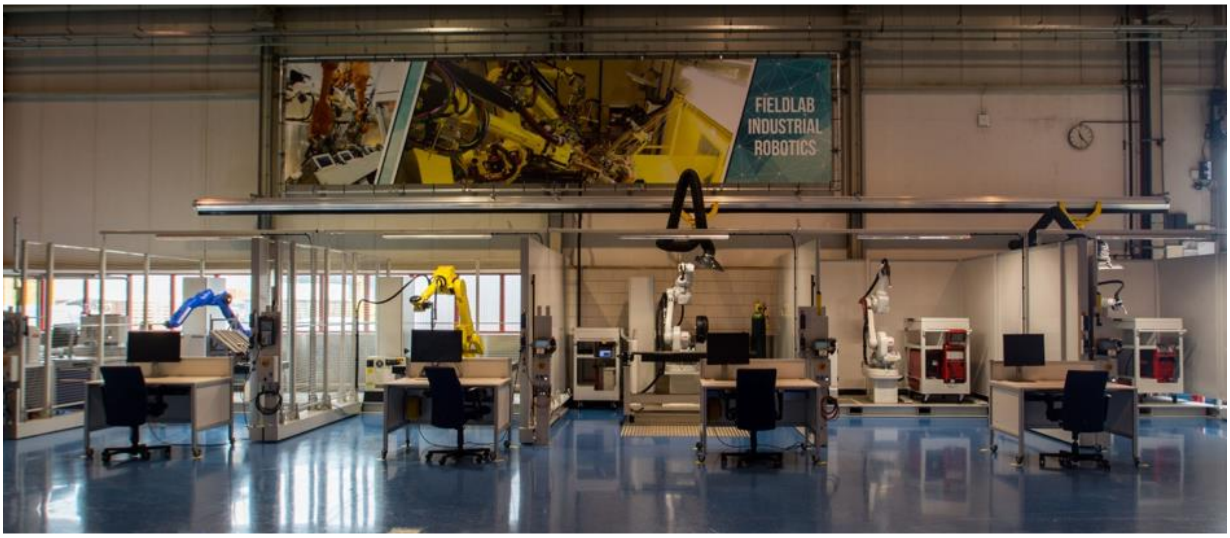


***Figure 27** Fieldlab Industrial Robotics, Harderwijk Source www.fieldlabir.nl*

9.5.8 Fieldlab Campione, ROC van Tilburg, Gilze-Rijen

Fieldlab Campione, located in Gilze-Rijen, is an initiative that focuses on maintenance and asset management within the context of Industry 4.0. Their aim is to develop and implement innovative technologies and approaches to optimize maintenance processes and increase the reliability and availability of assets. Some of the industry 4.0 subjects that Fieldlab Campione focuses on include:

- Predictive maintenance: Utilizing data from sensors, IoT devices, and machine learning algorithms to predict and prevent equipment failures, enabling maintenance activities to be performed proactively and minimizing unplanned downtime.
- Condition monitoring: Implementing monitoring systems and techniques, such as vibration analysis, thermography, and oil analysis, to continuously assess the condition of assets and detect potential issues before they cause significant problems.
- Asset data management: Utilizing data analytics and digital platforms to collect, store, and analyse asset-related data, enabling better decision-making, optimizing maintenance strategies, and improving overall asset performance.
- Augmented and virtual reality: Exploring the use of augmented and virtual reality technologies to support maintenance activities, providing technicians with real-time information, remote assistance, and virtual training.
- Robotics and automation: Investigating the integration of robotics and automation technologies into maintenance processes, such as autonomous inspection robots, robotic maintenance arms, and automated data collection.
- Asset lifecycle management: Focusing on the entire lifecycle of assets, from design and installation to operation and decommissioning, and leveraging Industry 4.0 technologies to optimize asset management strategies throughout each phase.

Figure 28 *Fieldlab Campione, Gilze-Rijen Source: www.worldclassmaintenance.com/project/fieldlab-campione/*

9.5.9 Smart Welding Factory, ROC van Twente, Hengelo

Smart Welding Factory in Hengelo specializes in:

- Welding automation and robotics: Exploring the use of robotic welding systems and automation technologies to improve welding efficiency, productivity, and quality control.
- Sensor integration and monitoring: Utilizing sensors and data analytics to monitor welding parameters, such as temperature, voltage, and current, in real-time for process optimization and quality assurance.
- Digitalization and connectivity: Leveraging digital technologies and connectivity solutions to enable data-driven decision-making, remote monitoring, and control of welding processes.
- Augmented reality (AR) and virtual reality (VR): Investigating the use of AR and VR technologies for training, simulation, and visualization in welding processes, allowing for enhanced precision and reduced rework.
- Welding process optimization: Applying data analytics and machine learning algorithms to analyse welding data and optimize process parameters for improved efficiency, reduced material waste, and enhanced product quality.
- Welding quality control and inspection: Implementing advanced inspection techniques, such as non-destructive testing (NDT) methods, computer vision, and artificial intelligence, to ensure weld quality and detect defects.

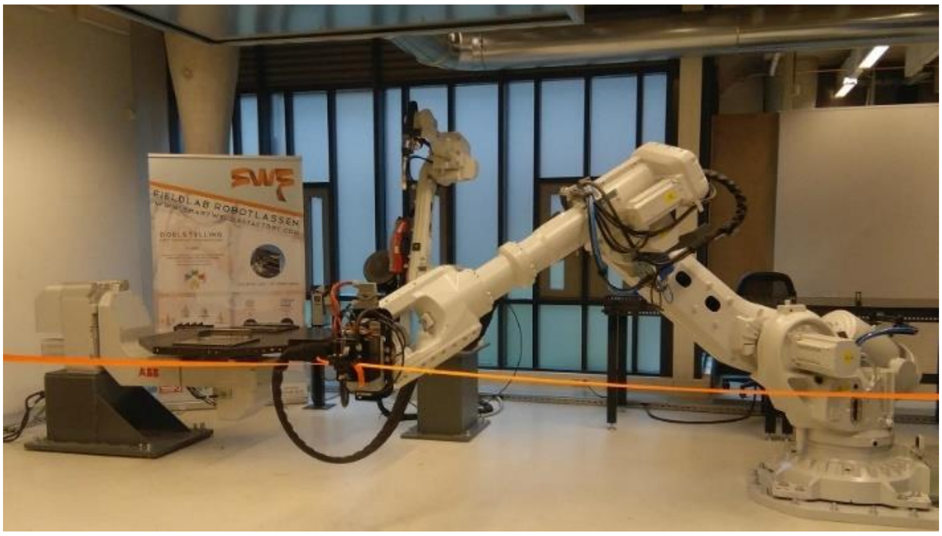


Figure 29 *Smart Welding Factory, Hengelo Source: www.lac.nl*

9.5.10 Spark Makers Zone, Koning Willem I College, Den Bosch

Spark Makers Zone has a strong focus on the following Industry 4.0 topics:

- Rapid prototyping and additive manufacturing: Emphasizing the use of technologies such us 3D printing, laser cutting, and CNC machining to enable fast and cost-effective prototyping and small-batch production.
- Internet of Things (IoT) and connectivity: Exploring the integration of sensors, networks, and data analytics to enable smart and connected devices, systems, and processes.
- Artificial Intelligence (AI) and Machine Learning (ML): Leveraging AI and ML algorithms to optimize processes, enable predictive maintenance, and enhance decision-making.
- Robotics and automation: Developing and implementing robotic systems for various applications, such as manufacturing, logistics, and healthcare, to improve efficiency, productivity, and flexibility.
- Digitalization and data analytics: Utilizing advanced analytics techniques to analyse large volumes of data, extract insights, and drive data-driven decision-making for process optimization and continuous improvement.
- Sustainable manufacturing: Focusing on the development and application of environmentally friendly and energy-efficient technologies and practices to promote sustainability within manufacturing processes.
- Skills development and training: Offering training programs, workshops, and educational resources to develop skills and competences in areas related to Industry 4.0 technologies.

9.5.11 Make Centre, ROC Midden Nederland, Nieuwegein

- Make Centre in Nieuwegein, with the website www.makecenter.nl, is a makerspace and innovation centre that focuses on various Industry 4.0 subjects related to digital manufacturing and product development. Some of the areas they may cover include:
- Digital fabrication: Make Centre emphasizes digital manufacturing technologies such as 3D printing, laser cutting, CNC machining, and rapid prototyping. They provide access to equipment and expertise to enable individuals and businesses to create physical objects using these digital fabrication techniques.
- Design thinking and product development: Make Centre supports the iterative design and development process, offering tools and resources for ideation, concept development, and prototyping. They may provide workshops and guidance on using design thinking methodologies to create innovative and user-centred products.
- Internet of Things (IoT) and connected devices: Make Centre may focus on the integration of IoT technologies into product development, enabling the creation of smart and connected devices. This can include sensor integration, data collection, and utilizing IoT platforms for device management and control.
- Additive manufacturing and materials: Make Centre likely explores different aspects of additive manufacturing, including material selection, optimization of print parameters, and post-processing techniques. They may provide access to a range of materials suitable for additive manufacturing processes.
- Digital design tools and software: Make Centre may provide access to various software tools for 3D modelling, CAD design, and simulation. They may offer training or support in using these tools effectively for product design and digital manufacturing processes.
- Skills development and education: Make Centre likely offers workshops, training programs, and educational resources to develop skills and knowledge in areas related to Industry 4.0. This can include hands-on training in digital manufacturing techniques, design software, and other relevant technologies.

Figure 30 *Make Centre, Nieuwegein Source: www.makecenter.nl*

9.5.12 TechValley-NH, Hogeschool InHolland (HVET), Alkmaar

- Internet of Things (IoT) and connectivity: Exploring the integration of sensors, networks, and data analytics to enable smart and connected devices, systems, and processes.
- Artificial Intelligence (AI) and Machine Learning (ML): Leveraging AI and ML algorithms to optimize processes, enable predictive maintenance, and enhance decision-making.
- Digitalization and data analytics: Utilizing advanced analytics techniques to analyse large volumes of data, extract insights, and drive data-driven decision-making for process optimization and continuous improvement.
- Robotics and automation: Developing and implementing robotic systems for various applications, such as manufacturing, logistics, and healthcare, to improve efficiency, productivity, and flexibility.
- Additive manufacturing and 3D printing: Implementing technologies for rapid prototyping, customization, and small-batch production using 3D printing and additive manufacturing methods.
- Cybersecurity: Addressing the security challenges and considerations related to the implementation of Industry 4.0 technologies, such as protecting connected devices and data from cyber threats.

9.5.13 Fieldlab 5Groningen, NHL Stenden Hogerschool (HVET), Groningen

Fieldlab 5Groningen, located in Groningen, focuses on various Industry 4.0 subjects related to the deployment and utilization of 5G technology. Some of the areas they may focus on include:

- 5G-enabled Internet of Things (IoT): Exploring how 5G networks can support the massive connectivity and data transfer requirements of IoT devices, enabling real-time communication, data collection, and control of connected devices and systems.
- Smart city and infrastructure: Investigating the use of 5G in creating smart city solutions, such as smart lighting, traffic management, waste management, and environmental monitoring. 5G can facilitate fast and reliable communication between various sensors, devices, and control systems, enabling efficient management and optimization of urban infrastructure.
- Industrial automation and robotics: Exploring how 5G can enable reliable and low-latency communication for industrial automation and robotic systems. This includes applications such as remote control, real-time monitoring, and collaborative robotics, enhancing productivity and flexibility in manufacturing and other industrial sectors.

- Augmented Reality (AR) and Virtual Reality (VR): Utilizing the high bandwidth and low latency of 5G networks to deliver immersive AR and VR experiences. This includes applications in training, remote assistance, virtual collaboration, and immersive entertainment.
- Digital Twins: Investigating the use of 5G to enable real-time data exchange and synchronization between physical assets and their digital twins. This allows for remote monitoring, simulation, and optimization of assets and processes.
- Edge computing and network slicing: Exploring the use of 5G network capabilities such as edge computing and network slicing to enable low-latency processing and customized network configurations, catering to the specific needs of different Industry 4.0 applications.

9.5.14 Technohub Digital Twinning, ROC Nijmegen

Technohub Digital Twinning with Graafschap College focuses on several Industry 4.0 subjects related to digital twinning and its applications. Digital twinning involves creating a virtual replica or simulation of physical assets, processes, or systems. While I could not find specific information about Technohub Digital Twinning with Graafschap College, here are some common industry 4.0 subjects that organizations focusing on digital twinning may cover:

- Digital Twin Development: Exploring the development and implementation of digital twins for various assets, such as machinery, equipment, buildings, or entire production lines. This includes creating accurate and real-time digital representations that capture the behaviour, performance, and characteristics of physical assets.
- IoT Integration: Incorporating Internet of Things (IoT) technologies into digital twin models to collect real-time data from sensors and devices embedded within physical assets. This allows for continuous monitoring and analysis of asset performance, enabling predictive maintenance and optimization.
- Simulation and Visualization: Utilizing simulation techniques and visualization tools to replicate and interact with digital twin models. This includes running virtual scenarios, conducting what-if analyses, and simulating various operating conditions to optimize performance, energy efficiency, or production output.
- Data Analytics and Predictive Maintenance: Leveraging data analytics and machine learning algorithms to analyse the data collected from digital twin models. This can help identify patterns, anomalies, and predictive insights for maintenance planning, operational optimization, and quality control.
- Process Optimization: Applying digital twin technology to improve and optimize complex processes, such as manufacturing workflows, supply chain operations, or energy management systems. By simulating and analysing the digital twin models, organizations can identify bottlenecks, inefficiencies, and opportunities for improvement.
- Collaborative Decision-Making: Facilitating collaborative decision-making by sharing and visualizing digital twin models among multiple stakeholders. This allows for better communication, coordination, and alignment between different teams or departments involved in asset management or process optimization.

9.5.15 Conclusions

Although all VET centres have different Industry 4.0 facilities, they are focused on learning approaches and do not have defined products. All labs have their own unique approach based on the specific regional industries involved, but they have in common that all have a mix of the following elements: Access to state-of-the-art facilities, Project-based learning, Collaboration with industry partners, Entrepreneurship focus and Career guidance and support.

The centres have facilities and equipment to rather easy set up LF configurations. They are already using a very valuable features that enrich those labs as mentioned before. Based on this situation it is expected that most centres could set up a LF, with an entire production value chain to manufacture a product.

9.6 SLOVENIA

In Slovenia we have not found any VET schools with established LFs, following the definition of IALF (see section 1.3). There are other initiatives such as the **Inter-enterprise Training Centres**, which have similar aims to LFs but with a rather different methodology.

The LFs in Slovenia are established as Inter-enterprise Training Centres focused on providing entrepreneurial training, coaching, and mentorship to individuals interested in starting or growing a business in the engineering industry. They are designed to provide resources, tools, and knowledge necessary for aspiring students to develop new products and launch their ventures. The VETs that host LF offer a variety of courses, workshops, and networking events to help students acquire the skills and knowledge required to thrive in the engineering and business sector.

In addition to its educational offerings, the Inter-enterprise Training Centre also provides access to experienced industry professionals who can offer guidance, advice, and mentorship to students as they navigate the challenges of starting and developing products. Through its partnerships with local businesses, ITC are dedicated to fostering a thriving engineering ecosystem in Slovenia's industry.

After having carried out a meticulous investigation at the state level in Slovenia, there are 20 ITCs at VET centres with programs ranging from tourism, computer science up to engineering LF that include I4.0. 12 ITCs are involved in engineering LFs. We selected the 4 biggest ITC’s for the LCAMP project.

9.6.1 University of Maribor

The Faculty of Mechanical Engineering of the University of Maribor has established a SDLF 4.0 used with students on EQF levels 6 to 8. (University of Maribor, 2022)

The laboratory for oil hydraulics LaOH is organizationally included in the scheme/operates under the auspices of the Institute for Production Mechanical Engineering at the Faculty of Mechanical Engineering of the University of Maribor.

Figure 31 *SDLF in Maribor University. Source: FESTO Didactics*

The activity of the laboratory is much broader than can be concluded on the basis of the official title: depending on the topic of the industrial project, they connect with relevant experts within the faculty and outside it.

The field of operation of the laboratory could be briefly described as "Automation of machines and devices where the transmission of energy and signals is carried out in combination with liquids or compressed air" or in short: "FLUIDTRONIKA".

The purpose of establishing the Oil Hydraulics Laboratory.

The laboratory currently has research and teaching equipment for experimental work in the field of hydraulics and pneumatics (components and software).

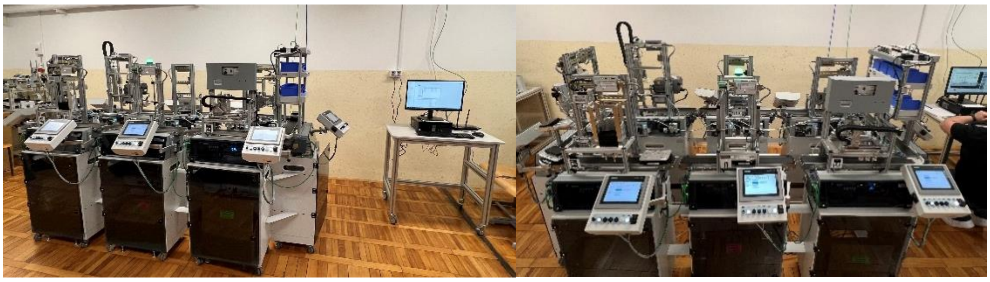


Figure 32 *Scale Down LF at University of Maribor. Source: FESTO Slovenia*

9.6.2 School Centre Novo Mesto

The Novo Meso The Inter-enterprise Training Centre ITC (EQF 5), (Novo-Mesto ITC, 2022) is an independent organisational unit within the Novo mesto School Centre. All the activities of the ITC are aimed at providing quality vocational education and training, which should be linked as closely as possible to the economy and the trades that need or want to provide additional practical training.

The activities of the ITC are carried out in a modern and rational way. In addition to practical training, the ITC is also involved in the development of new technologies and innovative activities, thus contributing to the economic and technological progress of the region. The activities of the ITC also include encouragement for vocational and professional education and various additional services in the field of vocational and professional education.

The ITC carries out its activities according to the prescribed programmes defined by the publicly applicable vocational programmes, and for additional activities they have developed our own programmes. However, ITC can also prepare a programme of practical training or other activities according to the client's requirements.

The tasks of the Inter-enterprise Education Centre:

- Training to improve competences and acquire new competences
- Education and training for the unemployed
- National Vocational Qualifications
- Linking the training centre with enterprises
- Management and implementation of development projects in the field of vocational education and training
- Maintenance and modernisation of workshop equipment
- Public procurement and investment

Indirectly involved in the delivery of the teaching process:

- Organisation of practical training in specialised workshops for pupils and students
- Organisation of practical training with employers
- Promotional activities for vocational education and training.

9.6.3 School Centre Celje

The Inter-enterprise Education Centre (EQF 5) has been operating as an independent organisational unit within the Celje School Centre since 2007 (Celje School Centre , 2021), with the aim of improving the quality and speed of knowledge transfer between schools and the economy. The design of the ITC, which was developed at the time of its establishment, includes the integration of the Celje School Centre with other educational organisations, business and craft, the Celje Regional Development Agency, the Employment Office and other interested partners.

The purpose of the ITC is to:

- Practical education of pupils and students,
- adult education (education on publicly valid programmes, retraining, further training, specialisation, training on other programmes, etc.),
- cooperation with the social partners,
- project work, and
- promotional activities.
- The aim of our activities is to carry out our activities in a high-quality manner in order to meet the needs and wishes of the trainees and other partners, and above all to contribute our share to the all-round development and excellence of the Celje School Centre.

The vision of the Inter-enterprise Education Centre of the Celje School Centre is to strengthen the links between education and the development of the economy in the region. The mission of the Celje School Centre ITC is to respond to the needs of the economy and to adapt the education and training system for key competences.

Target groups: VET/HVET students related with mechanical engineering and mechatronics.

9.6.4 School Centre Velenje

Velenje School Centre (Valenje, 2022) as one of the leading school centres in Slovenia. to offer and share with national and international our own knowledge, teaching effectiveness, innovation and creative experience.

ITC activities (EQF 5)

- Education
- Functional training
- Research, development, design and prototyping
- Project work
- Energy engineering
- Promotional and service activities

9.6.5 School Centre Ravne Na Koroškem

In order to create a modern and technologically advanced Inter-enterprise Education Centre of the School Centre Ravne na Koroškem (EQF5) extension was built and state-of-the-art equipment was supplied, which will improve the quality of the practical part of the education and training of pupils, students and adult participants, will stimulate research and development activities, and will improve the quality of the education and training of pupils, students and adult participants through excellence, innovation, by technological development and an entrepreneurial approach, talented young people will be more likely to choose to study metal processing and machining or mechanical engineering. The ITC ŠC Ravne project will thus create the conditions for innovative approaches to education and research in the professions of metal designer, mechatronics operator, car technician, metallurgist, mechanical technician, electrotechnician, computer and mechanical technician, process assistant, as well as practical training on various tools. (ITC ŠC Ravne, 2018) an

9.6.6 Conclusion Slovenia

In Slovenia we have not found VET school with established Learning Factories, following the definition of IALF in section 1.3. There are other initiatives such as the **Inter-enterprise Training Centres,** which have similar aims than LFs but their methodology is rather different.

9.7 SPAIN

9.7.1 Scope of the study in Spain

The research study about the use of LFs in VET carried out in Spain covers the national Vocational Education and Training network for the areas of mechanical manufacturing, mechatronics, automation and industrial robotics. 4 Specialization programs for VET have also been included: Advanced Manufacturing Smart Maintenance, Big Data and Additive Manufacturing (LOIFP 3/2022, 2022). The research focuses in greater depth on the Basque Country region owing to the strong VET system established there.

The number of VET centres providing study programs of interest for this study are shown in the table below (**Table 6**). However, the study addressed only a selection of those, considering only the reference centres in each Spanish region. The study addresses a total number of 15 VET centres in the Basque Country and 25 centres in the rest of Spain from whom 7 and 11 were reached respectively. (See **Table 8**)

VET PROGRAMS (EQF 5)	BASQUE COUNTRY	SPAIN	TOTAL
Production Programming in Mechanical Manufacturing	31	112	143
Mechanical Manufacturing Design	22	54	76
Industrial Automation and Robotics	25	189	214
Industrial Mechatronics	21	164	185
Specialization programs	**Basque Country**	**Spain**	**TOTAL**
Smart maintenance	6	24	30
Advance manufacturing	4	30	34
Big Data	6	54	60
Additive manufacturing	3	19	22

➢ ***Table 6:*** *Number of VET centres with study programs related to advanced manufacturing. Source https://www.todofp.es/que-estudiar/ciclos/curso-especializacion.html)*

The following VET centres and research centres have been selected for the study:

a) Tknika, Applied Innovation centre for VET and coordinator of the LCAMP CoVE
b) Miguel Altuna LHII, partner in LCAMP CoVE and member of the Spanish Network of Vocational Excellence centres in Advanced Manufacturing
c) 12 VET centres that integrate the Spanish Network of Vocational Excellence centres in Advanced Manufacturing (8) and Mechatronics (4). From those 12 VET excellence centres this study covers the 5 of them that currently have SDLFs. See **Table 7**
d) 28 VET centres that currently use SDLFs. See **Table 8.**

Region	VET Excellence Centre	Field	SDLF
CASTILLA-LA MANCHA	IES CONDESTABLE ÁLVARO DE LUNA	Advanced Manufacturing	NO
ANDALUCIA	IES FERNANDO III	Advanced Manufacturing	NO
NAVARRE	CI SAN JUAN-DONIBANE	Advanced Manufacturing	NO
CATALUNYA	ESCOLA DEL TREBALL BCN	Advanced Manufacturing	YES
VALENCIA	IES COTES BAIXES	Advanced Manufacturing	NO
CASTILLA Y LEÓN	CIFP SIMÓN DE COLONIA	Advanced Manufacturing	YES
BASQUE COUNTRY	CIFP MIGUEL ALTUNA LHII	Advanced Manufacturing	YES

MURCIA	CIPF POLITÉCNICO DE MURCIA	Advanced Manufacturing	NO
CASTILLA-LA MANCHA	IES CONDESTABLE ÁLVARO DE LUNA	Advanced Manufacturing	NO
MADRID	IES LUIS VIVES	Mechatronics	NO
NAVARRE	CIP VIRGEN DEL CAMINO	Mechatronics	YES
BASQUE COUNTRY	CIFP TOLOSALDEA LHII	Mechatronics	YES
ASTURIAS	CIFP DE LOS SECTORES INDUSTRIAL DE SERVICIOS	Mechatronics	NO

➢ ***Table 7****: VET centres in Spanish Network of Vocational Excellence Centres in Advanced Manufacturing and Mechatronics.*

The identification of VET centres and other organizations **currently using SDLFs** was supported by SMC International training Spain and FESTO Didactics Spain. 41 organization were identified.

A survey was carried out among the **identified 45 SDLF 4.0 user organizations** from whom distinguish 3 types of users (see **Table 8**)

- 6 VET centres form the Spanish Network of Vocational Excellence centres, 3 in Advanced Manufacturing, 2 in Mechatronics and 1 in energy.
- 27 VET centres
- 12 Universities or Innovation Centres

Number of organizations addressed for the survey				
REGION	**TOTAL**	**SPANISH EXCELLENCE CENTRES**	**VET**	**UNIVERSITIES, INNOVATION CENTRES**
Basque Country	**16**	3	9	4
Spain	**29**	3	18	8
Total	**45**	6	27	12
Number of answers				
Basque Country	**7**	2	5	Not applicable
Spain	**11**	1	10	Not applicable
Total	**18**	3	15	Not applicable

➢ ***Table 8****: Number of answers obtained in the survey.*

9.7.2 *Results from the analysis*

After analysing the results in the surveys, and considering that only 54.5% of the sample responded, the main findings are the following:

Use of the term Learning Factories

83,3% of the respondents are familiarized with the term Learning Factory, however the 16,7% don't use it, even being users of SDLF. See **Figure 33**.

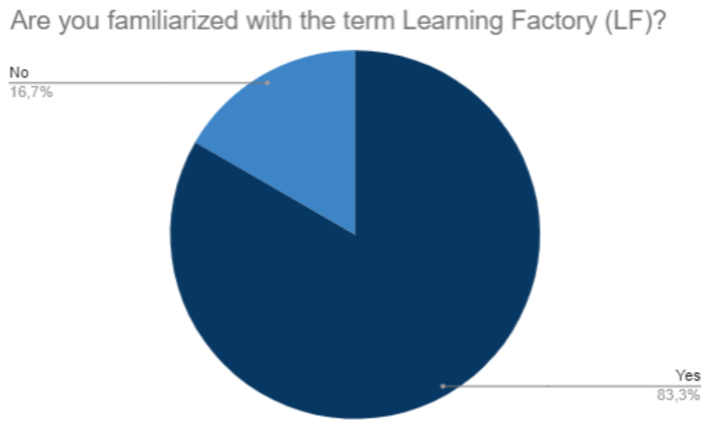


***Figure 33**: Results of the familiarization of the term Learning Factory Source: Authors' creation*

Application fields

The main application of the SDLFs is for training courses in the courses Industrial Automation and Robotics (52,4%) and Industrial Mechatronics (33,3%). This LFs are used to a lesser extent in Industrial Maintenance (9,5%) and in the specialization of Advanced Manufacturing. (4,8%). See **Figure 34**)

When analysing these figures, we must consider that not all the respondents provide courses in all the fields. For instance, 100% of the VET centres that offer specialization of Advanced Manufacturing use the SDLF. The usual case is that the VET centres use the SLDF in all the Vet programs related to industry 4.0 that they offer.

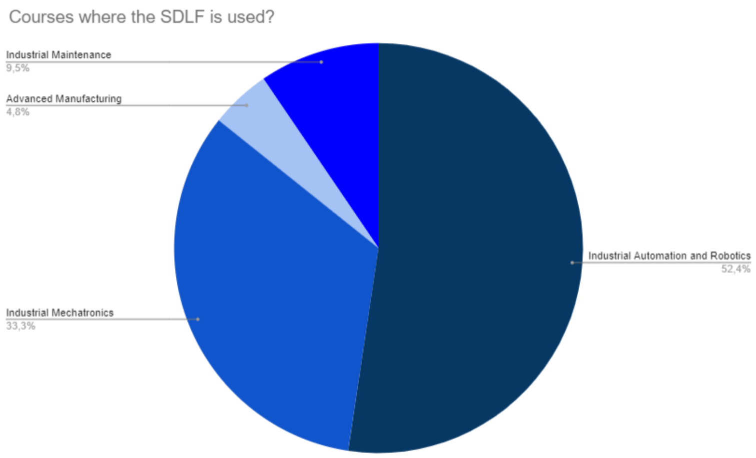


***Figure 34** Courses where the SDLFs are used in answered VET centres. Source: Authors' creation*

Life Size Learning Factories

Only the centres involved in Exam4.0 and LCAMP COVE projects claim that they use life size LF. No other respondents have life size LF.

There are interesting comments given by some of the respondents claiming that they are scaling up their SDLFs, adding self-designed modules or technologies or creating independent modules following the approach of the SDLFs.

3 of the interviewed VET centres have also implemented equipment set ups whose approaches are close to the LF concept, besides the commercial SDLF 4.0 that the study addresses.

Scale Down Learning Factories

Total number of 33 VET centres and 12 universities that use SDLFs are identified in Spain, including the Basque Country. The

Competences developed in the SDLF

The competences developed using the SDLF are in all the respondents' answers related to the technical skills of the training programs involved. Some mentioned topics are: PLC programming, machine safety, collaborative robotics, artificial, vision, industrial communications, sensorics, configuration of a connected cells, production control with the Scada, MES, ERP systems, digital twins, virtual and augmented reality, applications using RFID.

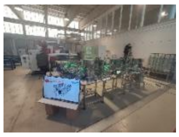
There are some mentions also of the transversal skills developed; autonomous work, teamwork, analytical skills, problem-solving, use of integrated knowledge.

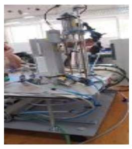
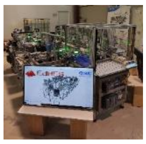
There are 2 examples of the use of the SDLF for applied research activities, test beds for digital technologies and applications, development of new training concepts.

9.7.3 VET centres with Scale Down LFs in Spain

The table below lists the VET centres and other organizations identified in Spain that are using SDLF. Only those SDLF with industry 4.0 modules are included.

NAME OF CENTRE	REGION	TYPE OF CENTRE	EQF level	LINK	PHOTO
CIFP MIGUEL ALTUNA LHII	Basque Country	VET centre. LCAMP CoVE Spanish network of VET excellence in Advanced Manufacturing	3-5	https://www.maltuna.eus/en/	
TKNIKA	Basque Country	Basque VET applied research centre LCAMP CoVE		https://tknika.eus/en/	
CIFP TOLOSALDEA LHII	Basque Country	VET centre Spanish network of VET excellence in Mechatronics	3-5	https://tolosaldea.hezkuntza.net/web/guest_english	

ARRATIA ZULAIBAR LHII	Basque Country	VET centre	3-5	https://www.zulaibar.net/	
EGIBIDE	Basque Country	VET centre	2-5	https://www.egibide.org/eu/	
EASO POLITEKNIKOA	Basque Country	VET centre	3-5	https://easo.hezkuntza.net/es/formacion/ciclos	
SALESIANOS DEUSTO	Basque Country	VET centre	3-5	https://www.salesianosdeusto.com/	
SALESIANOS URNIETA	Basque Country	VET centre	3-5	http://urnietakosalesiarrak.com/erabateko-prestakuntza/	
CIFP EMILIO CAMPUZANO LHII	Basque Country	VET centre	3-5	https://www.atxuri.net/	
LEA ARTIBAI	Basque Country	VET centre	3-5	https://www.leartik.eus/	
CIFP USURBIL LHII	Basque Country	VET centre Spanish network of VET excellence in Energy	3-5	https://lhusurbil.eus/web/default.aspx?lng=eu	
ARMERIA ESKOLA	Basque Country	VET centre	3-5	https://armeriaeskola.eus/en/	
IES ANDRA MARI	Basque Country	VET centre	3-5	https://fpandramari.eus/eu/hasiera/	
CIP VIRGEN DEL CAMINO	Navarra	VET centre Spanish network of VET excellence in Mechatronics	3-5	https://cipvirgendelcamino.educacion.navarra.es/web/	
CIFP TAFALLA	Navarra	VET centre	3-5	http://politecnicotafalla.educacion.navarra.es/web	
IES LA PUEBLA DE ALFINDEN	Aragon	VET centre	3-5	https://ieslapuebladealfinden.com/	
CIFP DE COIA	Galicia	VET centre	3-5	https://www.edu.xunta.gal/centros/cifpcoia/	
CIFP AVILÉS	Asturias	VET centre	3-5	https://www.cifpaviles.net/	

IES FERNÁNDEZ VALLÍN	Asturias	VET centre	3-5	https://institutosfp.com/centro/ies-fernandez-vallin-gijon/	
ESCUELA DE APRENDICES DE SEAT	Catalonia	VET centre	3-5	https://www.aprendices.seatformacion.com/	
INS MOLLET DEL VALLÉS	Catalonia	VET centre	3-5	http://www.insmollet.cat/	
ESCOLA TREBALL SABADELL	Catalonia	VET centre	3-5	https://www.escolaindustrial.org/	
ESCOLA TREBALL BARCELONA	Catalonia	VET centre Spanish network of VET excellence in Advanced Manufacturing	3-5	https://escoladeltreball.org/ca/	
MILA I FONATNALS	Catalonia	VET centre	4-5	https://agora.xtec.cat/iesmila/	
IES LACETANIA	Catalonia	VET centre	3-5	https://agora.xtec.cat/inslacetania/	
SAEZ DE BURUAGA	Extremadura - Badajoz	VET centre	3-5	http://www.iessaenzdeburuaga.es/informacion-general	
FREMM	Murcia	VET centre	3-5	http://www.fremm.es/portal/faces/index.jsp	
CIPFP CATARROJA	Valencian Community	VET centre	3-5	https://labora.gva.es/es/web/cipfp-catarroja/	
IES GONZALO DE BERCEO	La Rioja	VET centre	2-5	https://iesgonzaloberceo.larioja.edu.es/	
IES DON BOSCO	Castilla La Mancha	VET centre	2-5	https://www.iesdonbosco.com/	
IES CASTILLA	Castilla La Mancha Guadalajara	VET centre	2-5	http://iescastilla.es/	

IES LUIS DE LUCENA	Castilla La Mancha Guadalajara	VET centre	2-5	http://www.iesluisdelucena.com/jooml a/	
IES UNIVERSIDAD LABORAL TOLEDO	Castilla La Mancha-Toledo	VET centre	3-5	https://www.ulaboral.org/	
IES UNIVERSIDAD LABORAL ZAMORA	Castilla Leon-Zamora	VET centre	3-5	http://iesuniversidadlaboral.centros.educa.jcyl.es/sitio/	
CENTRO GALEGO DE INNOVACIÓN DE FP FERNANDO BARREIROS	Galicia	Innovation Centre for VET of Galicia			
CIFPA	Aragon	Innovation centre for VET of Aragon		https://cifpa.aragon.es/	
ITI	Valencian Community	Research Centre		https://www.iti.es/	
UPV (AI2)	Valencian Community	University		https://www.ai2.upv.es/	
DEUSTO	Basque Country	University	6-8	https://www.deusto.es/	
UNIVERSITY MONDRAGON	Basque Country	University	5-8	Link	
UPV-EHU	Basque Country	University	6-8		
Universidad Francisco de Vitoria	Madrid	University	6-8	https://www.ufv.es/	
Universidad Europea de Madrid	Madrid	University	6-8	https://universidadeuropea.com/	
Universidad Politécnica de Catalunya	Catalunya	University	6-8	https://www.upc.edu/	
UNIVERSIDAD SANTIAGO DE COMPOSTELA	Galicia	University	6-8	https://www.usc.gal/es	

➢ *Table 9 Scale Down Learning Factories in Spain*

9.7.4 Tknika

“Basque VET Applied Research Centre”, “promoted by the Deputy Ministry of Vocational Education and Training of the Education Department of the Basque Government” (Tknika, 2016). Through the direct involvement of Basque VET teaching staff and networking, this centre, develops innovation projects in education, technology and management areas.

Concerning the use of LFs

Lab for Industry 4.0

The lab is equipped among other things with a SIF400 SDLF 4.0 by SMC International training (see **Figure 35**)

Figure 35 SIF400 SDLF by SMC International Training at TKNIKA, Source: Tknika.

The lab is mainly used as a test bench for the developments made at TKNIKA. It is used also for trainings for teachers and trainers from the Basque VET centres network. The lab is equipped with the SMC International training SIF400 equipment's operative modules. The full range of technologies is available: Tracking systems RFID, NFC, QR-codes, Barcodes. communications: OPC-UA, IO-Link, ethernet IP, Modbus. Robots: Different type of robots: UR3 robot, Scara robot, AMR - Autonomous Mobile Robot.

The profile of staff are automation and industrial robotics, mechatronics, and industrial IT professionals.

Products and tools developed in the Industry 4.0 lab

1. IoM 2040 Passarella:
2. IoMBian operative system :
3. Thingsboard IIoT platform. Open source data analysis platform. This is free for schools where they can develop their own projects. Example of personalized data they can develop
4. Digital twins developed on the Simumatik platform: A total of 11 digital twins have been developed and will be published on the Simumatik platform. (Simumatic, 2020)

YEAR	TRAINING COURSES FOR VET TEACHERS AND TRAINERS
2019-2020	1. Industry 4.0: SIF-400 Sistem https://tknika.eus/cont/cursos/industria-4-0-sistema-sif-400/ 2. Industry 4.0: IO-Link and RFID https://tknika.eus/cont/cursos/industria-4-0-io-link-y-rfid/ 3. Industry 4.0:OPC-UA and Node-RED https://tknika.eus/eu/cont/cursos/industria-4-0-opc-ua-eta-node-red/
2020-2021	1. Industry 4.0: Industrial IoT, Monitory data from SMEs https://tknika.eus/eu/cont/cursos/industria-4-0-industrial-iot-eteen-datuak-monitorizatzeko/ 2. INDUSTRIA 4.0: Digita twins, Virtual commissioning https://tknika.eus/eu/cont/cursos/industria-4-0-biki-digitalak-automatizazio-proiektuen-martxan-jartze-birtuala-virtual-commissioning/ 3. INDUSTRIA 4.0: Industrial IoT, Monitory data from SMEs https://tknika.eus/eu/cont/cursos/industria-4-0-industrial-iot-eteen-datuak-monitorizatzeko-2/
2021-2022	1. Digital twins. Build your virtual lab https://tknika.eus/eu/cont/cursos/biki-digitalak-eraiki-zure-laborategi-birtuala-2/. . 2. Industry 4.0: Pilot IoM pilotajea, Monitoring Data from VET lab's machines https://tknika.eus/cont/cursos/industria-4-0-iom-pilotajea-ikastetxeko-makinen-datuak-bistaratzeko-2/
2022-2023	1. Digital twins. Build your virtual lab https://tknika.eus/eu/cont/cursos/biki-digitalak-eraiki-zure-laborategi-birtuala-4/ https://tknika.eus/eu/cont/cursos/biki-digitalak-eraiki-zure-laborategi-birtuala-2022_23/

➢ ***Table 10*** *Training courses for VET teachers provided in the Industry 4.0 lab at TKNIKA.*

Tknika coordinated the EXAM4.0 CoVE participating also in the conception and piloting of the CLF EXAM 4.0. It was responsible for developing some of the applications to be included in the CLF concepts.

9.7.5 Miguel Altuna LHII

Miguel Altuna LHII is leading the work package for the design and establishment of the CLF in the LCAMP project.

Miguel Altuna LHII is a VET centre located in Bergara (Basque Country), with advanced resources and methodologies to respond the needs of people and companies. In order to respond to those requirements the centre is working for training based on innovation and continuous improvement (MIGUEL ALTUNA LHII, 2020) All the study programs are run under the pedagogical framework, called ETHAZI (MIGUEL ALTUNA LHII, 2020 b). In this context, the use of LFs as a scenario to foster Industry 4.0 (i4.0) technologies is currently implemented in 3 labs. In Miguel Altuna, there are 2 different types of LFs: On the one hand two SDLFs and on the other hand the Advanced Manufacturing 4.0 lab (UNEVOC-BILT, 2019) where the activities of EXAM 4.0 and LCAMP are developed.

CLF, EXAM4.0.

In the CoVE Excellence Advanced Manufacturing 4.0 (EXAM 4.0, 2020) the conceptual design of the CLF was defined and piloted. The use of LFs as scenario to foster Industry 4.0 (i4.0) technologies in VET studies is extended to collaborate with external organizations and stakeholders. The CLF is using the real size industrial machinery of the manufacturing workshop to produce some of the components included in the main product, which is a mobile autonomous robot. In **Figure 36** the prototype of the modular mobile robot designed in EXAM4.0 is shown, This modular robot is being updated in the LCAMP project.

(a) (b) (c)

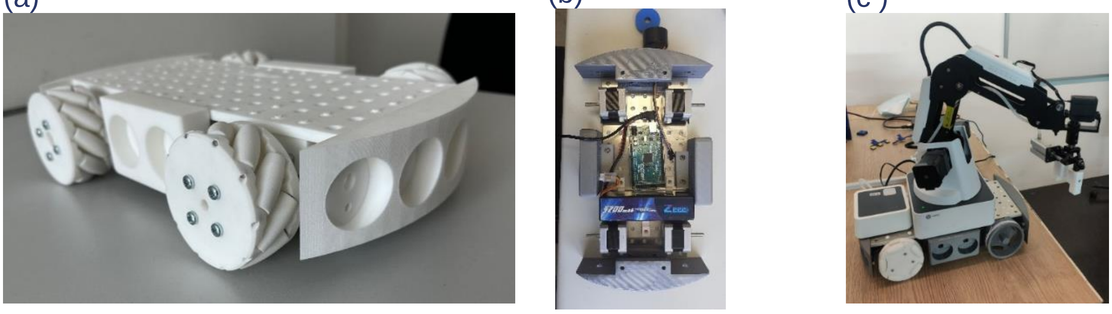


Figure 36 LCAMP Robots, (a) 3D printed version (b) Electronics for the standard version Source: LCAMP c) EXAM4.0 robot carrying a jointed arm robot. Source DHBW

Figure 37 Labs for Advanced manufacturing at Miguel Altuna. Source: Miguel Altuna

SDLF1 , SMC International Training

Miguel Altuna LHII is using the 5 modules of the SIF-400 by SMC International Training installed in the advanced manufacturing lab.

"The SIF-400 training system simulates a highly automated Smart Factory, including Industry 4.0 technologies, advanced manufacturing concepts and the reality of the connected enterprise." (SMC Corporation, 2023).

They are designed to be highly efficient and flexible, allowing for fast and easy reconfiguration to meet changing needs. They are scaled to fit a small to medium size production space. They are also equipped with high-end analytics and data collection capabilities, allowing for real-time monitoring and optimization of the production process.

This modular LF allows the fabrication of single unit containers as well as packs of containers. Furthermore, it can send both, unitary containers, and packs, as well as pallets of packs. It can only be worked by the little marbles that the laboratory carries. However, there are many options on where can be operate; such as the colour of the marbles, the type of container…

Figure 38   SDLF, 5 stations SMC SIF-400 at Miguel Altuna. Source: Miguel Altuna

SDLF 4.0 by FESTO Didactics:

This didactic material is mainly used by Industrial Automation and Robotics students. The lab consists of MPS 400 – I4.0 system and MPS Mechatronics, along with the MPS PA 204 – Continuous Process Industry.

The MPS 400 – I4.0 is a versatile training system that focuses on Industry 4.0 concepts. It consists of three modules: distribution, joining, and classification. The distribution module explores the fundamentals of material handling and logistics in an automated environment. It includes conveyor belts, sorting units, and robotic arms for efficient product distribution.

The joining module emphasizes the techniques and technologies used in the joining processes. It covers concepts such as welding, screwing, and adhesive bonding. Students can learn about different joining methods and their applications.

The classification module deals with sorting and identifying objects based on various criteria. It includes systems such as vision sensors and barcode readers to classify and categorize products accurately.

The MPS Mechatronics system is an extensive training system comprising 21 modules, covering various aspects of mechatronics and automation, including: verification, processing, handler, shelving, separation, pick and place, measuring, warehouse, packaging, electric drives and axes with stepper motor and drivers or servo motor and drivers...

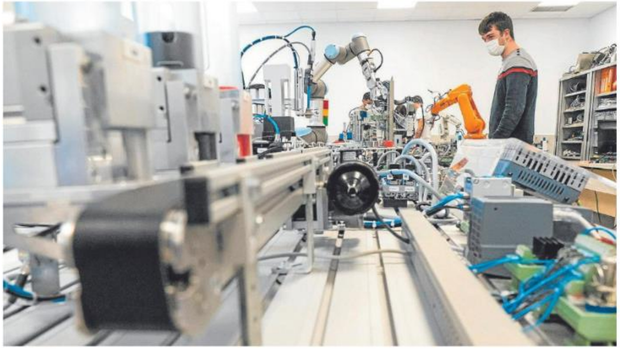


Figure 39 *SDLF, FESTO Didactics 4.0 Lab at Miguel Altuna Source: Miguel Altuna*

9.7.6 Active methodologies in VET centres

The Basque network of VET centres introduced the ETHAZI methodology in all the VET centres in a process started in 2013. ETHAZI stands for High Performance cycles. The central component on which the entire learning model is connected in the collaborative learning based on challenges. The problematic situations are presented to the class and in groups, the students have to solve the challenge by generating the essential knowledge needed to achieve the best solutions. (Tknika, Ethazi, 2016) (Tknika, ETHAZI (b), 2016)

The ETHAZI methodology is implemented also in all the VET centres with industrial study programs. In many cases the challenges developed in those programs are real cases given by industry partners. Therefore, the experiential learning is a strategic ingredient included in the Basque VET system.

The way that Challenges- based learning operates is similar to LFs approaches although is not the same. In ETHAZI not all the rules established in LF are always fulfilled. However, an evolution of the ETHAZI’s challenges towards LFs approaches would be doable. Considering the state-of-the-art equipment available in many VET schools and the expertise in active methodologies developed in recent years both working on ETHAZI and using SDLFs, the development of Life size LFs is possible if there is a will to move in that direction.

9.7.7 Conclusions

The use of life size Learning Factories in Spain is not common. However, the SDLFs have emerged as a valuable approach to VET in Spain, particularly in the field of mechatronics and industrial automation and robotics.

The study identifies 27 VET centres out of the 214 centres in Spain (12%) using Industry 4.0 SDLFs. These figures are taken for the program *Industrial automation and robotics*. For the Basque Country 9 VET centres out 25 (36%) have established SDLF for Industry 4.0 for the same program. The establishment of the Spanish network of VET excellence centres would also foster this tendency. Currently %41 of those excellence centres operating in the mentioned fields are using SDLFs for Industry 4.0. SDLFs are also used in universities. We have identified 12 universities with such equipment used in engineering degrees.

The term LF is not well known and there is certain confusion using it. LFs are, to a certain extent, linked to the modules commercialized by SMC International Training and FESTO Didactics whereas the core LF approach, using life size equipment, is not widely known. 17% of the SDLF users do not use the term LF and they are not aware of the life size LF approaches.

Concerning the core LF approaches, the study identifies very few examples. The CLF piloted in the EXAM4.0 initiative and currently followed up in LCAMP is one of those.

It is remarkable that the use of active methodologies is the standard in the Basque Country. VET centres work within the ETHAZI framework where the entire learning model is connected in a collaborative learning method based on challenges. The scheme used is very often close to the LF approach although this term is not commonly used. In other regions of Spain similar approaches are also becoming the norm.

The fact that frameworks such as ETHAZI are successfully implemented shows a clear strategy to foster methodologies where transversal skills are enhanced. In that sense, the success of the LFs could draw to evolve the competence frameworks and to explore new opportunities for VET centres.

9.8 SWEDEN

9.8.1 Curt Nicolin Gymnasiet

In Curt Nicolin Gymnasiet (CNG) located in Finspång, Sweden, there are various labs whose set ups and uses are close to the LF concepts. Curt Nicolin Gymnasiet works with a methodology called CDIO. CDIO are trademarked initials for Conceive Design Implement Operate. The CDIO Initiative is an educational framework that stresses engineering fundamentals set in the context of conceiving, designing, implementing and operating real-world systems and products.

CNG also teaches based on a model called PBL – problem-based learning. CNG utilizes the PBL model in such a way that a significant portion of the students' learning occurs through presenting them with a problem, which they solve based on the knowledge they have acquired in previous lessons. In this manner, CNG promotes a learning approach that encourage independent inquiry and ideas, precisely the kind of thinking desired in a professional setting.

***Figure 40** LF – ABB robotic cell. Source CNG*

An example of a LF used in CNG is the ABB robotic cell (**Figure 40**) This LF provides hands-on training and practical experience to the students in the field of robotics and automation. The set-up contains an ABB IRB 140, along with its associated control system. The robot is integrated with grippers (designed and printed by students in the schools SLM printer, EOS P110 FORMIGA), sensors, a conveyor belt, an EMCO turn 55, a grinding belt and compressor air. The cell is configured to simulate a real-world manufacturing environment.

The LF is designed to offer a progressive series of training modules, starting from basic concepts and gradually advancing to more complex automation tasks. Each module is covering specific topics such as robot programming, system integration, safety procedures, troubleshooting and optimization.

The students can program the robot using ABB's programming language, RobotStudio. They learn how to teach the robot tasks, program motion sequences, configure inputs and outputs and implement logic-based decision-making processes.

To reinforce their learning, students work on automation projects within this LF. These projects also include tasks like material handling, material processing, CNC-processing, assembly operation, quality inspection. The students are responsible for designing, programming and optimizing the robot cell to achieve specific production objectives.

For example, in one module, the students could be tasked with a manufacturing line. The students would learn how to program the robot to pick up components from the conveyor belt, use the robot to set up the EMCO turn, process the material, program the robot to pick out the part, grind the back of the part and place the finished product on an output conveyor.

Throughout the module, students gain practical experience in various aspects of automation, such as developing motion paths, implementing error handling routines, implementing CNC-manufacturing and optimizing the overall production process. They also learn how to troubleshoot common issues and perform maintenance tasks on the robotic cell.

By this ABB robotic cell as a LF, students develop valuable skills in robotics and automation, which are highly relevant in today's industrial landscape. The hands-on experience gained in CNG prepares the students for real-world challenges and enhances their employability in industries.

9.8.2 VET centres with SDLF

In Sweden studies have been undertaken in 10 different VET-schools like Curt Nicolin Gymnasiet. However, information could not be obtained regarding their use of SDLF.

These are the names of the organizations mentioned:

NAME	LOCATION	TYPE OF CENTRE	BUSINESS PARTNER	BRANCH
ABB-gymnasiet	Västerås	VET centre	ABB	Robotics, automation
Göranssonska skolan	Sandviken	VET centre	Sandvik	Manufacturing industry – cutting technique, tools
Göteborgregionens Tekniska Gymnasium	Gothenburg	VET centre	Volvo	Manufacturing industry - cars
Göteborgs Tekniska College	Gothenburg	VET centre	Volvo	Manufacturing industry - cars
Hitachi Gymnasiet	Ludvika	VET centre	Hitachi	Manufacturing industry - electric power system
Mälardalens Tekniska Gymnasium	Mälardalen	VET centre	Scania / AstraZeneca	Manufacturing industry – Trucks, medicine
Perstorp Tekniska Gymnasium	Perstorp	VET centre	Perstorp AB	Process industry - Chemistry
SKF Tekniska Gymnasium	Gothenburg	VET centre	SKF	Manufacturing industry - ball bearings

Vattenfallgymnasiet	Forsmark	VET centre	Vattenfall	Electrical power, nuclear power
Volvogymnasiet	Skövde	VET centre	Volvo	Manufacturing industry - car engines

➢ ***Table 11*** *VET schools in Sweden with active methodological approach*

All the VET centres mentioned above (**Table 11**) have pieced LFs and active methodological approaches. These schools together with Curt Nicolin Gymnasiet are a part of the FRIND-group, whose mission and purpose are to develop innovative individuals who, in the long term, contribute to strengthening Sweden's position as a technological and industrial nation. To provide a high-quality technical and industrial technical education that meets the skills needs of industrial companies, and to develop education that corresponds to today's and tomorrow's technology development and responds to the companies' environmental and sustainability goals.

Many of these schools aim their education to respond the needs of their business partners and owner companies. Therefore, the Labs set up in those schools usually use close approaches to the LF concept, which are also close to the production concepts of the partner businesses.

When conducting this study, various attempts to contact FESTO DIDATICS and SMC International Training were made to identify other SDLF's users in Sweden. Unfortunately, this effort was unsuccessful, and the researchers did not identify more VET centres using LF or SDLF concepts.

9.8.3 Open Innovation Enviroments in Sweden

In addition to the effords mention in the previous section, the conducted research found a study carried out by the University of Skövde and founded by the Swedish Vinnova organization under the hood of the project Production2030 (Produktion2030, 2023). tittled "Mapping of open innovation environments for production development in Sweden" (Syberfeldt, 2022). This report mentions the increased demand in the Swedish manufacturing industry for environments that strengthen companies' innovative capacity and competence in new advanced technologies. The study analyses open environments where companies, researchers and other actors can collaborate. In many cases this partner actors are universities and this type of environment include equipment very close to their industrial owners manufacturing processes, in a smaller scale. The equipment is used to carry out research but also education at different levels, with lot of focus in Life Long Learning, which could be consider LFs. In **Figure 41** a LF is shown, in **Figure 42** assisted digital workstations and in **Figure 43** a SDLF:

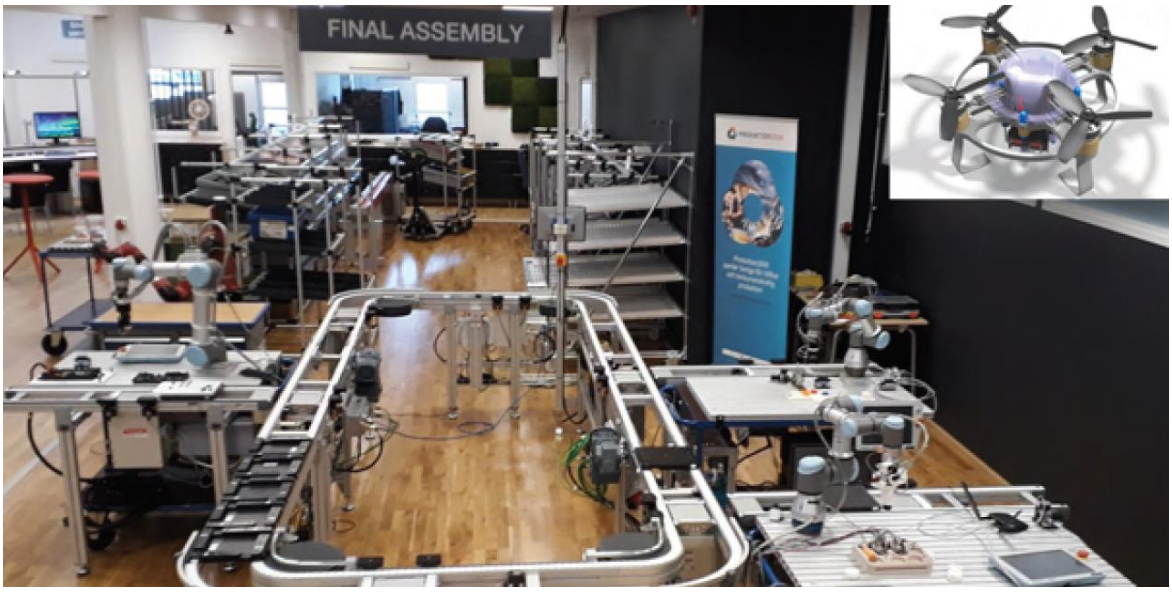


Figure 41 *Stena Industry Innovation Lab Göteborg. Source (Produktion2030, 2023)*

Figure 42: *Virtual Manufacturing's Work Station One, Göteborg (Produktion2030, 2023)*

Figure 43: *SDLF at MITC, Source: (Produktion2030, 2023)*

The following table lists 12 of these environments in Sweden, differentiating the ones that are used somehow in education (VET or University level) and not just industry research.

NAME	LOCATION	TYPE OF CENTRE	OWNERS / PARTNERS	Link	LF used in education
ASSAR INDUSTRIAL INNOVATION ARENA	SKÖVDE	University	IDC West Sweden AB, Science Park Skövde AB, Högskolan i Skövde, Volvo Cars and Volvo AB	assarinnovation.se	Yes
CAMPX AB VOLVO GROUP	GÖTEBORG	University	Volvo Group	volvogroup.com/campxx	No
EPIC INNOVATION & TECHNOLOGY CENTER	VÄXJÖ	University	GoTech and Syd- svenska Industri	goepic.se	No
FAB LAB	HALMSTAD	University	Fab Foundation and Högskolan i Halmstads	hh.se/fablab	**Yes**
MITC	ESKILSTUNA	University	Mälardalens högskola and industry (Volvo CE, Volvo GTO, GKN, Alfa Laval and Hexagon)	mitc.se	**Yes**
PTC	TROLLHÄTTAN	University	Högskolan Väst, GKN Aerospace, IUC Väst and Swerim	innovatum.se/starta-och-utveckla/produktionstekniskt-centrum	**Yes**
SANDBACKA SCIENCE PARK	SANDVIKEN	University	Sandvikens kommun	sandbackapark.se	No
SCANIA SMART FACTORY LAB	SÖDERTÄLJE	University	Scania, Ericson, ABB	scania.com/group/en/home/about-scania/innovation/ research/smart-labs.html	**Yes**
STENA INDUSTRY INNOVATION LAB	GÖTEBORG	University	Chalmers and Stena Industry	sii-lab.see	**Yes**
SYNERLEAP POWERED BY ABB	VÄSTERÅS	University	ABB AB, Västerås stad, Mälardalen University Sweden, Automa- tion Region, Almi företagspartner, Västerås Science Park, Vinnova, Rise, Robotdalen, Bio Venture Hub, Västmanland, Region Västmanland and Create busi- ness incubator	synerleap.com	No

SÖDERTÄLJE SCIENCE PARK	SÖDERTÄLJE	University	KTH, Södertälje kommun, Scania and AstraZeneca	sscp.se	No
VIRTUAL MANUFACTURING 'S WORK STATION ONE	GÖTEBORG	University	Virtual Manufacturing Sweden AB	virtual.se	No

Table 12 Organizations involved in the Open Innovation Enviroments

9.8.4 Conclusion

The conclusion of the research carried out in Sweden is that there are a variety of VET centers using LABS close to the LF concept. Life sized LF and SDLF are usually implemented in universities and HVET centres. Schools and companies are not eager to hand out too much information about equipment and educational methods. This may have been due to a lack of time and interest on their side.

On the other hand, there is a network of open innovation enviroment operating in Sweden with good examples of training facilities for life long learning on advanced manufacturing. The 12 organisations are public private partesrhip involving uninversities, research centres, large companies. Furthermore, some of those large companies have VET centres integrated. These open innovation enviroments operate LFs or SDLFs for their training and research activities.

9.9 TÜRKİYE

9.9.1 Model Factory Approach

In Türkiye, the establishment of Model Factories is an initiative aimed at promoting lean production and digital transformation in businesses. These centres, created in collaboration with the Ministry of Industry and Technology, the Directorate of Strategic Research and Efficiency, and the United Nations Development Programme (UNDP), serve as experiential learning centres.

Model Factories provide training and consultancy services for small and medium-sized enterprises (SMEs) in lean transformation and digital transformation, specifically in the manufacturing industry. They focus on enhancing practical skills and competences of the manufacturing workforce. By integrating productivity improvement techniques with digital technologies such as IoT, cloud computing, AI, robotics, and more, Model Factories facilitate competence development through experiential learning.

The connection between Model Factories and LFs resides in their common objective of offering hands-on training and advancing operational excellence. While LFs are limited to specific VET schools and focus on advanced production techniques, Model Factories extend their reach to SMEs and emphasize lean and digital transformations in the manufacturing sector. Both aim to enhance skills and knowledge through hands-on learning experiences.

Figure 44 Model Factory Source: Türkiye Ministry of Industry and Technology

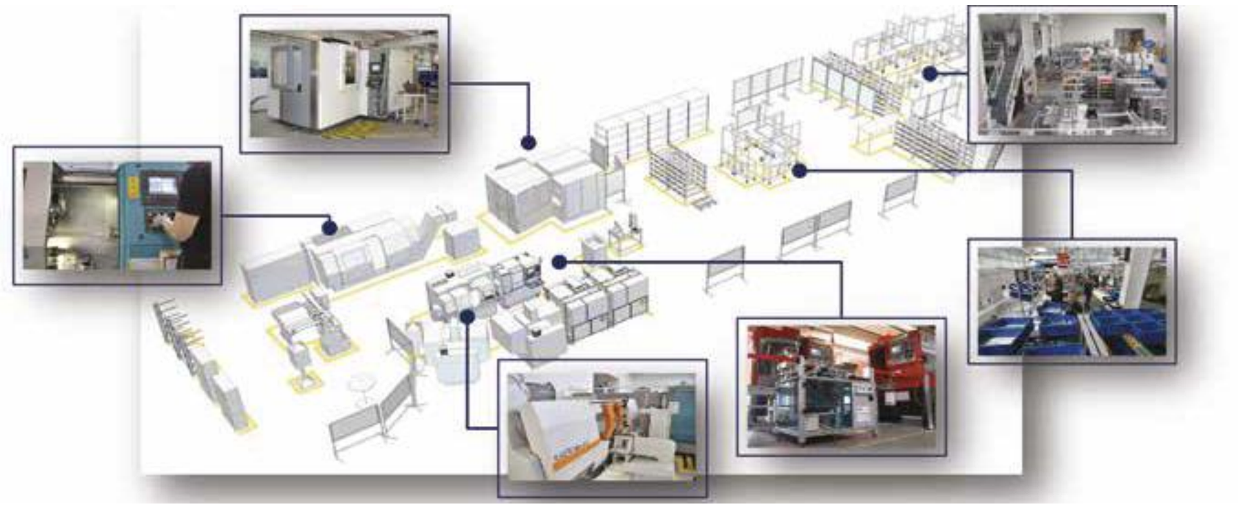


Figure 45 Design of Model Factory. Source: Türkiye Ministry of Industry and Technology

Their target audience includes manufacturing enterprises, especially SMEs, sector employees, university students, and academics, covering areas such as lean transformation, digital transformation, quality, and product development.

9.9.1.1 Model Factories in Türkiye

In Türkiye, the studies in the field of Model Factory were initiated in 2015 under the coordination of the Ministry of Industry and Technology of the Republic of Türkiye. Through national and international funding, the establishment of 8 Model Factories has been completed in the provinces of Adana, Ankara, Bursa, Gaziantep, Izmir, Kayseri, Konya, and Mersin, and they have been put into operation. Model Factories, which provide guidance to businesses in their transformation journeys, primarily focus on lean production training and consultancy services. Additionally, infrastructure and human resources development activities are conducted to enable them to operate in the field of digital transformation.

Figure 46 *Model factories in Türkiye Source: Türkiye Ministry of Industry and Technology*

In addition to the currently operational 8 Model Factories, the establishment of Model Factories in Denizli, Eskişehir, Kocaeli, Malatya, Samsun, and Trabzon provinces (Blue) are still ongoing See **Figure 46**.

NAME OF CENTRE	REGION	TYPO OF CENTRE	VET LEVEL (EQF)	Type of LF	LINK	Presentation
Adana Competence and Digital Transformation Centre	Adana	VET	3-5	Standard	https://www.sanayikampusu.com/	https://www.sanayi.gov.tr/assets/pdf/birimler/AdanaMFTanitimveBilgilendirmeToplantisi.pdf
Ankara Competence and Digital Transformation Centre	Ankara	VET	3-5	Standard	https://www.modelfabrika.org/	https://www.sanayi.gov.tr/merkez-birimi/92d9c73bddbb/model-fabrika/b81233
Bursa Competence and Digital Transformation Centre	Bursa	VET	3-5	Standard	https://www.bursamodelfabrika.com/	https://www.sanayi.gov.tr/assets/pdf/birimler/SAVGMBursaModelFabrikaSunum.pdf
Gaziabtep Competence and Digital Transformation Centre	Gaziantep	VET	3-5	Standard	www.gaziantepmodelfabrika.com	https://www.sanayi.gov.tr/assets/pdf/birimler/GaziantepMFTanitimveBilgilendirmeToplantisi.pdf
İzmir Competence and Digital Transformation Centre	İzmir	VET	3-5	Standard	https://www.izmirmodelfabrika.com/	https://www.sanayi.gov.tr/assets/pdf/birimler/IzmirMFTanitimveBilgilendirmeToplantisi.pdf
Kayseri Competence and Digital Transformation Centre	Kayseri	VET	3-5	Standard	http://www.kayserimodelfabrika.com/	https://www.sanayi.gov.tr/assets/pdf/birimler/KayseriMFTanitimveBilgilendirmeToplantisi.pdf
Konya Competence and Digital Transformation Centre	Konya	VET	3-5	Standard	https://www.modelfabrika.com.tr/	https://www.sanayi.gov.tr/assets/pdf/birimler/KonyaMFTanitimveBilgilendirmeToplantisi.pdf
Mersin Competence and Digital Transformation Centre	Mersin	VET	3-5	Standard	https://mersinmodelfabrika.com/	https://www.sanayi.gov.tr/assets/pdf/birimler/MersinMFTanitimveBilgilendirmeToplantisi.pdf

➢ ***Table 13*** *List of model Factories in Türkiye*

9.9.2 METEKIII Project

METEKIII project aims to improve the Quality of Vocational Education Through the Establishment of Sectoral Centres of Excellence Grant Program.

The main objective of the **METEK III Project**, carried out by the central government and with a budget of 20 million Euros; The Project, a government initiative with a substantial budget, aims to enhance vocational education by supporting the professional growth of VET teachers and providing practical training opportunities for students. This endeavor, which prioritizes the establishment of sectoral centers, capacity building for vocational trainers, and the development of training programs, materials, and networks, aligns with the principles of the LF concept.

Priorities of the Grant Program:

1. Establishment of sectoral centres for the development of vocational education competences.
2. Increasing the capacity of vocational trainers through training ourses.
3. Preparation of in-service training program and material.
4. Increasing the awareness of the business world within the vocational training.
5. Establishing networks to bring together vocational education institutions and the business world.

Figure 47 Ankara Sectoral Excellence Centre. Source: Türkiye Ministry of Industry and Technology

Sectoral Centres of Excellence

An important component of the MEETEK III Program is the establishment of **Sectoral Excellence Centres** in **vocational and technical Anatolian high schools**. These centres aim to enhance the specialized competences of teachers working in vocational and technical secondary education institutions through on-the-job learning and distance learning methods like the experiential learning approach adopted by LFs. In Ankara, Istanbul, Bursa, **Kocaeli**, Antalya, and Izmir, a total of 15 Sectoral Excellence Centres has been established.

There are 14 Sectoral Excellence Centres covering a total of **25 vocational fields**, as well as one centre focusing on vocational foreign languages, mathematics for vocational training, and science for vocational training. The objective of these centres, established in **14 vocational and technical schools**, is to increase collaboration between vocational and technical education and the manufacturing sectors through joint projects, various field research activities, R&D, and production activities. In line with this objective, the centres will organize training activities to convey industrial developments to teachers and support their personal and professional development.

Additionally, another important component of the program is the Sectoral Excellence Centres established in **Chambers of Commerce and Industrial Zones**. These centres collaborate with the other 15 centres opened in VET schools to enhance the vocational skills of teachers through application-oriented training in line with the needs of the industry, 7 of which incorporate the SDLF concept, to provide targeted and industry-relevant training to teachers and enhance their vocational skills. See **Table 14**.

NAME OF CENTRE	NAME OF PROJECT	REGION	Budget	VET LEVEL (EQF)	Type of LF	LINK
Türkiye Informatics Foundation	Increasing the Capacities of MTE Institutions in Innovation Approaches in IT Transformation (BC2IT)	Istanbul	555,930.56	3-4-5	-	-
Electricity Distribution Services Association	Establishment of Sectoral MTE Competence Development Centre in Electricity Distribution Sector	Ankara	536,126.36	3-4-5	-	-
Aegean Region Chamber of Industry	EBSO Sectoral Excellence Centre in Electronics Technologies	Izmir	426,618.05	3-4-5	Scaled LF	https://projematik.ikg.gov.tr/miswebsite/Default.aspx?projeID=239661
Natural Gas Distributors Association of Türkiye	Energy Excellence Centre	Ankara	539,125.87	3-4-5	-	-
Keşan Chamber of Commerce and Industry	Vocational Competence Centre for Trakya Metal and Industrial Automation Technologies	Edirne	458,839.92	3-4-5	Scaled LF	https://www.kesantso.org.tr/
Ermetal Technological Education Foundation	Sectoral Centres for Competence Development in MTE for Future Facilities	Bursa	468,515.10	3-4-5	Scaled LF	www.ertev.org
Gedik Education and Social Aid Foundation	Establishment of an Education Centre for Increasing Technical Capacities of Welding Technology Educators	Istanbul	469,324.35	3-4-5	Scaled LF	www.gedikegitimvakfi.org.tr/
Turkish Construction Industrialists Employers' Association	Leading Construction Teachers	Ankara	340,889.21	3-4-5	-	-
Turkish Ports, Maritime, Shipyard and Warehouse Workers' Union	Improving Vocational Education in Machine Technologies and Maritime Sector	Ankara	594,065.07	3-4-5	-	-
Mersin Chamber of Commerce and Industry	Meeting Changing Needs of the Business World through Integration of Vocational and Technical Education	Mersin	364,238.35	3-4-5	Scaled LF	https://www.mtso.org.tr/en
Ankara Chamber of Commerce	Innovative Vocational and Technical Competence Development Centre in Metal	Ankara	584,962.35	3-4-5	-	-

	and Metallurgy Sector (In-TECH)					
MESS Education Foundation	Multilayered Solution for MTE: Change Ambassadors	Istanbul	492,550.42	3-4-5	Scaled LF	www.messegitim.com.tr
Osmaniye Chamber of Commerce and Industry	Improving the Quality of Vocational and Technical Education in Machine Technologies in Osmaniye and Surrounding Provinces	Osmaniye	287,554.88	3-4-5	-	-
Association of Turkish Metal Industrialists (MESS)	Design Academy	Istanbul	595,410.21	3-4-5	-	-
Association of Turkish Textile Industry Employers	Improving the Quality of Vocational and Technical Education in the Textile Industry	Istanbul	489,270.01	3-4-5	-	-
Denizli Chamber of Commerce	Improving the Quality of VET in Textile Technology through the Establishment of a SMM in Denizli	Denizli	460,106.78	3-4-5	-	-
Association of Turkish Plumbing Engineers	Improving the Quality of Vocational and Technical Education in Plumbing Technologies and HVAC Sector	Ankara	323,114.47	3-4-5	-	-
Bursa Chamber of Commerce and Industry	Next Generation Vehicle Technologies Sectoral VET Competence Development Centre	Bursa	553,923.89	3-4-5	Scaled LF	www.butgem.org.tr

➢ ***Table 14*** *Sectoral Excellence Centres established in Chambers of Commerce and Industrial Zones*

9.9.3 Project: Establishment of Training Centres of Excellence

In 2022, 4 Training Centres of Excellence were established in Mersin, Istambul, Bursa and Izmir. Those centres are designed to work in the Industry 4.0 concepts and it is expected that 1000 Technical Teacher will be trained in those facilities. In **Figure 48** the details of the 4 Training Centres of Excellence are shown. SDLF are implemented in those centres.

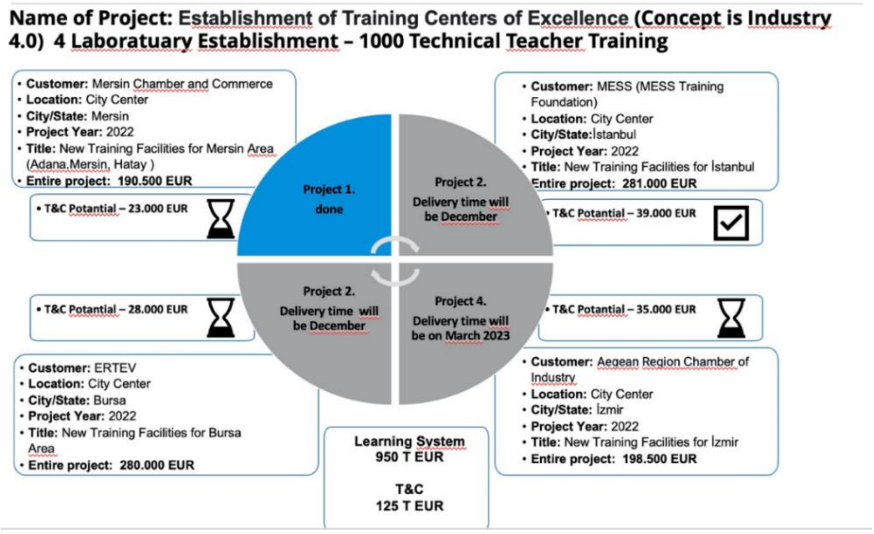


Figure 48 *Establishment of Training Centres of Excellence Project Source: FESTO Turkiye A. Ş.*

9.9.4 İMES Centre of Excellence

The iMES OIZ Excellence Centre was established in 2020 with the aim of meeting the industrial human resources training needs of the companies in the region. This centre, established in the Standard LF format, aims to meet the advanced manufacturing industry personnel needs required by companies. In the simulated real production environment in the centre, another aim is to increase the added values of the products produced in the sector with R&D activities and to enable companies to benefit from grant incentive programs with consultancy activities.

The main goal of the Excellence Centre, supported by the Eastern Marmara Development Agency, is;

- to increase the industrial human resources capability in the region,
- to realize knowledge-based production technology,
- to produce high value-added products,
- to increase productivity, and to conduct necessary research and development activities
- to increase companies' innovation capabilities within a noteworthy excellence centre established through industry-academia cooperation.

9.9.5 BEYSAD Project

The BEYSAD Project aims to establish a competence centre in Türkiye for the white goods sector, similar to those found in the USA and EU. This centre will provide technical infrastructure and a dedicated team to support members in their Industry 4.0 transformation. The competence centre will benefit sub-sectors such as electronics, chemical, glass, and plastics, offering technical consultancy, pilot project testing, training infrastructure, certification programs, and advanced research opportunities with academic staff from universities. The CP Factory system by FESTO Didactic TR is being implemented in this centre. See **Figure 49** and **Figure 50**.

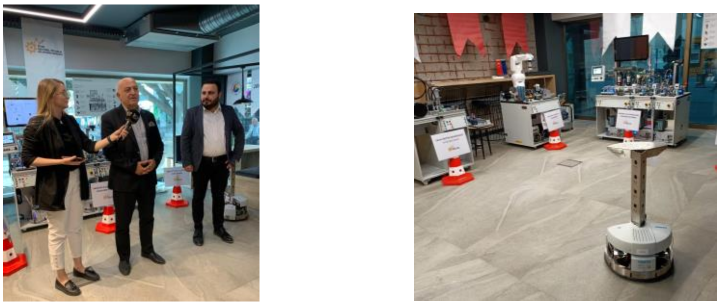


***Figure 49** BEYSAD FESTO CF Factory Source: FESTO Türkiye A. Ş.*

***Figure 50** BEYSAD CP Factory Project Photos Source: FESTO Türkey A.Ş.*

In **Figure 51** some details of the Beysad CP factory are given.

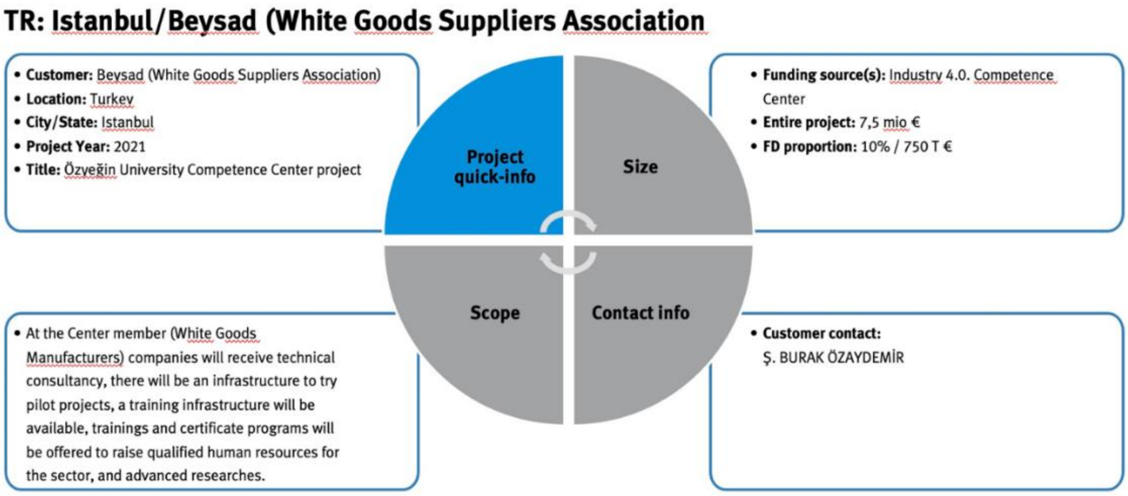


Figure 51 BEYSAD CP Factory Project Quick Info Source: FESTO Türkiye A.Ş.

9.9.6 Conclusions

In Türkiye, the use of LFs for advanced production techniques courses in VET schools is limited to a small number of schools. However, in the Kocaeli region, only 12 out of 80 vocational high schools have training workshops/labs including pieced LFs where production can take place. These facilities do not simulate an entire factory but include specific sections such as production and packaging. 4 of these 12 VET schools have dedicated training classrooms where advanced manufacturing techniques, such as SDLFs can be taught. In the engineering departments of three universities located in Kocaeli, SDLFs are widely used for engineering education.

On the other hand, in Türkiye, various efforts have been made to enable businesses to benefit from lean production and digital transformation processes, including training personnel and interns. One such initiative is the establishment of the Applied SME Competence Centres (Model Factories) in collaboration between the Ministry of Industry and Technology of the Republic of Türkiye and the United Nations Development Programme (UNDP), which have the concept of standard LFs.

In some VET schools in Türkiye, SLDF have been established with the support of the central government and local development agencies at various levels. However, the general approach is to establish learning environments such as life-size factories or SDLFs (Model Factories) in industrial organizations, Industrial Zones (OIZ), or institutions coordinated by Industrial Chambers. This is because these training environments, which are established at high costs, have high sustainability costs such as basic maintenance, calibration, and renovation. Since it is not feasible for VET schools to consistently meet these costs, these training facilities eventually become idle. Therefore, Model Factories are established under the coordination of industrial institutions. The established model factories are associated with VET schools in the region.

The primary purpose of Model Factories is to provide training and consultancy services in lean transformation (aimed at improving operational efficiency) and digital transformation (implementing the principles of the Fourth Industrial Revolution) to small and medium-sized enterprises. Moreover, through the protocols established between Model Factories and VET schools, students enrolled in the 12th grade of VET schools can carry out their internship training in these facilities. Additionally, some courses are conducted in these facilities to enhance the practical skills and competences of VET schools.

9.10 CANADA

9.10.1 Classification of Canadian Learning Factory Environments

The educational framework under which Canada's LFs operate is unusual. Although the federal government provides financial support for job training and skill development, it has no direct authority over education funding, which is instead managed by the provincial and territorial governments. Educational facilities are governed by provincially appointed boards of directors that may include industry representatives, community leaders, and other government appointees, as well as faculty, support staff, and/or student representation, depending on the province or territory involved. Because of this, the development of institutes of higher learning in Canada has historically varied by region, with substantial autonomy given to individual facilities. (Dennison, 1995). In other words, Canadian tertiary education operates without federal authority because all educational activities in the commonwealth are the responsibility of the provinces or territories.

Canada follows the pattern of a segmented tertiary system, with universities at the top providing knowledge creation, professional education and higher-level degrees at a national level (albeit with provincial or territorial control), colleges at the bottom providing practical and job-oriented tertiary education (with provincial or territorial control and local community mandates), and polytechnics and institutes in the middle offering advanced technical training and a knowledge-creating bridge between colleges and universities. This hierarchy has resulted in universities being funded at a significantly higher level than institutes and polytechnics, which are in turn funded at a significantly higher level than colleges.

These two factors have resulted in vocational education and training being firmly established as the purview of the 213 public colleges (local) and institutes (regional); every Canadian lives within 50 kilometres of a college, and all colleges are intentionally and deeply aligned with their local communities. Most of these provide vocational education and training, most often through dedicated trades programming, and operate largely through a combination of provincial monies, tuition, and private fundraising. There are areas of specialization, but each college is different in their approach, learning outcomes, and pedagogies. Broad-ranging applied research programs are represented throughout the provinces but there are no scale-down, life-size, or virtual LF environments at the college level. Instead, most colleges have trades programs that involve applied learning through the use of discrete elements of factory production where students can experience using specific equipment. These elements often include modules or equipment that come close to the LF model, but they are typically segmented across different trades and engineering areas rather than being fully integrated into a single full-scale environment.

Because of this constitutionally mandated provincial autonomy, LFs in Canada have historically operated differently by region; although over time, and especially in the past twenty years, they have increasingly drawn from each other's successes to develop more consistent organization across the country. Most Canadian colleges operate using a combination of direct vocational education, academic programs that provide transfer credits to university programs, and degree programs offered in conjunction with university diplomas (degree-granting by colleges is a relatively new role).

There is, however, evidence that this state of affairs may be changing. In November 2022, **Mohawk College** announced their intention to create a Smart Factory Living Lab, which would act as a full-scale digital LF, with assistance from the government of Ontario, and in March 2023 **Niagara College** announced the purchase of new equipment and infrastructure to develop a full process automation station which would act as an LF-like environment. Both projects remain underway and may point to a growing use of LF environments at the college level in the coming years.

One province has taken a somewhat different approach: the **CEGEP (Collèges D'enseignement Général Et Professionnel)** system, a publicly funded post-secondary education institute integrated with the education system of Québec. Attending these colleges is mandatory in order to pursue a university degree, with enrolment streams leading either to university or technical education. Many of the CEGEPs provide vocational education and training, and some are quite advanced in their provision of LF components, including elements of digital LFs.

Additionally, there is a Canadian organization that supports a dedicated group of colleges designated as incorporating **Technology Access Centres (TACs**). These TACs are all embedded within college structures, but they exist to support SME access to advanced technologies within particular economic sectors. TACs can be thought of as a corollary to the established college and institute's structure, providing applied research activities for students, faculty, communities, and local businesses. Many TACs have LF elements, mostly used to support industry clients and only peripherally involved in curricular activities.

In order to facilitate understanding of the Canadian context for this examination of LFs, the following will be divided into four major categories: CCTTs and CEGEPs, Polytechnics and Institutes, Technology Access Centres, and University LFs.

9.10.2 Synchronex College Centres for the Transfer of Technologies (CCTT)

Network of College Centres for the Transfer of Technologies and Innovative Social Practices located at Quebec CEGEPs *https://reseaucctt.ca/en*

The province of Quebec operates a separate network of 48 colleges known as CEGEPs. Quebec's LF-like systems operate under the Network of College Centres for the Transfer of Technologies and Innovative Social Practices (CCTT Network.) Established in 1992, the Synchronex CCTT Network now unites 59 CCTTs, each of which devotes itself to a specific field of activity and is linked to a CEGEP in its region of Quebec. Quebec's CEGEP system is unique in Canada as a method of improving access to both skilled trades and university learning, with students required to undertake a three-year program in order to matriculate to other forms of post-secondary education. As a result, Quebec students have access to highly specialized research environments, and local SMEs and entrepreneurs can contact applied research facilities tailored to their specific needs. Many CCTTs also operate as national TACs; of Quebec's 59 CCTTs, 24 are also Technology Access Centres (TACs) and act as a link between Synchronex and Canada's TAC network. Examples include:

9.10.2.1 Composites Development Centre of Quebec (CDCQ)

Cégep de Saint-Jérôme, Saint-Jérôme, QC *https://www.cdcq.qc.ca/en/*

The CDCQ helps regional companies meet their composites needs through applied research, technical assistance, and information dissemination services, enabling them to improve the quality and performance of their products. The CDCQ provides its partners with a multifunctional workshop with equipment covering most industrial processes and an ISO 17025-accreddited a state-of-the-art material testing laboratory, forming a modular testing and LF-like environment in the field of composite engineering. Students take part in CDCQ activities through work-study programs in conjunction with the CDCQ and industry partners, focusing on specialized projects and training.

Figure 52 *Le CDCQ offre un service de formation du personnel qui est élaboré en fonction des besoins des entreprises. Source : https://www.cdcq.qc.ca/services/*

9.10.2.2 Innofibre

Cégep de Trois-Rivières, Trois-Rivières, QC *https://innofibre.ca/en/*

Innofibre contributes to the field of bioprocesses and bioproducts, assisting regional SMEs through the development of industrial processes and product diversification. Drawing on unique facilities for the development and treatment of cellulosic and bio-based products and materials, Innofibre provides applied research expertise, technical assistance, and customized training for student and professionals. Innofibre combines state of the art analysis and laboratory equipment with its entirely unique pulp and paper pilot plant, which can pilot the papermaking process all the way from wood chips to final paper products, and which is useable either individually or in combination.

Figure 53 *Innofibre pulp treatment. Source: https://innofibre.ca/en/*

9.10.2.3 Mechanium

Cégep Beauce-Appalaches, Saint-Georges, QC https://www.mecanium.ca/

Mechanium supports Quebec’s SMEs in the field of mechatronics solutions and manufacturing, updating processes and developing products to help local companies remain competitive in a global marketplace. It accomplishes this through product development, applied research, and knowledge transfer, working alongside Cégep Beauce-Appalaches to bring students to the Mechanium Technology Park to undertake mechatronic learning and innovation in a controlled and supervised environment.

Figure 54 The Mechanium at Cégep Beauce-Appalaches. Source : https://cegepba.qc.ca/nouvelles/mecanium-recevra-1m-pour-le-maintien-de-ses-activites/mecanium/

9.10.2.4 Merinov

Cégep de la Gaspésie et des Isles, Gaspé, QC *https://merinov.ca/en/*

Merinov supports the blue economy in Quebec, primarily in the fields of fisheries and aquaculture. In addition to direct applied research, they provide extensive technology transfer and technical assistance services, design and process engineering, and profitability and process optimization. Merinov also supports SMEs through diagnostics and analysis of existing processes and products. Merinov’s technological base is highly specialized, including unique equipment for fisheries development and diversification, shellfish and seaweed farming, bio-food process development and aquatic biotechnology, and industrial processing methods for the blue economy.

Figure 55 Industrial Seafood Diagnostic. Source: https://merinov.ca/en/centres-expertise/industrial-processing-methods/

9.10.2.5 Vestechpro

Cégep Marie Victorin, Montréal, Quebec, *https://vestechpro.com/en/*

The Vestechpro Apparel Research and Innovation Centre supports the needs of Quebec's garment industry through technical support (especially in the fields of smart clothing, specialized and adaptive garments, and circular economy), training, information, and applied research services. Working with direct garment designers and manufacturers and with satellite companies, Vestechpro's state-of-the-art laboratory includes scanning systems, high-performance design software, and a unique clothing prototyping lab.

Figure 56 *Vestechpro Prototyping Lab. Source: https://vestechpro.com/en/services/detail/our-asset-a-technological-laboratory-and-its-state-of-the-art-equipment/*

9.10.3 Polytechnics Canada

Ottawa, Ontario https://polytechnicscanada.ca/

Canadian polytechnic institutes are large, technologically oriented postsecondary institutions that combined applied research and degree programs, creating a bridge between typical college and university operations in both the programs that they offer and their methods of operation. Because of this bridge, Canada's thirteen polytechnic institutes represent two-thirds of Canada's student population, and many of them have the resources and desire to create fully developed LF environments.

Several polytechnic institutes also operate TACs, including NAIT, Red River College, and Saskatchewan Polytechnic. Others operate independently of the TAC network, and their LFs are listed below. As with the colleges mentioned in Section 1, polytechnics typically include a variety of infrastructure and modules that can serve as a modular LF environment. Full equipment and instrumentation lists are available from each institute on request; the examples listed below serve as representative of Canada's polytechnic institutes, rather than an exhaustive list.

9.10.3.1 British Columbia Institute of Technology (BCIT) Centre for Applied Research & Innovation (CARI)

British Columbia Institute of Technology, Burnaby, BC

Classification: Onsite, Real, Product Oriented https://www.bcit.ca/applied-research/cari/

CARI is home to five applied research centres and ten research labs, which provide applied research expertise and training to students and industry professionals. In particular, the MAKE+ product development lab serves as a fully operating LF in which students can either work on their own projects using industry-certified technology, or work with industry professionals on multidisciplinary product development, under the supervision and support of BCIT's highly trained faculty. Their facilities include a full-scale fabrication lab, a motion capture lab with physiological monitoring capabilities, a textile fabrication lab, an electronics fabrication lab, and simulation facilities to evaluate prototypes and develop products.

Figure 57 *The Make+ fabrication lab at BCIT. Source : https://www.bcit.ca/applied-research/makeplus-product-development/labs/*

9.10.3.2 Humber Centres of Innovation (COI) Network

Humber College, Orangeville, ON

Classification: Onsite, Modular, Product and Service Oriented https://humber.ca/coi-network/

The COI Network combines five applied research centres across Humber College's three campuses into a modular LF environment that allows students to design and facilitate their own research projects or work in conjunction with faculty and industry experts on initiatives ranging from theoretical projects to industry product development. These research centres combine technology, business, and social innovation into a unified whole, granting both direct onsite experience through the Cyber-Physical Factory at the Barrett Centre for Technology Innovation and indirect business and social development to surround completed projects.

Figure 58: Student workers. Source: https://humber.ca/coi-network/

9.10.3.3 Barrett Centre for Technology Innovation (Barrett CTI)

Humber College, Toronto, Ontario https://humber.ca/barrett-centre-for-technology-innovation/

The Barrett CTI is the research centre at the heart of the Humber COI Network. Its Cyber-Physical Factory combines a FESTO Industry 4.0 Digital Factory with a Product Prototyping Facility in order to provide students with an integrated model that begins with digital prototyping and progresses through a modular Smart Factory system, used for both vocational education and applied research purposes. As of 2022, the Cyber-Physical Factory was the only infrastructure of its kind in a Canadian learning institution. Currently there are several institutions pursuing funding for this technology.

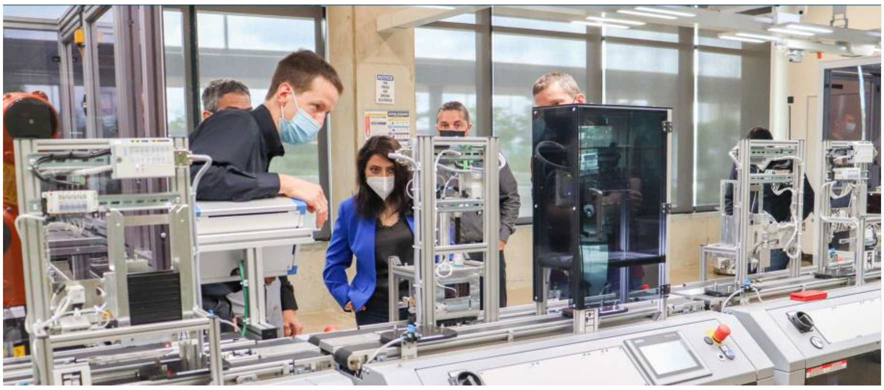


Figure 59 *Festo Industry 4.0 Digital Factory at Barrett CTI source: https://humber.ca/barrett-centre-for-technology-innovation/faculty.html*

9.10.3.4 Seneca Innovation

Seneca Polytechnic, Toronto, Ontario *https://www.senecacollege.ca/innovation.html*

Classification: Onsite, Real, Product Oriented

Seneca Innovation supports applied research, innovation, and entrepreneurship through five specialized centres of excellence. Its LF environments create industry-academic partnerships in physical and digital automation and life science development, based out of the Seneca Centre for Innovation, Technology and Entrepreneurship.

Figure 60 *Seneca students working on food crop growth project.*
Source : https://www.senecacollege.ca/news-and-events/seneca-news/seneca-partners-with-just-vertical-to-improve-harvestable-yields-in-non-ideal-growth-conditions.html

9.10.4 Technology Access Centres (TACs)

Tech-Access Canada, Ottawa ON

A Technology Access Centre (TAC) is an applied research and innovation centre, affiliated with a Canadian college or CEGEP, that provides companies – particularly small and medium-sized enterprises (SMEs) – with access to value-added R&D and innovation services to develop new prototypes, scale-up processes and solve unique business challenges while allowing their industry partners to retain full intellectual property rights. TACs provide a collective total of over 2,000 experts in applied research and business innovation to Canadian entrepreneurs. They deliver customized training for industry professionals to upgrade technical skills and de-risk the financial investment of implementing new equipment and adopting emerging technologies, as well as training and providing industry contacts for students attending the post-secondary institutions at which they are located. TACs are given their designation by the Natural Sciences and Engineering Research Council of Canada (NSERC), which also provides them with annual funding via multi-year Technology Access Centre Grants.

Canada's 60 TACs typically each operate as a community-scale LF; they do not have the full resources of a LF but operate under similar principles. These LFs are not primarily designed for vocational education; while every TAC compliments education at their associated institution, they primarily serve to exemplify practices to business, with most having limited applications for vocational training at this time. TACs organize through Tech-Access Canada, a national not-for-profit organization which helps its members to share information, connects potential clients and innovators to the network member best positioned to provide support, and serves as an advocacy group for the benefits the TAC network provides to Canadian industry.

The following are representative samples of Canada's TAC program. As with colleges and polytechnics, each TAC has a unique list of equipment and infrastructure which is available upon request.

9.10.4.1 Camosun Technology Access Centre (CTAC)

Camosun College, Victoria, BC

Classification: Onsite, Modular, Product Oriented

The Camosun Technology Access Centre (CTAC) supports students, faculty, and local industry through applied research projects and grants. With expertise in advanced manufacturing, composites engineering, rapid prototyping, digital scanning and productivity enhancement, CTAC helps companies adopt advanced manufacturing technologies and acts as a key link between the manufacturing sector and Camosun College's students and faculty. All of CTAC's advanced equipment is also used for student training, offering many their first non-curricular experience of applied research. Training focuses on activities, outcomes, and the underpinning of Camosun's intentional approach to developing relevant research skills. Faculty use CTAC facilities for curricular teaching activities, CTAC supports student capstone courses, students are employed as workers on a term-by-term basis, and recent graduates frequently transition from academic employment to regional job placement. (Camosun Innovates, 2023)

Figure 61 *Camosun Technology Access Centre. Source: https://camosun.ca/innovates*

9.10.4.2 Digital Integration Centre of Excellence (DICE)

Saskatchewan Polytechnic, Saskatoon, SK

Classification: Onsite, Modular, Service Oriented

DICE is a TAC focused on digital environments and data management. It focuses its efforts on data challenges facing partner organizations, particularly those related to data integrity, data transmission, and data analysis and storage. DICE operates in the specialties of asset management and monitoring, cybersecurity, the Internet of Things, time-sensitive networking, and mesh communication and control. Students and industry personnel have access to DICE's digital LF environment, in which they can experiment and develop digital applied research projects under controlled conditions, using cutting-edge industry-standard tools (Saskatchewan Polytechnic, 2023).

Figure 62 *AI and data approach aims to mobilize wealth.*
Source : https://saskpolytech.ca/news/posts/2020/ai-and-data-approach-aims-to-mobilize-wealth-of-knowledge-at-keyleaf.aspx

9.10.4.3 Lambton Manufacturing Innovation Centre (LMIC)

Lambton College, Sarnia, ON

Classification: Onsite, Modular, Product Oriented

LMIC is an innovation hub for regional advanced manufacturing with enhanced capabilities in additive printing and product/process/materials development. LMIC also provides offerings to address the significant industry training needs of regional and provincial manufacturing. Areas of research include automation and process optimization, additive and advanced manufacturing, circular economy manufacturing, automation and process optimization, product development and validation, product simulation, material testing and development, and digital technology adoption for manufacturing applications. LMIC's eight research and manufacturing labs serve as both industrial hubs for advanced research and development, and training facilities for students and industry professionals to train in a real-time manufacturing setting. Each lab is highly focused, allowing for manufacturing, processing, and testing in the fields of additive manufacturing, extrusion and industrial materials, prototyping and fabrication, advanced material testing, advanced material processing, nanotechnology, and instrumentation and control research (Lambton College, 2023).

Figure 63 *LMIC Prototyping and Fabrication Lab. Source: https://www.lmic.ca/facilities*

9.10.4.4 Northern Alberta Institute of Technology (NAIT) TACs

Northern Alberta Institute of Technology (NAIT), AB

Classification: Onsite, Modular, Product Oriented

The 3 TACs linked to the NAIT are listed below:

Technology Access Centre for Sensors and System Integration (TACSSI)

NAIT Productivity and Innovation Centre, Edmonton, AB, Canada,

NAIT operates several interlinked applied research centres, building subject matter expertise in particular research areas and focused on allied development goals, applied to complex industry-driven projects. With five general applied research centres and three Technology Access Centres, NAIT has a unique array of precision applied research knowledge in the fields of boreal forest management, culinary innovation, renewable and clean energies and technologies, innovative media, and sensors and systems integration. With access to multiple highly specialized research lab environments, NAIT can provide LF environments for a variety of precise research goals. By taking part in focused research activities with highly-trained industry professionals, students gain access to contextual learning in line with current industrial practices for a wide variety of local and regional industries (NAIT , 2023).

Figure 64 TACSSI students at work. Photographer: Sachin Pundir

- **Boreal Forest Plant & Seed Technology Access Centre (BFPS)**
- **Technology Access Centre for Oil Sands Sustainability (TACOSS)**

9.10.4.5 SEATAC

Classification: Onsite, Modular, Product Oriented

Placed at the Nova Scotia Community College, Dartmouth, Nova Scotia the SEATAC supports growth of the ocean economy by providing research services to local businesses that work in the ocean technology sector (NSCC - Nova Scotia Community College, 2023). SEATAC's research and development services include mechanical/electrical design-and-build with an emphasis on prototyping and advanced manufacturing support, and including product testing, data analytics and communication, and advanced coastal mapping services. Drawing on students and faculty from NSCC's fourteen campuses and two institutes across Nova Scotia, SEATAC provides access to conceptual design and advanced manufacturing training focused on the ocean economy, along with product testing and digital design services that allow students to train by developing their own prototypes and bringing them to life via onsite manufacturing facilities.

Figure 65 SEATAC. Source: https://www.nscc.ca/about/research-and-innovation/seatac.asp

9.10.4.6 Technology Access Centre for Aerospace & Manufacturing (TACAM)

Classification: Onsite, Real, Product Oriented

Placed in the Red River College, Winnipeg, Manitoba, the TACAM supports the aerospace and manufacturing sectors by providing access to technological assets, applied research expertise and specialized training. Applied research and development services are provided by a team of experts, faculty, and students working together in the fields of advanced manufacturing, digital design and simulation, composites, inspection, reverse engineering and prototyping. Equipment and expertise can also be used for technical and business services, supporting the manufacturing and aerospace industries directly as fee-for-service projects, and TACAM provides local SMEs and large industrial clients with access to Red River College Polytechnic for training, technology validation, and knowledge dissemination (Red River College, 2022).

Figure 66 *IMSC iFactory.*
Source: https://www.rrc.ca/ar/2021/06/25/reinventing-the-irrigation-system-wheel/

The RRC Polytechnic Smart Factory is a fully-equipped, realistic manufacturing environment dedicated to applied research, education, and knowledge transfer designed for industry 4.0 environments. It features collaborative robotics, robotic autonomous factory vehicles and end-of-arm tools, flexible robotic work cells, additive manufacturing of metals using direct energy, deposition with 5-axis milling capability, robotic high-speed laser 3d metrology, industrial manufacturing automation, industrial networking and data acquisition and control systems.

9.10.5 University Learning Factories

All but two of Canada's 97 public universities operate through a mixture of federal and provincial funding, tuition, and private fundraising. University applied research programs are often well-funded compared to direct vocational education, and several universities offer full-scale LF environments; most complete LFs in Canada are thus operated by public universities. Key examples include:

9.10.5.1 The Allfactory Aquaponics 4.0 LF

University of Alberta, Edmonton, AB

Classification: Onsite, Real, Product Oriented

The Allfactory revolves around the production systems focusing on vertical farming and sustainable, environmentally friendly Aquaponics 4.0 systems and processes. (University of Alberta, 2022). The target engineering systems provide effective designs, tools, and methods for the growth of various selected crops. Technologies such as digital twins, IoT networks, intelligent decision making, robotics, knowledge modelling (ontologies), and autonomous systems are at the core of this environment's development, testing, and validation, performed by professors, industry professionals, schoolteachers, graduate students, and groups of students alike. The Allfactory is the only Canadian member of the International Association of Learning Factories; its current director and founder, Dr. Rafiq Ahmad, is a board member of the International Society of Automation and a specialty editor in international journals and conferences.

Figure 67 *Robotics in agriculture. Source: https://allfactory.ca/research-in-vertical-farming/#3*

9.10.5.2 Composite Research Network (CRN) LF

University of British Columbia, Vancouver, BC

Classification: Onsite and Virtual, Real, Product Oriented

The CRN Learning Factory, (Univerity of British Columbia, 2022) trains students in the field of composites manufacturing by bringing together production, research, and education, exists to address an identified gap in composites manufacture and development. Under current conditions, composite manufacturing largely functions through the use of computer simulation in early stages, followed by physical manufacturing and iterative development, with a fully linked digitalization not currently possible. The CRN LF serves as both training and experiment, a scale-down and controlled environment capable of satisfying academic and industry needs in both the fields of research and production, while developing data which can be scaled up for industry partners and clients. The LF is a modular and reconfigurable space, capable of choosing from a wide array of sensors and data analysis to provide the information most necessary for each project. It is attached to a virtual facility, hosted at the UBC Vancouver campus, which combines received information and onsite simulators to understand and optimize the design and production of advanced aerospace composites structures, develop new AI simulation engines, and drive computer simulation research.

Figure 68 *CRN. Source : https://crn.ubc.ca/projects/composites-knowledge-network/*

9.10.5.3 Intelligent Manufacturing Systems (IMS) Centre iFactory Laboratory

University of Windsor, Windsor, ON

Classification: Onsite, Real, Product Oriented

Housed in the Centre for Engineering Innovation (CEI), the iFactory was the first fully reconfigurable assembly system in North America and the second in the world. Built to the latest standards in industrial automation and control, it contains robotic assembly and inspection stations, automated retrieval and storage systems, and material handling systems that can easily be changed into several configurations and layouts; its intelligent neighbour-aware control system does not require re-programming or set-up after re-configuration (Univerity of Wisdor, 2022).

The IMS Centre researches manufacturing services ranging from smart, cognitive, and digital manufacturing through to additive manufacturing and fabrication. Its objective and vision are "to pursue leading-edge research in the multidisciplinary field of manufacturing systems and related topics from products design to manufacturing and the complete product lifecycle."

Figure 69 *IMSC iFactory.*
Source: https://www.uwindsor.ca/intelligent-manufacturing-systems/299/ims-centre-laboratories

9.10.5.4 W Booth School of Engineering Practice and Technology LF

McMaster University, Hamilton, ON

Classification: Onsite, Real, Product Oriented

Located in the Engineering Technology Building at McMaster University, the W Booth School of Engineering Practice and Technology has developed a specialized LF centred on metal additive manufacturing, CNC machine tooling, 3D printing, injection moulding, laser cutting, electronics, marking and tracing information, assembly of mechanical and electronic components, and packaging and testing (McMaster University, 2022). The LF is designed as a series of manufacturing and post-processing stations, equipped with RFID readers that track students' process and provide data to assist with manufacturing. The result allows students to train with active industry technology and develop their innovation skills in a controlled environment.

Figure 70 *Student Ryan McMinn in front of manufacturing engineering equipment. Source : https://www.eng.mcmaster.ca/news/manufacturing-engineering-grad-shares-how-he-narrowed-down-his-path-career-he-loves/*

9.10.6 Conclusions

The nature of Canada's development of LFs is intrinsically tied to the nature of federal and provincial educational funding and oversight. While a few Canadian universities have successfully drawn on federal and provincial funding to create fully realized LFs, most LF-like environments in the country are piecemeal, providing factory-like modules, often specialized to particular industries or methodologies, within academic contexts serving both educational and production goals. These modular facilities, organized across regional and national networks, provide students and industry professionals with applied research environments in which to develop their skills and learn upcoming industry standards.

LCAMP

Learner Centric Advanced Manufacturing Platform

Co-funded by the European Union