THE EXCELLENT ADVANCED MANUFACTURING 4.0

ENGLISH

The Advanced Manufacturing 4.0 Framework

Advanced manufacturing 4.0 LABs

02

EXAM 4.0
THE EXCELLENT ADVANCED MANUFACTURING 4.0

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EXAM 4.0 partners:

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Abbreviations

AI	Artificial Intelligence
AM	Advanced Manufacturing
AR	Augmented Reality
CAD	Computer Aided Design
CAM	Computer Aided Manufacturing
CoVE	Centres of Vocational Excellence
CPS	Cyber-Physical systems
D	Deliverable
EQF	European Qualifications Framework
EXAM 4.0	Excellent Advanced Manufacturing 4.0
HVET	Higher Vocational Education and Training
I4.0	Industry 4.0
ICT	Information and communications technologies
IoT	Internet of Things
IIoT	Industrial Internet of Things
IT	Information Technology
KETs	Key Enabling Technologies
M2M	Machine to machine communication
OT	Operational Technology
RFID	Radio Frequency Identification
VET	Vocational Education and Training
VR	Virtual Reality
WP	Work Package

1 Abstract

Industry 4.0 sets new demands on workers, new technologies require innovative solutions, thus innovative workers who can adapt to the required adjustments and provide value to the Industrial sector. The new demands on workers do in turn generate new requirements on education. Institutions have a major impact on education, a great responsibility to ensure that the right educational approach is used. LABs or Learning Factories, thus learning environments, plays a key role in VET/HVET education and excellence. A model for describing existing and future LABs is created in this report. The model ensures that information regarding LABs in Europe can be gathered, evaluated, and compared. Collected information regarding LABs is relevant to see the status of VET/HVET centres in Europe but also for VET/HVET centres who want to cooperate, share excellence, equipment, and knowledge, with other VET/HVET centres.

2 Introduction

This report includes the final version of an EXAM 4.0 VET/HVET centre model for describing AM LABS. The model is divided into 9 + 1 sections and it concerns equipment, machines, ICT applications, learning methodologies, etc used in the LAB and information regarding training programmes with education in the LAB as well as the structure of the LAB, production, and products. The model is elaborated by the consortium partners and is based on Abele's model for describing Learning Factories. All LABs are not in fact Learning Factories, all Learning Factories can however be defined as LABs. The model, produced to describe Learning Factories, is therefore, in this report, developed to have the possibility to describe all LABs. Describing existing LABs is the first measure that needs to be taken to create excellence within VET/HVET education.

CATEGORIZE EXISTING & NEW LABS

Describing I4.0 educational LABs for VET is not an easy task, considering the European context of the EXAM 4.0 consortium. The realities for each country and even each partner's institutional model differ although the basics for the definition of the labs can be similar. Furthermore, the lack of a common standard for VET curriculums, levels, targets etc makes it even more difficult to establish a common definition of labs. In order to overcome these issues, we have adopted the morphology of learning factories defined by Abele et al as a common standard to describe our labs.

Abele et al faced the same issue when describing learning factories: Realistic learning environments are developed to educate students and existing employees in the manufacturing sector and school sector. There is no available structured framework to use when describing learning factories. Even though the methodology is comparable between learning factories there are differences between the design and orientation of the LABs (Abele et al., 2015b).

Abele et al. declares that the CIRP CWG and the project Network of Innovative Learning Factories (NIL) have established and confirmed the following description model due to the lack of characterization and standardized description models for learning factories. The description model can be used for both new and old learning factories, educational LABs (Abele et al., 2015b).

By using this standard, it would be possible to compare not only the LABs from the EXAM 4.0 partners but also other VET centre LABs. Furthermore, our Labs will be comparable to existing learning factories which make it easier to detect ways to improve and adapt our current configurations.

However, it is important to mention that not all the LABs described in EXAM 4.0 could be considered learning factories so far as they do not meet some of the essential characteristics of the Learning Factories, in some cases there is no actual product, in other cases they are not configured as a production line etc. However, regarding comparability, we will describe them using the same standard.

The description model consists of 59 features with individual elements, categorized in 7 groups (Abele et al., 2015b).

Operating model

This is the first table in the model for describing Learning Factories. It is used to describe the foundation of the Learning Factory, including aspects like the operator of the factory and the different funding methods.

1.1	Operator	academic institution			non-academic institution					profit-oriented operator	
		university	college	BA	vocational school / gymnasiet	chamber	union	employers´ association	industrial network	consulting	producing company
1.2	Trainer	professor	researcher	student assistant		technical expert /int. Specialist			consultant	educationalist	
1.3	Development	own development			external assisted development				external development		
1.4	Initial funding	internal funds			public funds				company funds		
1.5	Ongoing funding	internal funds			public funds				company funds		
1.6	Funding continuity	short term funding (e.g., single events)			midterm funding (projects and programmes < 3 years)				long term funding (projects and programmes > 3 years)		
1.7	Business model for trainings	open models			closed models (training programme only for single company)						
		club model	course fees								

Figure 1 Operating model (Abele et al., 2015b)

Purpose and targets

The second table is concerning the purposes of the Learning Factory, e.g., learning or research as well as the different targets it is used for.

2.1	**Main purpose**	education	vocational training	research												
2.2	**Secondary purpose**	test environment / pilot environment	industrial production	innovation transfer	advertisement for production											
2.3	**Target groups for education & training**	pupils	students			employees							entrepreneurs	freelancer	unemployed	open public
										managers						
			bachelor	master	phd students	apprentices	skilled workers	semi-skilled workers	unskilled	lower mgmt	middle mgmt	top mgmt				
2.4	**Group constellation**	homogeneous	heterogeneous (knowledge level, hierarchy, students + employees, etc.)													
2.5	**Targeted industries**	mechanical & plant eng.	automotive	logistics	transportation	FMCG	aerospace									
		chemical industry	electronics	construction	insurance / banking	textile industry	...									
2.6	**Subject-rel. learning contents**	prod. Mgmt & org.	resource efficiency	lean mgmt	automation	CPPS	work system design	HMI	design	Intralogistics design & mgmt	...					
2.7	**Role of LAB for research**	research object	research enabler													
2.8	**Research topics**	production management & organization	resource efficiency	lean mgmt	automation	CPPS	changeability	HMI	didactics	...						

Figure 2 Purpose and targets (Abele et al., 2015b)

Process

The third table is regarding the life cycle of different aspects of the Learning Factory, the functions of it as well as the production process.

<table>
<tr><td>3.1</td><td>Product life cycle</td><td>product planning</td><td>product development</td><td>product design</td><td>rapid prototyping</td><td>manufacturing</td><td colspan="2">assembly</td><td>logistics</td><td colspan="2">service</td><td>recycling</td></tr>
<tr><td>3.2</td><td>LAB life cycle</td><td>investment planning</td><td>factory concept</td><td>process planning</td><td>ramp-up</td><td>manufacturing</td><td colspan="2">assembly</td><td>logistics</td><td colspan="2">maintenance</td><td>recycling</td></tr>
<tr><td>3.3</td><td>Order life cycle</td><td>configuration & order</td><td>order sequencing</td><td colspan="2">production planning and scheduling</td><td>manufacturing</td><td colspan="2">assembly</td><td>logistics</td><td colspan="2">picking, packaging</td><td>shipping</td></tr>
<tr><td>3.4</td><td>Technology life cycle</td><td>planning</td><td>development</td><td colspan="2">virtual testing</td><td>manufacturing</td><td colspan="2">assembly</td><td>logistics</td><td colspan="2">maintenance</td><td>modernization</td></tr>
<tr><td>3.5</td><td>Indirect functions</td><td>SCM</td><td>sales</td><td colspan="2">purchasing</td><td>HR</td><td colspan="3">finance / controlling</td><td colspan="3">QM</td></tr>
<tr><td>3.6</td><td>Material flow</td><td colspan="4">continuous production</td><td colspan="7">discrete production</td></tr>
<tr><td>3.7</td><td>Process type</td><td colspan="2">mass production</td><td colspan="2">serial production</td><td colspan="5">small series production</td><td colspan="2">one-off production</td></tr>
<tr><td>3.8</td><td>Manufact. organization</td><td colspan="2">fixed-site manufacturing</td><td colspan="2">work bench manufacturing</td><td colspan="5">workshop manufacturing</td><td colspan="2">flow production</td></tr>
<tr><td>3.9</td><td>Degree of automation</td><td colspan="2">manual</td><td colspan="5">partly automated / hybrid automation</td><td colspan="4">fully automated</td></tr>
<tr><td>3.10</td><td>Manufact. Methods</td><td>cutting</td><td colspan="2">trad. primary shaping</td><td>additive manufact.</td><td colspan="2">forming</td><td>joining</td><td colspan="2">coating</td><td colspan="2">change material properties</td></tr>
<tr><td>3.11</td><td>Manufact. Technology</td><td colspan="3">physical</td><td colspan="4">chemical</td><td colspan="4">biological</td></tr>
</table>

Figure 3 Process (Abele et al., 2015b)

Setting

The fourth table concerns the different settings of the Learning Factory, e.g., how the factory is designed. Concerning size and changeability of it and to what extent it is a physical or virtual environment.

<table>
<tr><td>4.1</td><td>Learning environment</td><td>purely physical (planning + execution)</td><td colspan="2">physical supported by digital factory (see line “IT-Integration”)</td><td colspan="2">Physical, extended virtually</td><td>purely virtual (planning + execution)</td></tr>
<tr><td>4.2</td><td>Environment scale</td><td colspan="3">scaled down</td><td colspan="3">life-size</td></tr>
<tr><td>4.3</td><td>Work system levels</td><td>workplace</td><td colspan="2">work system</td><td colspan="2">factory</td><td>network</td></tr>
<tr><td>4.4</td><td>Enablers for changeability</td><td>mobility</td><td>modularity</td><td colspan="2">compatibility</td><td>scalability</td><td>universality</td></tr>
<tr><td>4.5</td><td>Changeability dimensions</td><td>layout & logistics</td><td>product features</td><td colspan="2">product design</td><td>technology</td><td>product quantities</td></tr>
<tr><td>4.6</td><td>IT-integration</td><td colspan="2">IT before SOP (CAD, CAM, simulation)</td><td colspan="2">IT after SOP (PPS, ERP, MES)</td><td colspan="2">IT after production (CRM, PLM…)</td></tr>
</table>

Figure 4 Setting (Abele et al., 2015b)

Product

The fourth table concerns the different settings of the Learning Factory, e.g., how the factory is designed. Concerning size and changeability of it and to what extent it is a physical or virtual environment.

5.1	**Materiality**	material (physical product)					immaterial (service)		
5.2	**Form of product**	general cargo				bulk goods		flow products	
5.3	**Product origin**	own development			development by participants			external development	
5.4	**Marketability of product**	available on the market			available on the market but didactically simplified			not available on the market	
5.5	**Functionality of product**	functional product			didactically adapted product with limited functionality			without function / application, for demonstration only	
5.6	**No. of different products**	1 product	2 products	3-4 products	> 4 products	flexible, developed by participants		acceptance of real orders	
5.7	**No. of variants**	1 variant	2-4 variants	4-20 variants	…	flexible, depending on participants		determined by real orders	
5.8	**No. of components**	1 comp.	2-5 comp.	6-20 comp.		21-50 comp.	51-100 comp.		> 100 comp.
5.9	**Further product use**	re-use / re-cycling		exhibition / display		give-away	sale		disposal

Figure 5 Product (Abele et al., 2015b)

Didactics

The sixth table includes questions regarding learning methods.

<table>
<tr><td>6.1</td><td>Competence classes</td><td colspan="2">technical and methodological competencies</td><td colspan="2">social & communication competencies</td><td colspan="2">personal competencies</td><td colspan="3">activity and implementation-oriented competencies</td></tr>
<tr><td>6.2</td><td>Dimensions learn. targets</td><td colspan="2">cognitive</td><td colspan="3">affective</td><td colspan="4">psycho-motorial</td></tr>
<tr><td>6.3</td><td>Learn. scenario strategy</td><td>instruction</td><td colspan="3">demonstration</td><td colspan="2">closed scenario</td><td colspan="3">open scenario</td></tr>
<tr><td>6.4</td><td>Type of learn. environment</td><td colspan="4">greenfield (development of factory environment)</td><td colspan="5">brownfield (improvement of existing factory environment)</td></tr>
<tr><td>6.5</td><td>Communication channel</td><td colspan="4">onsite learning (in the factory environment)</td><td colspan="5">remote connection (to the factory environment)</td></tr>
<tr><td>6.6</td><td>Degree of autonomy</td><td colspan="2">instructed</td><td colspan="3">self-guided / self-regulated</td><td colspan="4">self-determined/ Self organized</td></tr>
<tr><td>6.7</td><td>Role of the trainer</td><td>presenter</td><td colspan="2">moderator</td><td colspan="3">coach</td><td colspan="3">instructor</td></tr>
<tr><td>6.8</td><td>Type of training</td><td>tutorial</td><td colspan="2">practical lab course</td><td colspan="2">seminar</td><td colspan="2">workshop</td><td colspan="2">project work</td></tr>
<tr><td>6.9</td><td>Standardization of trainings</td><td colspan="4">standardized trainings</td><td colspan="5">customized trainings</td></tr>
<tr><td>6.10</td><td>Theoretical foundation</td><td>prerequisite</td><td colspan="2">in advance (in bloc)</td><td colspan="2">alternating with practical parts</td><td colspan="2">based on demand</td><td colspan="2">afterwards</td></tr>
<tr><td>6.11</td><td>Evaluation levels</td><td>feedback of participants</td><td colspan="2">learning of participants</td><td colspan="2">transfer to the real factory</td><td colspan="2">economic impact of trainings</td><td colspan="2">return on trainings / ROI</td></tr>
<tr><td>6.12</td><td>Learning success evaluation</td><td>knowledge test (written)</td><td colspan="2">knowledge test (oral)</td><td>written report</td><td colspan="2">oral presentation</td><td colspan="2">practical exam</td><td>none</td></tr>
</table>

Figure 6 Didactics (Abele et al., 2015b)

Metrics

The last table shows the variety of learners that can train in the Learning Factory simultaneously.

7.1	**No. of participants per training**	1-5 participants	5-10 participants	10-15 participants	15-30 participants	30> participants	
7.2	**No. of standardized trainings**	1 training	2-4 trainings	5-10 trainings		> 10 trainings	
7.3	**Aver. duration of a single training**	≤ 1 day	> 1 day until ≤ 2 days	> 2 days until ≤ 5 days	> 5 days until ≤ 10 days	> 10 days until ≤ 20 days	> 20 days
7.4	**Participants per year**	< 50 participants	50-200 participants	201-500 participants	501-1000 participants	> 1000 participants	
7.5	**Capacity utilization**	< 10%	> 10 until ≤ 20%	> 20%until ≤ 50%	> 50%until ≤ 75%	> 75%	
7.6	**Size of LAB**	≤ 100 sqm	> 100 sqm bis ≤ 300 sqm	> 300sqm bis ≤ 500 sqm	>500 sqm bis ≤ 1000 sqm	> 1000 sqm	
7.7	**FTE in LAB**	< 1	2-4	5-9	10-15	> 15	

Figure 7 Metrics (Abele et al., 2015b)

LEARNING FACTORIES

It makes sense to adapt the Learning factories approach when it comes to create the EXAM 4.0 Advanced Manufacturing labs for VET definition. There are many statements that support that decision:

Industry 4.0 is occurring right now, industries are therefore working towards the revolution and creating smart factories. Adapting to industry 4.0 processes requires a totally new diverse collection of skills for engineers and other personnel participating (Karukapadath and Parekattil 2019).

Industry 4.0 causes the assignments for workers to be more difficult, from both an organizational and technological perspective. Workers training and qualification needs to be adapted to the new requirements, is the only way to make it a possibility for companies to transform towards Industry 4.0 (Gewerbliche Schule Crailsheim n.d).

Learning factory initiatives have received significantly more awareness the last few years, from local to European and finally to a worldwide degree (Abele 2015a).

Learning factories, LABs, are designed for educational functions such as research, manufacturing, service operations etc (Karukapadath and Parekattil 2019).

Learning factories can be identified as educational facilities which emulate activities in a real industry or factory (Karukapadath and Parekattil 2019).

Learning factories are networked systems that map digital networked production processes with high flexibility for career training and further education. At vocational schools, the primary purpose for learning factories is to prepare specialists and young professionals for the requirements of Industry 4.0. This is accomplished by introducing trainers and participants to further educational courses, regarding operation of systems, these systems are based on real industry standards (Wirtschaft digital Baden-Württemberg 2020).

A “Learning factory 4.0” in the context of schools is a factory model based on the requirements of Industry 4.0. The factory models are commissioning and implementing industrial automation processes for education. The applications related to these processes, mechanical and electrical engineering, are digitally linked with intelligent production and production control systems (Gewerbliche Schule Crailsheim n.d).

A learning factory 4.0 is a laboratory which contains similar structure and equipment as an industrial automation environment where the basics of application-oriented processes can be educated. The learning factories' purpose is to prepare specialists and students for the new requirements of the digitalization (Ministerium für Wirtschaft, Arbeit und Wohnungsbau Baden-Württemberg 2019).

As a summary of Learning factories:

A Learning factory is an environment with educational purpose, it is realistic compared to a real industrial factory and it offers admittance to production processes and conditions, which empower problem and action-oriented learning (Kreimeier, Dieter 2016).

A Learning factory could be explained as an education environment specified by processes. It is a model that resembles an actual value chain, a definite production of a product intertwined with a didactical concept (Abele, Metternich, and Tisch 2019).

Aforementioned information regarding Learning Factories shows that the Learning factories approach fits perfectly with the goals of EXAM 4.0 as a standard to follow.

PROS AND CONS REGARDING LEARNING FACTORIES

Pros of Learning factories as an educational method:

- It is a definitive method for educating I4.0 technologies.
- Learning factories are using realistic problem situations.
- Learning factories include hands-on learning.
- If creating a virtual learning factory, it is possible to map larger factory structures.
- Most Learning factories do produce products because they simulate a real value chain, this could result in income when selling these products.
- It is possible to merge classes because a Learning Factories will replicate a real production environment. Classes can, in this way, work with different assignments but towards the same production goal.
- Same quality requirements as in real production.

Cons of Learning factories as an educational method:

- A Learning factory simulates real industry production, the industry is evolving at a high pace, the learning factories will therefore be outdated quickly. It is therefore a heavy work to maintain a Learning factory.
- It is difficult and time-consuming to map entire factories or networks to create a Learning factory.
- There is a lack of mobility in learning factories since the production relies on certain machines.

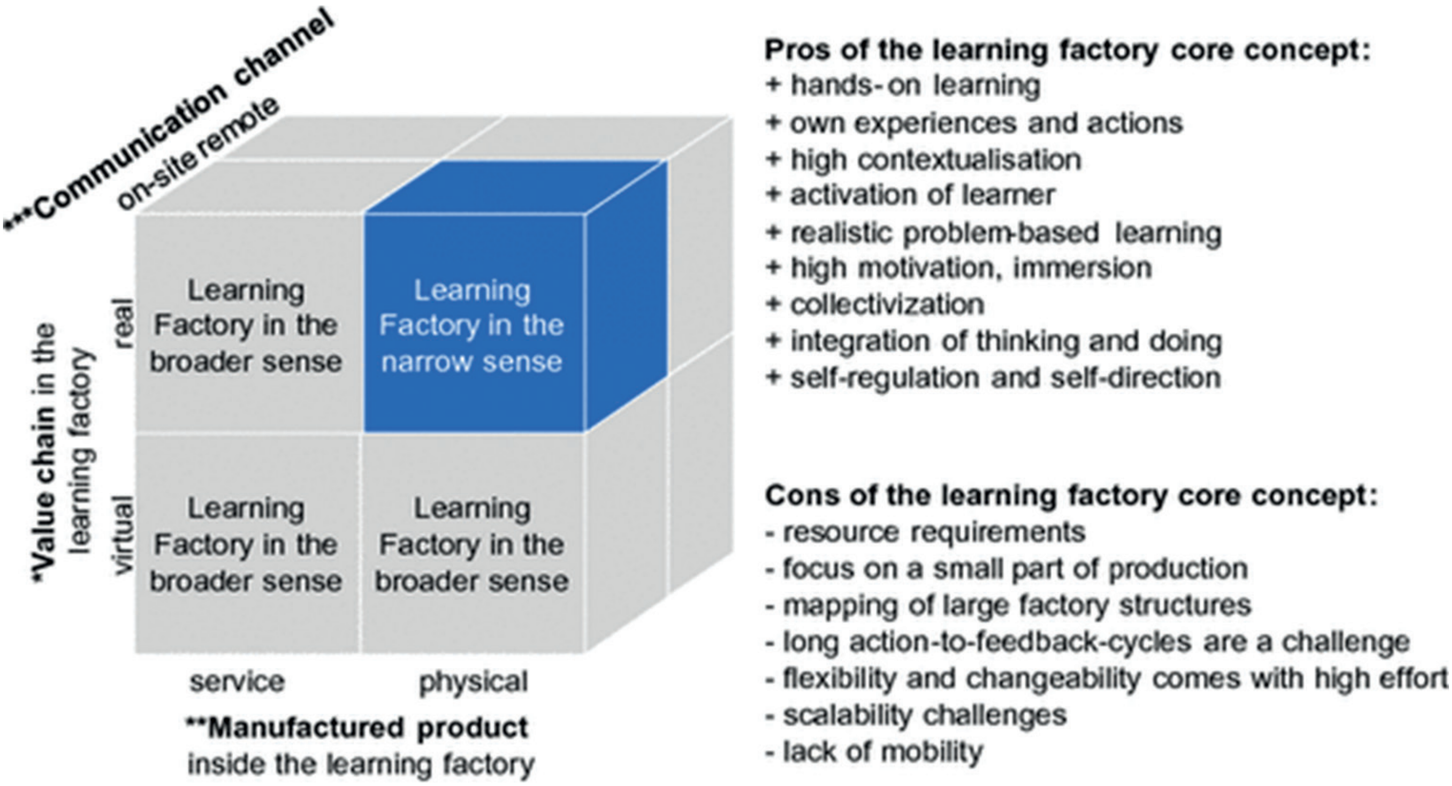

Figure 8 *Advantages and disadvantages of the learning factory core concept* (Abele, Metternich, and Tisch 2019)

EXAM 4.0 VET/HVET CENTRE MODEL FOR AM LABS

Introduction

This model is elaborated, by partners of the consortium with support from companies and associated partners and Abele’s et al. model for describing learning factories (Abele et al., 2015b), to describe existing and future AM LABs 4.0 and their characteristics.

The model has been developed to create a common structure for descriptions of AM LABs. The description model includes aspects of the LABs such as physical characteristics, equipment, ICT applications, I4.0 technologies, methodologies, learning strategies, etc. The description model is based on the description model for learning factories created in the report Learning Factory Morphology – Study Of Form And Structure Of An Innovative Learning Approach In The Manufacturing Domain written by Abele, Hummel, Metternich, Ranz and Tisch.

Partners, organisations, and institutions can take advantage of the descriptions of AM LABs 4.0 by evaluating and comparing information regarding different LABs.

In the following sections, a detailed description of several reference LABs is shown. All the LABs are described with the following structure:

The first section – General description, the summary table

The summary table below is established to present general information about a specific learning environment, AM 4.0 LAB. Further information about the AM LABs 4.0 in question, will be described additionally by the model of questions and tables in the subsequent section.

GENERAL INFORMATION	Name of the LAB	_						MAIN PURPOSE		
	VET/HVET centre	_						Education		_
	Floor space of the lab (sqm)	_						Training		_
	Main topic/learning content	_						Research/Applied innovation		_
	I4.0 related technologies	_								
PURPOSE	Learning content	_								
	Secondary purpose	_								
	LAB type	Specific			Mixed			Learning Factory		
LEARNING CONTENTS	Learning programmes/study programmes/levels	Name of the programmes carried out on the Lab				EQF Level	Lab hours	Nº subjects on the lab	Hour/Week x nº of weeks	Nº students (3)
		_				_	_	_	_ x _	_
		_				_	_	_	_ x _	_
		_				_	_	_	_ x _	_
		_				_	_	_	_ x _	_
		_				_	_	_	_ x _	_
		_				_	_	_	_ x _	_
SETTINGS	Nº of cell	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5	Cell 6	Cell 7	Cell 8	Cell 9
	Category of cell	_	_	_	_	_	_	_	_	_
	Nº machines	_	_	_	_	_	_	_	_	_
	I4.0 Enabler technologies used and implementation level	Robotics	Additive Manufacturing	Cloud	CPS	Mobile/Tablet	AR/VR	Big data analytics	Ai	IoT/IIoT
		Sensors/Actuators	RFID	M2M	Cybersecurity	Digital twin				

Specific lab: A lab designed and set up to teach/learn a specific technology. For example, Additive manufacturing LABs, Robotics LABs, IoT LABs (didactic LABs by Festo, SMC and others) etc.

Mixed lab: The main purpose of the lab is not a (I4.0) specific technology but those technologies are implemented to complement the main activity. It could be: Machining LABs with retrofitted machines with sensors and data acquisition systems included, metal forming LABs where cobots/robots are implemented etc

Learning Factory: A LF is an educational environment representing a real production manufacturing real product.

Study programmes: The learning activities carried out in the LABs are usually a part of a wider programme. The name of the programme and its EQF level is marked. The hours refer to the hours spent on activities in the lab.

The number of subjects refers to the different subjects or areas that could be covered by a group in the lab. They can be considered as the number of separate training activities.

Nº of students and groups per week in the lab. 3x20 means 3 groups of 20 students each. This is the max number of students/groups that can be working simultaneously in the LABs.

Cell/area: Part of the lab that groups a number of machines. Cells can be divided in 2 types:

a) Cells with machines with similar characteristics.

b) Cells with a sequenced number of machines where consecutive operations are carried out.

Usage level: Fully implemented | Implemented to certain degree | Planned to implement | Not implemented

The second section – detailed description

The tables in the model below are elaborated by the EXAM 4.0 partners, the model is a slightly transformed version of the model for describing learning factories from Abele's et al. (Abele et al., 2015b). These tables will be used to describe learning environments, AM LABs. All AM LABs are not Learning factories, the tables are therefore beneficially adapted to fit the model for describing LABs as a part of EXAM 4.0. The majority of AM LABs are however sub-sets or scale-downs of learning factories, thus the reason for the usage of these tables.

The green colour in the box underneath will be used to colour the windows in the tables below regarding the characteristics of the AM LAB 4.0 in question. The red colour can be used if an answer is relevant to a certain degree

OPERATIONAL MODEL

<table>
<tr><td rowspan="2">1.1</td><td rowspan="2">Operator</td><td colspan="4">academic institution</td><td colspan="7">non-academic institution</td><td colspan="2">profit-oriented operator</td></tr>
<tr><td>university</td><td colspan="2">college</td><td>BA</td><td colspan="3">vocational school / gymnasiet</td><td>chamber</td><td>union</td><td>employers´ association</td><td>industrial network</td><td>consulting</td><td>producing company</td></tr>
<tr><td>1.2</td><td>Trainer</td><td>professor</td><td colspan="2">researcher</td><td colspan="4">student assistant</td><td colspan="3">technical expert /int. Specialist</td><td>consultant</td><td colspan="2">educationalist</td></tr>
<tr><td>1.3</td><td>Development</td><td colspan="5">own development</td><td colspan="5">external assisted development</td><td colspan="3">external development</td></tr>
<tr><td>1.4</td><td>Initial funding</td><td colspan="5">internal funds</td><td colspan="5">public funds</td><td colspan="3">company funds</td></tr>
<tr><td>1.5</td><td>Ongoing funding</td><td colspan="5">internal funds</td><td colspan="5">public funds</td><td colspan="3">company funds</td></tr>
<tr><td>1.6</td><td>Funding continuity</td><td colspan="5">short term funding (e.g., single events)</td><td colspan="5">midterm funding (projects and programmes < 3 years)</td><td colspan="3">long term funding (projects and programmes > 3 years)</td></tr>
<tr><td rowspan="2">1.7</td><td rowspan="2">Business model for trainings</td><td colspan="6">open models</td><td colspan="7" rowspan="2">closed models (training programme only for single company)</td></tr>
<tr><td colspan="2">club model</td><td colspan="4">course fees</td></tr>
</table>

Description of funding methods:

PURPOSE AND TARGETS

2.1	**Main purpose**	education	vocational training	research												
2.2	**Secondary purpose**	test environment / pilot environment	industrial production	innovation transfer	advertisement for production											
2.3	**Target groups for education & training**	pupils	students			employees							entrepreneurs	freelancer	unemployed	open public
										managers						
			bachelor	master	phd students	apprentices	skilled workers	semi-skilled workers	unskilled	lower mgmt	middle mgmt	top mgmt				
2.4	**Group constellation**	homogeneous	heterogeneous (knowledge level, hierarchy, students + employees, etc.)													
2.5	**Targeted industries**	mechanical & plant eng.	automotive	logistics	transportation	FMCG	aerospace									
		chemical industry	electronics	construction	insurance / banking	textile industry	...									
2.6	**Subject-rel. learning contents**	prod. Mgmt & org.	resource efficiency	lean mgmt	automation	CPPS	work system design	HMI	design	Intralogistics design & mgmt	...					
2.7	**Role of LAB for research**	research object	research enabler													
2.8	**Research topics**	production management & organization	resource efficiency	lean mgmt	automation	CPPS	changeability	HMI	didactics	...						

Study programmes and the EQF level of each programme related to the LAB:

Description of the relation between each study programme and the LAB:

PROCESS

<table>
<tr><td>3.1</td><td>Product life cycle</td><td>product planning</td><td>product development</td><td>product design</td><td>rapid prototyping</td><td>manufacturing</td><td colspan="2">assembly</td><td>logistics</td><td colspan="2">service</td><td>recycling</td></tr>
<tr><td>3.2</td><td>LAB life cycle</td><td>investment planning</td><td>factory concept</td><td>process planning</td><td>ramp-up</td><td>manufacturing</td><td colspan="2">assembly</td><td>logistics</td><td colspan="2">maintenance</td><td>recycling</td></tr>
<tr><td>3.3</td><td>Order life cycle</td><td>configuration & order</td><td>order sequencing</td><td colspan="2">production planning and scheduling</td><td>manufacturing</td><td colspan="2">assembly</td><td>logistics</td><td colspan="2">picking, packaging</td><td>shipping</td></tr>
<tr><td>3.4</td><td>Technology life cycle</td><td>planning</td><td>development</td><td colspan="2">virtual testing</td><td>manufacturing</td><td colspan="2">assembly</td><td>logistics</td><td colspan="2">maintenance</td><td>modernization</td></tr>
<tr><td>3.5</td><td>Indirect functions</td><td>SCM</td><td>sales</td><td colspan="2">purchasing</td><td>HR</td><td colspan="3">finance / controlling</td><td colspan="3">QM</td></tr>
<tr><td>3.6</td><td>Material flow</td><td colspan="4">continuous production</td><td colspan="7">discrete production</td></tr>
<tr><td>3.7</td><td>Process type</td><td colspan="2">mass production</td><td colspan="2">serial production</td><td colspan="5">small series production</td><td colspan="2">one-off production</td></tr>
<tr><td>3.8</td><td>Manufact. organization</td><td colspan="2">fixed-site manufacturing</td><td colspan="2">work bench manufacturing</td><td colspan="5">workshop manufacturing</td><td colspan="2">flow production</td></tr>
<tr><td>3.9</td><td>Degree of automation</td><td colspan="2">manual</td><td colspan="5">partly automated / hybrid automation</td><td colspan="4">fully automated</td></tr>
<tr><td>3.10</td><td>Manufact. Methods</td><td>cutting</td><td colspan="2">trad. primary shaping</td><td>additive manufact.</td><td colspan="2">forming</td><td>joining</td><td colspan="2">coating</td><td colspan="2">change material properties</td></tr>
<tr><td>3.11</td><td>Manufact. Technology</td><td colspan="3">physical</td><td colspan="4">chemical</td><td colspan="4">biological</td></tr>
</table>

Specific equipment used in the LAB:

SETTING

<table>
<tr><td>4.1</td><td>Learning environment</td><td>purely physical (planning + execution)</td><td colspan="2">physical supported by digital factory (see line “IT-Integration”)</td><td colspan="2">Physical, extended virtually</td><td>purely virtual (planning + execution)</td></tr>
<tr><td>4.2</td><td>Environment scale</td><td colspan="3">scaled down</td><td colspan="3">life-size</td></tr>
<tr><td>4.3</td><td>Work system levels</td><td>workplace</td><td colspan="2">work system</td><td colspan="2">factory</td><td>network</td></tr>
<tr><td>4.4</td><td>Enablers for changeability</td><td>mobility</td><td>modularity</td><td colspan="2">compatibility</td><td>scalability</td><td>universality</td></tr>
<tr><td>4.5</td><td>Changeability dimensions</td><td>layout & logistics</td><td>product features</td><td colspan="2">product design</td><td>technology</td><td>product quantities</td></tr>
<tr><td>4.6</td><td>IT-integration</td><td colspan="2">IT before SOP (CAD, CAM, simulation)</td><td colspan="2">IT after SOP (PPS, ERP, MES)</td><td colspan="2">IT after production (CRM, PLM…)</td></tr>
</table>

For what purpose are different IT-integrations used:

PRODUCT

<table>
<tr><td>5.1</td><td>Materiality</td><td colspan="5">material (physical product)</td><td colspan="3">immaterial (service)</td></tr>
<tr><td>5.2</td><td>Form of product</td><td colspan="4">general cargo</td><td colspan="2">bulk goods</td><td colspan="2">flow products</td></tr>
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<tr><td>5.5</td><td>Functionality of product</td><td colspan="3">functional product</td><td colspan="3">didactically adapted product with limited functionality</td><td colspan="2">without function / application, for demonstration only</td></tr>
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<tr><td>5.7</td><td>No. of variants</td><td>1 variant</td><td>2-4 variants</td><td>4-20 variants</td><td>…</td><td colspan="2">flexible, depending on participants</td><td colspan="2">determined by real orders</td></tr>
<tr><td>5.8</td><td>No. of components</td><td>1 comp.</td><td>2-5 comp.</td><td colspan="2">6-20 comp.</td><td>21-50 comp.</td><td colspan="2">51-100 comp.</td><td>> 100 comp.</td></tr>
<tr><td>5.9</td><td>Further product use</td><td colspan="2">re-use / re-cycling</td><td colspan="2">exhibition / display</td><td>give-away</td><td colspan="2">sale</td><td>disposal</td></tr>
</table>

Further description of the products manufactured in the LAB:

DIDACTICS

<table>
<tr><td>6.1</td><td>Competence classes</td><td colspan="2">technical and methodological competencies</td><td colspan="2">social & communication competencies</td><td colspan="2">personal competencies</td><td colspan="3">activity and implementation-oriented competencies</td></tr>
<tr><td>6.2</td><td>Dimensions learn. targets</td><td colspan="2">cognitive</td><td colspan="3">affective</td><td colspan="4">psycho-motorial</td></tr>
<tr><td>6.3</td><td>Learn. scenario strategy</td><td>instruction</td><td colspan="3">demonstration</td><td colspan="2">closed scenario</td><td colspan="3">open scenario</td></tr>
<tr><td>6.4</td><td>Type of learn. environment</td><td colspan="4">greenfield (development of factory environment)</td><td colspan="5">brownfield (improvement of existing factory environment)</td></tr>
<tr><td>6.5</td><td>Communication channel</td><td colspan="4">onsite learning (in the factory environment)</td><td colspan="5">remote connection (to the factory environment)</td></tr>
<tr><td>6.6</td><td>Degree of autonomy</td><td colspan="2">instructed</td><td colspan="3">self-guided / self-regulated</td><td colspan="4">self-determined/ Self organized</td></tr>
<tr><td>6.7</td><td>Role of the trainer</td><td>presenter</td><td colspan="2">moderator</td><td colspan="3">coach</td><td colspan="3">instructor</td></tr>
<tr><td>6.8</td><td>Type of training</td><td>tutorial</td><td colspan="2">practical lab course</td><td colspan="2">seminar</td><td colspan="2">workshop</td><td colspan="2">project work</td></tr>
<tr><td>6.9</td><td>Standardization of trainings</td><td colspan="4">standardized trainings</td><td colspan="5">customized trainings</td></tr>
<tr><td>6.10</td><td>Theoretical foundation</td><td>prerequisite</td><td colspan="2">in advance (in bloc)</td><td colspan="2">alternating with practical parts</td><td colspan="2">based on demand</td><td colspan="2">afterwards</td></tr>
<tr><td>6.11</td><td>Evaluation levels</td><td>feedback of participants</td><td colspan="2">learning of participants</td><td colspan="2">transfer to the real factory</td><td colspan="2">economic impact of trainings</td><td colspan="2">return on trainings / ROI</td></tr>
<tr><td>6.12</td><td>Learning success evaluation</td><td>knowledge test (written)</td><td colspan="2">knowledge test (oral)</td><td>written report</td><td colspan="2">oral presentation</td><td colspan="2">practical exam</td><td>none</td></tr>
</table>

Specific competencies trained in the lab/trained with the technologies in the LAB:

Skills trained in the lab/trained with the technologies in the LAB:

Curriculum used:

METRICS

7.1	**No. of participants per training**	1-5 participants	5-10 participants	10-15 participants	15-30 participants	30> participants	
7.2	**No. of standardized trainings**	1 training	2-4 trainings	5-10 trainings		> 10 trainings	
7.3	**Aver. duration of a single training**	≤ 1 day	> 1 day until ≤ 2 days	> 2 days until ≤ 5 days	> 5 days until ≤ 10 days	> 10 days until ≤ 20 days	> 20 days
7.4	**Participants per year**	< 50 participants	50-200 participants	201-500 participants	501-1000 participants	> 1000 participants	
7.5	**Capacity utilization**	< 10%	> 10 until ≤ 20%	> 20%until ≤ 50%	> 50%until ≤ 75%	> 75%	
7.6	**Size of LAB**	≤ 100 sqm	> 100 sqm bis ≤ 300 sqm	> 300sqm bis ≤ 500 sqm	>500 sqm bis ≤ 1000 sqm	> 1000 sqm	
7.7	**FTE in LAB**	< 1	2-4	5-9	10-15	> 15	

FURTHER INFORMATION & ASPECTS TO IMPROVE

8.1	**Further information**	photographs	video
8.2	**Aspect to improve**	technical	methodological

CONCLUSION

The description of LABs is an excellent approach to use in order to get an understanding of VET/HVET-centres' LABs. It is possible to comprehensively describe and display LABs with this model in a non-time-consuming way. This model is perhaps of even greater use in today's times, when traveling is forbidden, making it easy to store information regarding LABs and evaluating these to get new perspectives and learning outcomes. This model will be used on the upcoming EXAM 4.0 platform, resulting in a large collection of described LABs, thus can this model be used to get an overview of the status of LABs in Europe. The model is, as aforementioned, based on a model for describing Learning Factories, but adapted to fit the targets of EXAM 4.0. The EXAM 4.0 model is therefore useful in order to describe both regular LABs and Learning Factories. The information regarding all LABs will be evaluated in order to define the structure of the ultimate EXAM 4.0 LAB for VET/HVET education in Europe. The model can help to see industrial educational trends at VET/HVET level in Europe and see if there are any measures that must be taken.

DESCRIPTION OF EXISTING LABS - EXAM 4.0 PARTNERS' LABS

Curt Nicolin Gymnasiet – Sweden

- **Name of the lab:**

  Curt Nicolin Gymnasiet Workshop

- **General aim/purpose (short summary):**

  Industry related education, focused on industrial demands from companies in our region.

- **Year of inauguration:**

  2014

- **LAB size (square metres):**

  1150

The first section – General description, the summary table

The summary table below is established to present general information about a specific learning environment, AM 4.0 LAB. Further information about the AM LABs 4.0 in question, will be described additionally by the model of questions and tables in the subsequent section.

GENERAL INFORMATION	Name of the LAB	**Curt Nicolin Gymnasiet Workshop**	MAIN PURPOSE	
	VET/HVET centre	Curt Nicolin Gymnasiet	Education	X
	Floor space of the lab (sqm)	1150	Training	X
	Main topic/learning content	Machining, CNC machining, robotics, Additive Manufacturing, Welding	Research/Applied innovation	_
	I4.0 related technologies	Additive Manufacturing, Cloud Computing, Mobile technologies, Robotics, M2M, Mobile, Sensors/Actuators, RFID		

PURPOSE	Learning content	Machine learning such as CNC machining, Additive Manufacturing, conventional lathe/milling		
	Secondary purpose	Production management, Safety, Smart maintenance, Lean Production		
	LAB type	Specific	Mixed	Learning Factory

		Name of the programmes carried out on the Lab	EQF Level	Lab hours	Nº subjects on the lab	Hour/Week x nº of weeks	Nº students (3)
LEARNING CONTENTS	Learning programmes/study programmes/levels	Service and Maintenance Technology	4	400	4	11x35	36
		Product and Machinery	4	400	4	11x35	22
		Welding technique	4	400	4	11x35	25
		Electricity and Energy Programme	4	300	3	9x35	48
		Technical Production	4	150	2	4x35	39
		TE4 Technical Production (engineering) / TE4 Design and Product Development (engineering)	5	100	1	3x35	15

SETTINGS	Nº of cell	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5	Cell 6	Cell 7	Cell 8	Cell 9
	Category of cell	Electrical assembly	Lathes & Mills	CNC	Additive Manufacturing	Robotics	Welding	Measuring Machine	Water Cutting Machine	VR/AR
	Nº machines	16	11	7	5	4	11	1	1	10
	I4.0 Enabler technologies used and implementation level	Robotics	Additive Manufacturing	Cloud	CPS	Mobile/Tablet	AR/VR	Big data analytics	Ai	IoT/IIoT
		Sensors/Actuators	RFID	M2M	Cybersecurity	Digital twin				

Specific lab: A lab designed and set up to teach/learn a specific technology. For example, Additive manufacturing LABs, Robotics LABs, IoT LABs (didactic LABs by Festo, SMC and others) etc.

Mixed lab: The main purpose of the lab is not a (I4.0) specific technology but those technologies are implemented to complement the main activity. It could be: Machining LABs with retrofitted machines with sensors and data acquisition systems included, metal forming LABs where cobots/robots are implemented etc

Learning Factory: A LF is an educational environment representing a real production manufacturing real product.

Study programmes: The learning activities carried out in the LABs are usually a part of a wider programme. The name of the programme and its EQF level is marked. The hours are referred to the hours spent on activities in the lab.

The number of subjects is referred to the different subjects or areas that could be covered by a group in the lab. They can be considered as the number of separate training activities.

Nº of students and groups per week in the lab. 3x20 means 3 groups of 20 students each. This is the max number of students/groups that can be working simultaneously in the LABs.

Cell/area: Part of the lab that groups a number of machines. Cells can be divided in 2 types:

a) Cells with machines with similar characteristics.

b) Cells with a sequenced number of machines where consecutive operations are carried out.

Usage level: Fully implemented | Implemented to certain degree | Planned to implement | Not implemented

The second section – detailed description

OPERATIONAL MODEL

<table>
<tr><td rowspan="2">1.1</td><td rowspan="2">Operator</td><td colspan="4">academic institution</td><td colspan="7">non-academic institution</td><td colspan="2">profit-oriented operator</td></tr>
<tr><td>university</td><td colspan="2">college</td><td>BA</td><td colspan="3">vocational school / gymnasiet</td><td>chamber</td><td>union</td><td>employers´ association</td><td>industrial network</td><td>consulting</td><td>producing company</td></tr>
<tr><td>1.2</td><td>Trainer</td><td>professor</td><td colspan="2">researcher</td><td colspan="4">student assistant</td><td colspan="3">technical expert /int. Specialist</td><td>consultant</td><td colspan="2">educationalist</td></tr>
<tr><td>1.3</td><td>Development</td><td colspan="5">own development</td><td colspan="5">external assisted development</td><td colspan="3">external development</td></tr>
<tr><td>1.4</td><td>Initial funding</td><td colspan="5">internal funds</td><td colspan="5">public funds</td><td colspan="3">company funds</td></tr>
<tr><td>1.5</td><td>Ongoing funding</td><td colspan="5">internal funds</td><td colspan="5">public funds</td><td colspan="3">company funds</td></tr>
<tr><td>1.6</td><td>Funding continuity</td><td colspan="5">short term funding (e.g., single events)</td><td colspan="5">midterm funding (projects and programmes < 3 years)</td><td colspan="3">long term funding (projects and programmes > 3 years)</td></tr>
<tr><td rowspan="2">1.7</td><td rowspan="2">Business model for trainings</td><td colspan="6">open models</td><td colspan="7" rowspan="2">closed models (training programme only for single company)</td></tr>
<tr><td colspan="2">club model</td><td colspan="4">course fees</td></tr>
</table>

Description of funding methods:

Curt Nicolin Gymnasiet is a non-profit, free school from Sweden, which in this case means that the regional government owns 49 % of the stake shares and the regional industrial companies owns 51 %. This means that Curt Nicolin Gymnasiet gets funding from both the government and the companies. The government owns as aforementioned only 49 % of the stake shares which means that Curt Nicolin Gymnasiet, unlike many other Swedish schools, can participate in income-generating events, projects, and programmes.

PURPOSE AND TARGETS

2.1	Main purpose	education	vocational training	research								
2.2	Secondary purpose	test environment / pilot environment	industrial production	innovation transfer	advertisement for production							
2.3	Target groups for education & training	pupils	students	employees	entrepreneurs	freelancer	unemployed	open public				
			bachelor	master	phd students	apprentices	skilled workers	semi-skilled workers	unskilled	managers		
										lower mgmt	middle mgmt	top mgmt
2.4	Group constellation	homogeneous	heterogeneous (knowledge level, hierarchy, students + employees, etc.)									
2.5	Targeted industries	mechanical & plant eng.	automotive	logistics	transportation	FMCG	aerospace					
		chemical industry	electronics	construction	insurance / banking	textile industry	...					
2.6	Subject-rel. learning contents	prod. Mgmt & org.	resource efficiency	lean mgmt	automation	CPPS	work system design	HMI	design	Intralogistics design & mgmt	...	
2.7	Role of LAB for research	research object	research enabler									
2.8	Research topics	production management & organization	resource efficiency	lean mgmt	automation	CPPS	changeability	HMI	didactics	...		

Study programmes and the EQF level of each programme related to the LAB:

Service and Maintenance Technology, Product and Machinery, Welding technique all are subsets of the study programme called Industrial technical programme, the ECF level of these programmes are 4.

Electricity and Energy Programme, EQF level is 4.

Technical Production, EQF level is 4.

TE4 Technical Production and TE4 Design and Product Development, EQF level is 5.

Vocational training for adults, EQF level is 4.

Description of the relation between each study programme and the LAB:

The programmes that spend the most time in LAB are the Industrial technical programmes and the Electricity and Energy Programme.

Technical production and the TE4 programmes include more theoretical thinking and are therefore combining theoretical and practical education.

Other study programmes such as the more theoretical technical programmes and the health and social care programme can have education in the LAB each Friday afternoon as an optional course.

PROCESS

3.1	**Product life cycle**	product planning	product development	product design	rapid prototyping	manufacturing	assembly		logistics	service		recycling
3.2	**LAB life cycle**	investment planning	factory concept	process planning	ramp-up	manufacturing	assembly		logistics	maintenance		recycling
3.3	**Order life cycle**	configuration & order	order sequencing	production planning and scheduling		manufacturing	assembly		logistics	picking, packaging		shipping
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3.10	**Manufact. Methods**	cutting	trad. primary shaping		additive manufact.	forming		joining	coating		change material properties	
3.11	**Manufact. Technology**	physical			chemical				biological			

Specific equipment used in the LAB:

Curt Nicolin Gymnasiet wants to be at the forefront regarding the state of art technology. Machines such as 3D-printers are therefore important aspects of the programmes. The largest owner company of the School is heavily investing in EOS metal SLM printers. These machines are not possible to have at the school. Curt Nicolin Gymnasiet has therefore invested in an EOS-formiga P110 SLM printer to, in the best way possible, simulate the usage of these metal printers.

There are also 4 plastic Fused Filament Fabrication 3D-printers in the LAB today. Curt Nicolin Gymnasiet will, in the near future, invest in new Fused Filament Fabrication 3D-printers, printing in carbon fibre materials.

Curt Nicolin Gymnasiet has 4 robots; these are standard, cobot and AGV. The school does also have a large variety of FESTO Automation stations.

The school is currently investing in Virtual and Augmented Reality, having 10 different headsets today. Curt Nicolin Gymnasiet are, at this moment, considering buying 30 new headsets to use the equipment in larger groups, thus making it possible to teach more students simultaneously.

Various of the owner companies are focusing on CNC-machinery, one of the subset programmes of the Industrial technical programme are mainly focusing on CNC-machinery. The school does therefore have 8 different CNC-machines and has recently received a new 5-axis Haas milling machine.

There are various of conventional mills, lathes, and pillar drills in the LAB. These machines are mainly usable for new students to achieve a benevolent foundation before education within advanced machines and more advanced production methods.

SETTING

4.1	**Learning environment**	purely physical (planning + execution)	physical supported by digital factory (see line "IT-Integration")		Physical, extended virtually		purely virtual (planning + execution)
4.2	**Environment scale**	scaled down			life-size		
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4.6	**IT-integration**	IT before SOP (CAD, CAM, simulation)		IT after SOP (PPS, ERP, MES)		IT after production (CRM, PLM…)	

For what purpose are different IT-integrations used:

Students at Curt Nicolin Gymnasiet often participate in projects, from idea to final product. IT-integrations such as CAD, CAM, simulation, and software regarding 3D-printing are vital in the projects. These programmes are important in order to be able to design a product as well as to manufacture the product.

PRODUCT

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</table>

Further description of the products manufactured in the LAB:

The products manufactured in Curt Nicolin Gymnasiet are not available on the market. The owner companies do however occasionally order specific products, these products are in most cases 3D-printed.

The products manufactured in the LAB vary almost every month because the students work in different projects, from idea to product. The students do consequently choose what they want to create if the manufacturing process matches the criterions for the course in question. The further use of the products is following; displayed at the school, used as give-aways at fairs and events and in some cases the students get to take the product home.

Example of products that will be produced in the LAB:

- 3D-printed prototypes for companies or bigger projects at the school.
- 3D-scanned objects.
- Stirling engines manufactured in CNC-machines.
- Robots, for the yearly robots-wars competitions at the school.
- Additions for the robots at the school, manufactured in various machines.
- Different customized grills.
- Additions for the machines via the CNC-machines.

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<tr><td>6.4</td><td>Type of learn. environment</td><td colspan="4">greenfield (development of factory environment)</td><td colspan="5">brownfield (improvement of existing factory environment)</td></tr>
<tr><td>6.5</td><td>Communication channel</td><td colspan="4">onsite learning (in the factory environment)</td><td colspan="5">remote connection (to the factory environment)</td></tr>
<tr><td>6.6</td><td>Degree of autonomy</td><td colspan="2">instructed</td><td colspan="3">self-guided / self-regulated</td><td colspan="4">self-determined/ Self organized</td></tr>
<tr><td>6.7</td><td>Role of the trainer</td><td>presenter</td><td colspan="2">moderator</td><td colspan="3">coach</td><td colspan="3">instructor</td></tr>
<tr><td>6.8</td><td>Type of training</td><td>tutorial</td><td colspan="2">practical lab course</td><td colspan="2">seminar</td><td colspan="2">workshop</td><td colspan="2">project work</td></tr>
<tr><td>6.9</td><td>Standardization of trainings</td><td colspan="4">standardized trainings</td><td colspan="5">customized trainings</td></tr>
<tr><td>6.10</td><td>Theoretical foundation</td><td>prerequisite</td><td colspan="2">in advance (in bloc)</td><td colspan="2">alternating with practical parts</td><td colspan="2">based on demand</td><td colspan="2">afterwards</td></tr>
<tr><td>6.11</td><td>Evaluation levels</td><td>feedback of participants</td><td colspan="2">learning of participants</td><td colspan="2">transfer to the real factory</td><td colspan="2">economic impact of trainings</td><td colspan="2">return on trainings / ROI</td></tr>
<tr><td>6.12</td><td>Learning success evaluation</td><td>knowledge test (written)</td><td colspan="2">knowledge test (oral)</td><td>written report</td><td colspan="2">oral presentation</td><td colspan="2">practical exam</td><td>none</td></tr>
</table>

Specific competencies trained in the lab/trained with the technologies in the LAB:

Transversal competencies: Innovation, creativity, teamwork, flexibility, decision-making, determination, self-organization.

Methodological competencies: Analytical thinking, strategical thinking, linked thinking, presentation competencies.

Technical competencies: Technical expertise, IT knowledge, project management, quality management and industrial hygiene.

At Curt Nicolin Gymnasiet students often work in projects, the aforementioned competencies are therefore included in the education via various projects.

Skills trained in the lab/trained with the technologies in the LAB:

Additive Manufacturing plays a significant role in the education at Curt Nicolin Gymnasiet. Skills related to 3D-printing are therefore essential. Example of such skills are:

- 3D Engineering
- 3D CAD: Designing, repairing, modifying 3D-CAD data
- Finishing: Assembling, painting, sanding, enhancing a 3D-model
- Maintenance: Calibrating, repairing, and testing 3D-printers
- Material Handling

Numerous other skills that are trained in LAB are for example welding, part measuring, blasting, colouring and various ICT-skills.

Curriculum used:

Läroplan, examensmål och gymnasiegemensamma ämnen för gymnasieskola 2011 (Gy 2011)

https://www.skolverket.se/undervisning/gymnasieskolan/laroplan-programme-och-amnen-i-gymnasieskolan/laroplan-gy11-for-gymnasieskolan

METRICS

7.1	**No. of participants per training**	1-5 participants	5-10 participants	10-15 participants	15-30 participants	30> participants	
7.2	**No. of standardized trainings**	1 training	2-4 trainings	5-10 trainings		> 10 trainings	
7.3	**Aver. duration of a single training**	≤ 1 day	> 1 day until ≤ 2 days	> 2 days until ≤ 5 days	> 5 days until ≤ 10 days	> 10 days until ≤ 20 days	> 20 days
7.4	**Participants per year**	< 50 participants	50-200 participants	201-500 participants	501-1000 participants	> 1000 participants	
7.5	**Capacity utilization**	< 10%	> 10 until ≤ 20%	> 20%until ≤ 50%	> 50%until ≤ 75%	> 75%	
7.6	**Size of LAB**	≤ 100 sqm	> 100 sqm bis ≤ 300 sqm	> 300sqm bis ≤ 500sqm	>500 sqm bis ≤ 1000 sqm	> 1000 sqm	
7.7	**FTE in LAB**	< 1	2-4	5-9	10-15	> 15	

FURTHER INFORMATION & ASPECTS TO IMPROVE

8.1	**Further information**	photographs	video
8.2	**Aspect to improve**	technical	methodological

Further information (link to video):

https://www.youtube.com/watch?v=ZO6vOLSKpbo

Aspects to improve:

Curt Nicolin Gymnasiet is always striving to implement the latest technologies in its educational programmes, thus Industry 4.0 technologies. However, all Industry 4.0 technologies are not educated at the school. This is one aspect that could be improved, thus implementing more I4.0 technologies in the education as well as improving the education within the technologies that already exist at the school.

TKNIKA, Basque VET Applied Research Centre- Basque Country, Spain

Industry 4.0 Factory LAB 1

Name of the lab:

Machining and mechanical assembly LAB

General aim/purpose (short summary):

Research in the field of industry 4.0, training of VET teachers

Year of inauguration:

2017

LAB size (square metres):

150

General information - summary table

Tknika is a centre promoted by the Deputy Ministry of Vocational Education and Training of the Education Department of the Basque Government. Innovation and applied research are at the core of Tknika in its ongoing efforts to place Basque Vocational Training at the European forefront. Through networking and direct involvement by the Basque Vocational Training teaching staff, the Centre develops innovative projects in the areas of technology, education and management. In Tknika there are different labs where applied innovation projects related to the industry are developed.

In the Industry 4.0 Factory LAB we develop research projects related to Digitization of industrial processes. Technologies related to this subject are: CPS, IIoT, data analysis, product tracking (RFID, NFC, QR codes), MES, Robotics, etc. Finally, the results obtained are transferred to the rest of the education and vocational training centers, with teacher training being the main tool so that the knowledge acquired in the projects can reach companies and students.

The summary table below is established to present general information about the Industry 4.0 Factory Lab . Further information about this LAB in question, will be described additionally by the tables in the subsequent section.

General information - summary table

GENERAL INFORMATION	Name of the LAB	**Industry 4.0 Factory Lab**						MAIN PURPOSE		
	VET/HVET centre	TKNIKA, Applied Research Centre						Education		
	Floor space of the lab (sqm)	150						Training		X
	Main topic/learning content	Digitization of factories: Industrial Internet of Things, Digital Twins						Research/Applied innovation		X
	I4.0 related technologies	CPS, IIoT, data analysis, product tracking (RFID, NFC, QR codes), MES, Robotics								
PURPOSE	Learning content	Applied Research								
	Secondary purpose	Teacher training								
	LAB type	Specific			Mixed			Learning Factory		
LEARNING CONTENTS	Learning programmes/study programmes/levels	Name of the programmes carried out on the Lab				EQF Level	Lab hours	Nº subjects on the lab	Hour/Week x nº of weeks	Nº students (3)
		IIoT for SMEs data visualization				5	46	3	-	3x20
		IIoT for SMEs data visualization				5	48	3	-	2x20
		Digital twins for virtual commissioning				5	36	3	-	2x21
		SIF-400 training				5	H	Y	-	1x15
SETTINGS	Nº of cell	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5	Cell 6	Cell 7	Cell 8	Cell 9
	Category of cell	Learning Factory	X	X	X	X	X	X	X	X
	Nº machines	14	Y	Y	Y	Y	Y	Y	Y	Y
	I4.0 Enabler technologies used and implementation level	Robotics	Additive Manufacturing	Cloud	CPS	Mobile/Tablet	AR/VR	Big data analytics	Ai	IoT/IIoT
		Sensors/Actuators	RFID	M2M	Cybersecurity	Digital twin				

Specific lab: : A lab designed and set up to teach/learn a specific technology. This could be the case for Additive manufacturing labs, Robotics labs, IoT labs (didactic labs by Festo, SMC and others) etc

Mixed lab: The main purpose of the lab is not a (i4.0) specific technology but those technologies that are implemented to complement the main activity. It could be: Machining labs with retrofitted machines with sensors and data acquisition systems included, metal forming labs where cobots/robots are implemented etc

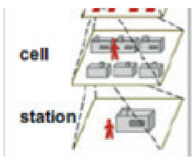
Learning Factory:

Study programmes: The learning activities carried out in the labs are usually a part of a wider programme. The name of the programme and its EQF level is marked. The hours are referred to the hours spent on activities in the lab.

The number of subjects is referred to the different subjects or areas that could be covered by a group in the lab. They can be considered as the number of separate training activities.

Nº students and groups per week in the lab. 3x20 means 3 groups of 20 students each. The timetable and schedule would be distributed in different days/hours in the lab in a period. This is the max number of students/groups that can be working simultaneously in the labs.

Cell/area: Part of the lab that groups a number of machines. Cells can be divided in 2 types:



a) Cells with machines with similar characteristics.

b) Cells with a sequenced number of machines where consecutive operations are carried out.

Usage level: Fully implemented | Implemented to certain degree | Planned to implement | Not implemented

Principle Layout of the Research Lab:

OPERATIONAL MODEL

1.1	**operator**	academic institution			non-academic institution					profit-oriented operator	
		university	college	BA	vocational school / high school	chamber	union	employers´ association	industrial network	consulting	producing company
1.2	**trainer**	professor	researcher	student assistant		technical expert /int. Specialist			consultant	educationalist	
1.3	**development**	own development				external assisted development			external development		
1.4	**initial funding**	internal funds				public funds			company funds		
1.5	**ongoing funding**	internal funds				public funds			company funds		
1.6	**funding continuity**	short term funding (e.g. single events)				mid term funding (projects and programs < 3 years)			long term funding (projects and programs > 3 years)		
1.7	**business model for trainings**	open models				closed models (training program only for single company)					
		club model	course fees								

Tknika is a publicly funded research center promoted by the Deputy Ministry of Vocational Education and Training of the Education Department of the Basque Government. Innovation and applied research are at the core of Tknika in its ongoing efforts to place Basque Vocational Training at the European forefront. Through networking and direct involvement by the Basque Vocational Training teaching staff, the Centre develops innovative projects in the areas of technology, education and management. In Tknika there are different specialization areas where applied innovation projects related to the industry are developed.

PURPOSE AND TARGETS

2.1	main purpose	education	vocational training	research												
2.2	secondary purpose	test environment / pilot environment	industrial production	innovation transfer	advertisement for production											
2.3	target groups for education & training	pupils	students			employees							entrepreneurs	freelancer	unemployed	open public
			bachelor	master	phd students	apprentices	skilled workers	semi-skilled workers	unskilled	managers						
										lower mgmt	middle mgmt	top mgmt				
2.4	group constellation	homogeneous	heterogeneous (knowledge level, hierarchy, students + employees, etc.)													
2.5	targeted industries	mechanical & plant eng.	automotive	logistics	transportation	FMCG	aerospace									
		chemical industry	electronics	construction	insurance / banking	textile industry	...									
2.6	subject-rel. learning contents	prod. Mgmgt & org.	resource efficiency	lean mgmt	automation	CPPS	work system design	HMI	design	Intralogistics design & mgmt	...					
2.7	role of LF for research	research object	research enabler													
2.8	research topics	production management & organization	resource efficiency	lean mgmt	automation	CPPS	changeability	HMI	didactics	...						

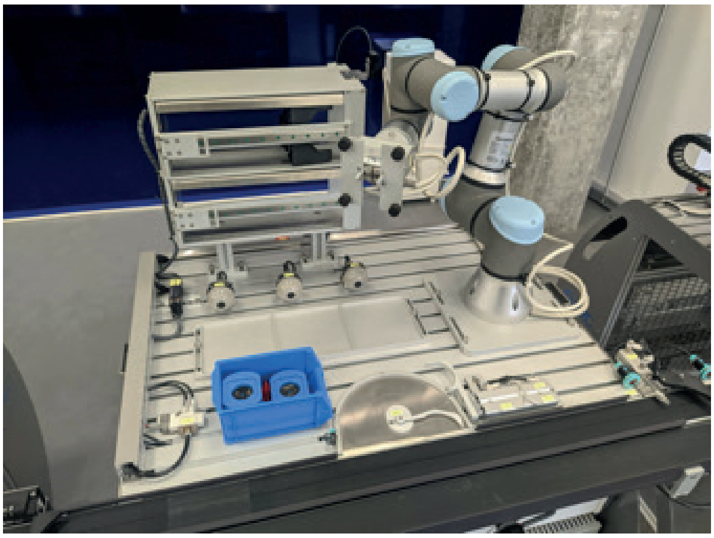
Tknika's main objective is to reduce the gap between educational needs and the constantevolution of technology. To do so, we believe that teacher training and networking are the main tools to be used. Since 2005, Tknika has played a key role in this field, involving high schools in large national and international projects and working with all kinds of new technologies. The way of working is through projects, where a group of teachers are released to develop and didactify these new technologies. First it is developed in Tknika and, once consolidated, it is transferred to the centers.

One of the technologies we have been working on in recent years is the concept of the Internet of Things, both in a more domestic and industrial environment. To work on the industrial side, a laboratory has been created where we incorporate new technologies that companies will apply in their processes.

In this Lab we have been working in 3 main research topics:

1. Digital and connected factory: Development of Cyber Physical Systems (CPS) for education (The physical part of CPS)
2. Digitization of industrial processes: Industrial Internet of Things (IIoT) for data analysis in SMEs
3. Virtualization and simulation of industrial processes: Digital twins for virtual commissioning (The virtual part of CPS)

1.Development of Cyber Physical Systems (CPS) for education:



In this area of research we collaborate closely with SMC International Training in the development and testing of its training equipment for Industry 4.0 (SIF-400). This equipment includes the following technologies:

- Product traceability systems: 4 systems, RFID, NFC, QR-code and Barcode.

- PLC-s that incorporate the Industry 4.0 OPC UA communication standard.

- Robots for the replacement of repetitive tasks in industrial processes. It incorporates 2 types of robots, one collaborative (UR3 COBOT) and the other industrial (OMRON SCARA).

- The process is fully automated and works in an integrated mode governed by a service or application called SIF-MES (Manufacturing Execution System).

- In the sensor and actuator layer it uses sensors with IO-Link technology.

- For product quality control, artificial vision cameras are used in a couple of points.

- The equipment includes energy consumption meters in the electrical part and air flow meters in the pneumatic part in order to optimize the energy efficiency of the system.

Application:

- **Teacher training:** At this moment we are already in the phase of transferring the knowledge acquired in the project.

- **Visits:** The laboratory has been intensively used in visits to Tknika. The system has made it easy to clearly and quickly explain the concept of Industry 4.0 to visitors.

2. Industrial Internet of Things (IIoT) for data analysis in SMEs: Digitization of industrial processes for data collection with a predictive analytical approach.

An IIoT gateway has been developed that allows us to communicate with any industrial controller that speaks OPC UA, Modbus or S7 protocols. The gateway is composed of hardware, in this case industrialized Raspberry Pi, and a software package (Node-RED, Thingsboard, MQTT) that has allowed us to create a teacher training course focused on the collection of data from industrial processes. This hardware is used as a training kit in the designed course. Due to the characteristics of the hardware and the chosen software package, we understand that these tools are very interesting for their application in SMEs and schools LABs, and that is why we have named the course thus: "Industrial Internet of Things for the collection and visualization of data in SMEs ". In the course all the tools mentioned above have been analyzed following the path traveled by the data from the production process to the Cloud.

Application:

The main application so far has been teacher training. We are currently in the phase of transferring the knowledge acquired in the project. We have created a course that allows teachers to incorporate technologies related to the Industrial Internet of Things concept. Two training actions have been carried out to provide teachers with tools to work on this topic in the classroom. Forty teachers from different vocational training centers in the Basque Country have been trained in these technologies.

As mentioned above, we also see that the development of the project can be used to collect data from school laboratories, as well as to develop projects with SMEs. Therefore, from Tknika we are going to promote a pilot service for data collection and analysis.

3. Digital twins for virtual commissioning:

In this research area we have been testing different software solutions to develop digital twin environments. Related to this, we have been working on the design of an online course. In the course we work with PLC-s simulators such as "PLCSim Advanced" from Siemens, robot simulators such as "Robodk" and with different software such as "Simumatik 3D" and "Factory IO", all this software allows us to simulate industrial environments in order to carry out the simulation. All this software allows us to simulate industrial environments for virtual commissioning.

The course also aims to carry out a demonstration of the digital twin with a hardware in the loop configuration, which will allow us to run a real controller connected to the digital twin, in order to work as it would in reality, subjecting it to different conditions context, thus shortening controller development, validation and commissioning times in a more secure, flexible and economical way.

Application:

So far, the main application has been teacher training. At the moment we are in the phase of transferring the knowledge acquired in the project. We have created a course that allows teachers to incorporate the technologies related to the Digital Twin concept. A training action has been carried out in which teachers have been provided with tools to work on this topic in the classroom. Twenty teachers from different vocational training centers in the Basque Country have been trained in this subject.

PROCESS

3.1	**product life cycle**	product planning	product development	product design	rapid prototyping	manufacturing	assembly		logistics	service		recycling
3.2	**factory life cycle**	investment planning	factory concept	process planning	ramp-up	manufacturing				maintenance		recycling
3.3	**order life cycle**	configuration & order	order sequencing	production planning and scheduling		manufacturing				picking, packaging		shipping
3.4	**technology life cycle**	planning	development	virtual testing		manufacturing				maintenance		modernization
3.5	**indirect functions**	SCM	sales	purchasing		HR	finance / controlling			QM		
3.6	**material flow**	continuous production				discrete production						
3.7	**process type**	mass production		serial production		small series production					one-off production	
3.8	**manufact. organization**	fixed-site manufacturing		work bench manufacturing		workshop manufacturing					flow production	
3.9	**degree of automation**	manual		partly automated / hybrid automation					fully automated			
3.10	**manufact. Methods**	cutting	trad. primary shaping		additive manufact.	forming		joining	coating	change material properties		
3.11	**manufact. Technology**	physical			chemical				biological			

• SIF-400 Cyber Physical System for Industry 4.0:

• **SIF-401 - Pallet and container feeding station.**

The function of this station is to feed containers and pallets to the system.

The containers can be of two types: cylindrical or quadrangular prisms. These are stored in gravity feeders that, being modular, can be easily disassembled and interchanged depending on production loads.

The containers are placed on the pallet by means of electric actuators and a gravity positioner. All pallets include an RFID tag that allows for their identification and traceability throughout the system.

- **SIF-402 - Container filling station - solid.**

In this station the containers of solid raw material are filled.

The raw material can be of three different colours (red, blue and yellow) and can be supplied independently or mixed, in different doses.

Once the containers are filled, the amount of material introduced into the container is checked.

• **SIF-403 - Container filling station - liquid.**

In this station the containers of liquid raw material are filled.

Two liquids of different densities can be supplied independently or mixed, with subsequent checking of the filling height.

The station has an area for regulating the flow of the resulting mixture.

- **SIF-404 - Container filling station.**

Customized product This station supplies the system with containers of customized material.

This station supplies the system with containers of customized material. To do this, the station has feeders adapted to the two available types of container. The customized product must be introduced into the containers previously by the user.

The containers can contain any externally produced objects (through 3D printing, turning, milling...) that fit in the available space.

- **SIF-405 - Capping station.**

In this station the corresponding cap is fitted depending on the type of container that arrives.

The caps are stored in two interchangeable feeders, for circular and square section caps. A pneumatic part type detection system recognizes what type of cap is in each feeder. The number of parts in each feeder is known in real time, detecting if either feeder is empty.

A machine vision camera verifies that the cap has been fitted in the correct position.

- **SIF-406 - Container warehouse station.**

This station acts as a warehouse for finished or semi-finished products.

This station acts as a warehouse for finished or semi-finished products. It can store 50 containers and their corresponding pallets.

The warehouse allows the containers to be introduced, extracted and moved internally according to the needs of the process.

• **SIF-407 - Container labelling and dispatching station**

This station has a double function: printing QR labels and dispatching the correct finished unit product orders.

First of all it prints QR labels that are stuck on the containers. A machine vision system inspects the code to link it to the RFID of the corresponding pallet and ensure the correct placement of the label.

Additionally, the station dispatches the correctly finished containers for unit product orders.

• **SIF-408 - Container packing station**

The station serves as a link between the assembly and logistics stations.

The containers arrive on the conveyor belt and a collaborative robot picks them up and places them in a pack in one of the three packing areas in the station.

The station contains a colour code to indicate the different stages of preparation of each pack.

• **SIF-409 - Pack warehouse station.**

This station acts as a warehouse for finished packs.It can store up to 8 packs in its different locations.

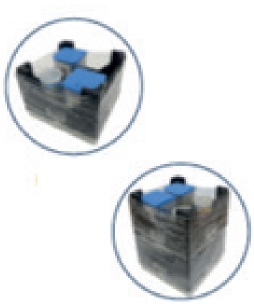
Subsequently, the finished packs can be transferred towards the dispatching station to be palletized and labelled.

• **SIF-410 - Pack palletizing station.**

This station is in charge of palletizing packs prepared in previous stages of the process.

It allows the creation of pallets of one or two pack levels. To do this, a SCARA robot feeds and places the packs on the pallets. Subsequently, the same robot packages them with plastic wrap.

The station includes transparent guards and safety barriers.



• **SIF-411 - Pack pallet labelling.**

This station dispenses NFC labels and prints barcodes on them in continuous movement.These labels are placed on the plastic wrap of the packs.

Before the package leaves the station, an NFC reader links its code to the system database to store all the information related to the order in one place (quantities, date of manufacture, content...).

• SIF-412 - Pack pallet dispatching station.

The function of this station is the dispatching of completed pack pallets for the delivery to the customer.

The pack pallet will be shipped by one of the three defined delivery methods. A colour-coded status indicator shows the current stage of the process.By placing a mobile device with an NFC scanner close to the pallet's shipping label, you can obtain information about the delivery of the order.

• **SIF-413 - Recycling station**

The station allows the solid raw material used during the process to be stored and recycled.

The solid raw material is separated and stored by colour thanks to three colour detection sensors and three blowers. In addition, the station has specific warehouses for containers, caps, packs and pallets.

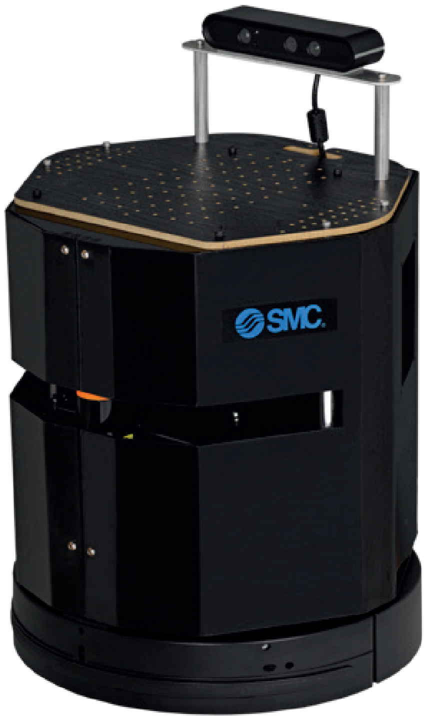
In this way, the material is available to be used again in the system. The entire recycling process is handled using the augmented reality application, VAR-400.

- **SIF-414 - IAV - Mobile robot**

This device helps in the transportation of various materials in the SIF-400 system at the request of the user.

- Follow me.
- Transfer between points.
- Precise positioning for battery charging.

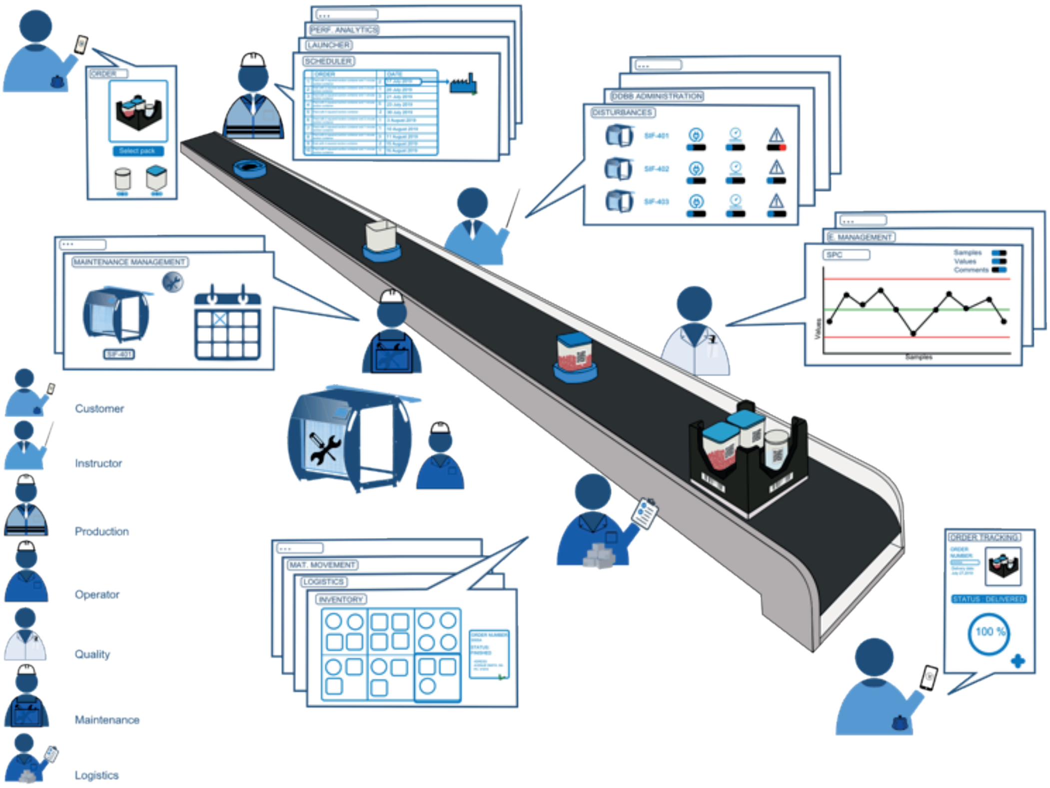
This mobile robot is controlled through a web application called IAV Easy Interface.



All the stations has the following common features: Extruded aluminium base structure, capacitive HMI display, stainless steel front with on / off switch and emergency push button, conveyor system with RFID / BCR / NFC, electric actuators, industrial controller with OPC UA server and distributed I/O and energy meter with wireless transmission (emitter).

• **SIFMES-400:**

Management software: Structured in different blocks, SIFMES-400 allows the control, supervision, management and monitoring of the entire system. It connects the different contributors in the supply chain with customers so their needs can be met. Suppliers, factories and customers merge into a CONNECTED chain.

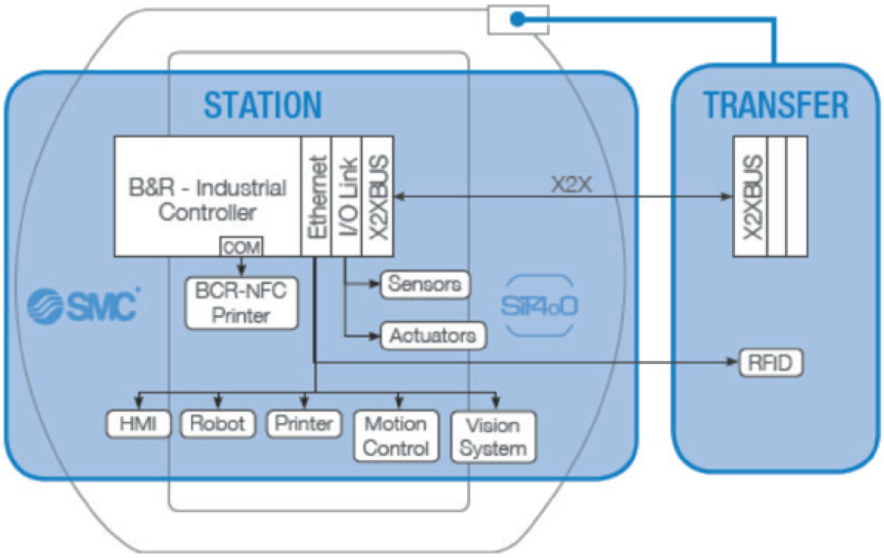


Communications:

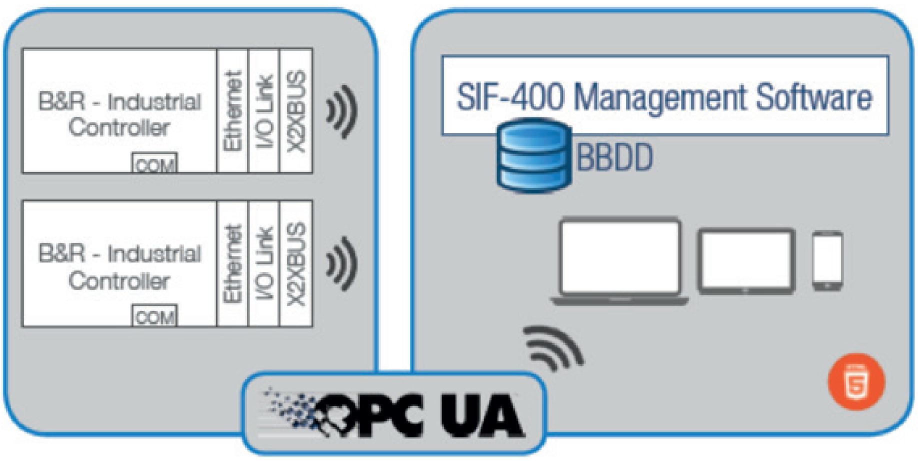
In the field of communications, different layers and different protocols can bex differentiated. At the station level, in the sensor-actuator layer, there are communications between PLCs and different technologies implemented in the stations.

Here we can find protocols such as:

- I/O Link
- X2X
- Modbus tcp
- Serial communication



At the system level, communication between each of the stations and MES, is carried out through the OPC-UA protocol. In this way the system can work automatically through the integrated mode.

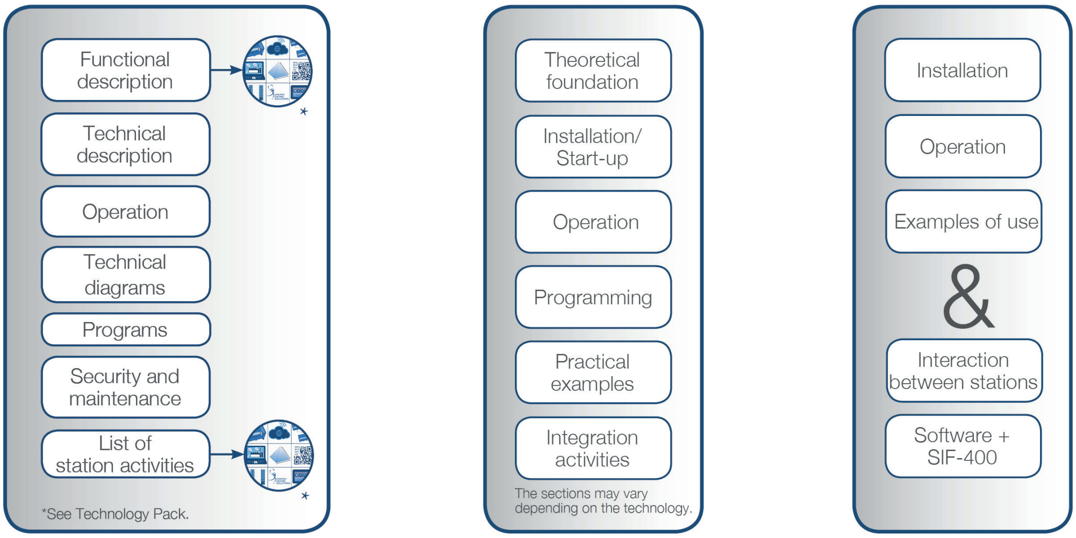


The teaching material is structured in three packs: station pack, technology pack and software and system pack.

- **Station**:
  This includes information on the function and operation of each station within the SIF-400 system as well as the technical details.

- **Technology**:
  This includes information, along with practical examples and integration activities that can be developed for each relevant technology.

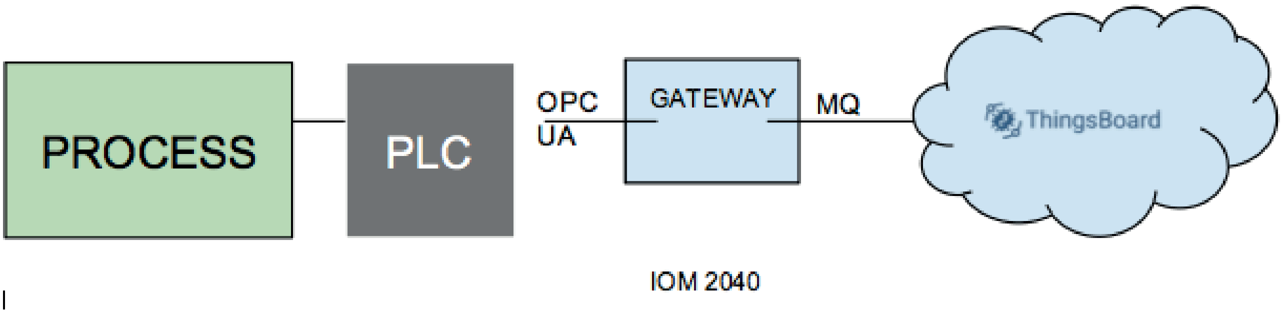
- **Software and system:**
  This includes information on how to install and operate the software. In addition, it includes case scenarios and challenges in which several stations are connected to each other or work together with the SIFMES-400 software.



Other equipment in the Lab:

- JBC RMS-2B Electronic Component Repair Station.
- PCB Prototyping equipment LPKF ProtoMat S63.

In the project we also developed our own IIoT equipment:



• **IIoT gateway:** This gateway can be used to collect data from different machines and also to teach teachers or students different practical IIoT concepts. The gateway consists of two part, hardware and software:

• **IoMBian (software):** IoMBian (or IoMBian OS) is the main operating system of the IoMBian project. It has been developed mainly for teachers (educational environments), in order to facilitate the implementation of IoM (Internet of Machines) and IIoT (Industrial Internet of Things) systems in embedded devices (Raspberry Pi).

IoMBian is based on the latest stable version of Raspberry Pi OS Lite, to which the following programs have been added:

• **Node-RED:** a visual development tool, originally created by IBM, that allows to collect information from hardware devices, APIs and online services as part of the Internet of Things.

• **Mosquitto:** a widespread MQTT server (broker) developed by the Eclipse Foundation.

• **MQTT Web Client:** MQTT web client thanks to which the user (student) can send his first MQTT messages without having to install anything in his computer. Combined with the pre-installed mosquitto broker, it allows you to start playing with the protocol in a few minutes.

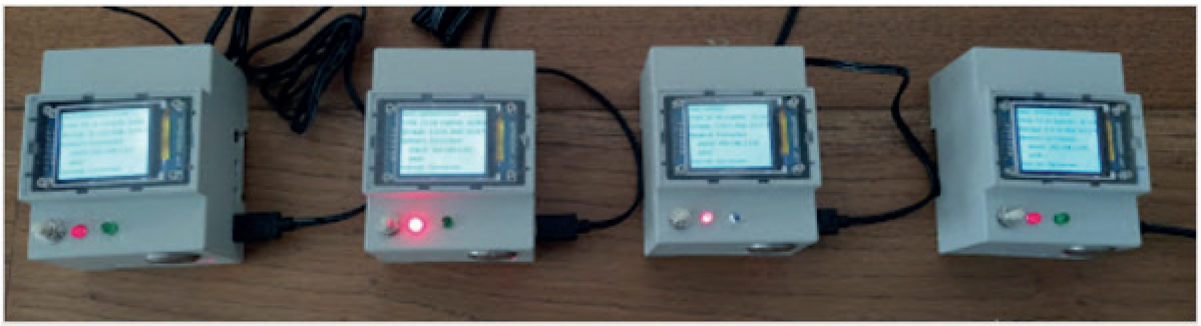
• **Monit:** program that can monitor the state of the system and is capable of sending notifications to the user (by email) when something does not work as expected.

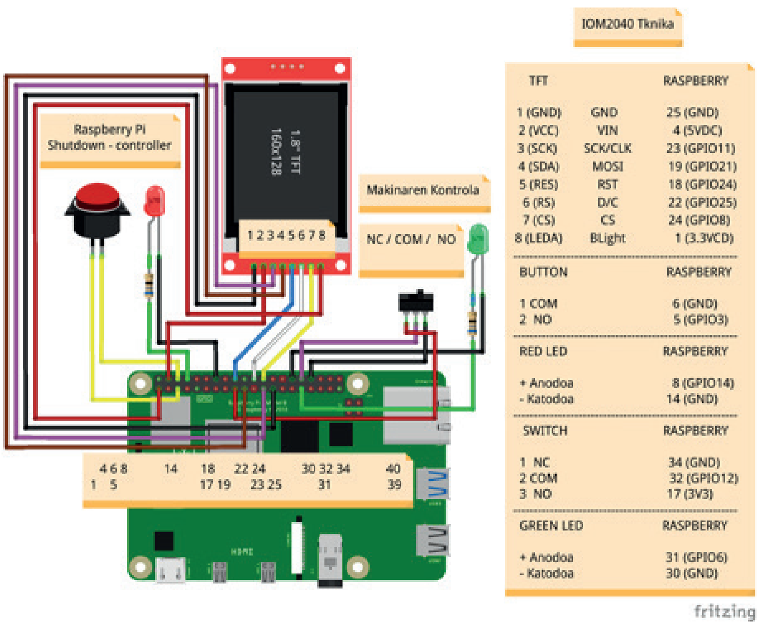
• **Led controller:** configuration that allows to know if the Raspberry Pi is on or not through a LED connected to the GPIO14.

• **Samba**: protocol that simplifies file exchange between the Raspberry Pi and any computer on the local network. By default only the "/data" folder is shared (the folder name is case sensitive).

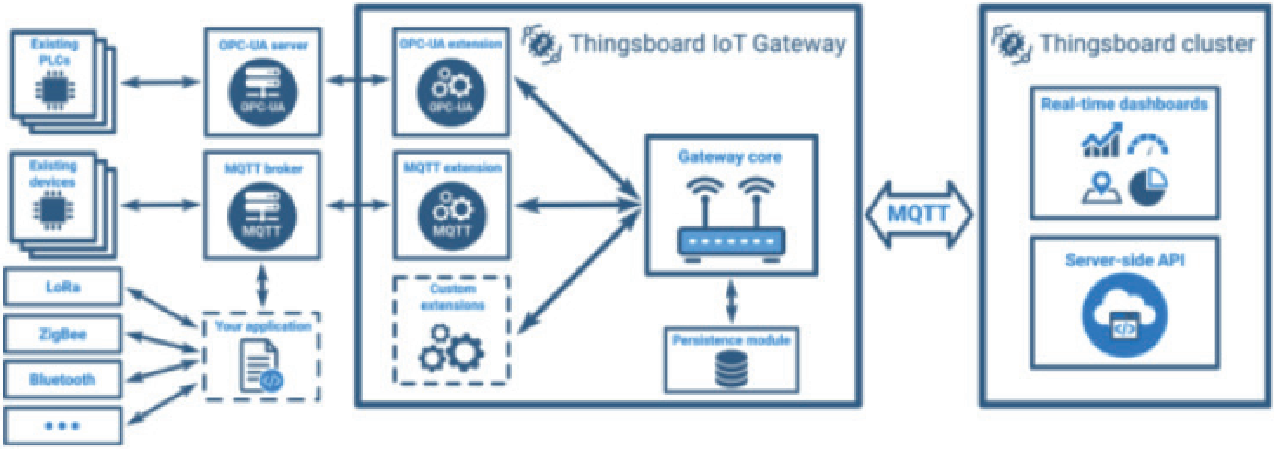
• **Confinit**: tool developed by José Riguera (@jriguera) that allows to configure the Raspberry Pi from a single text file hosted in the "boot" partition of the microSD card. A specific configuration has been created for IoMBian called iombian-confinit that facilitates the configuration of the following services.

• **IoM2040 (hardware):** IoM2040 (hardware for IoMBian OS) is a Raspberry Pi 4 based gateway hardware for industrial teaching areas.





• **Data analysis service for HVET/VET LABS is being deployed:** An IIoT platform has been deployed to provide a data analysis solution for HVET/VET LABS. The solution is based on the IIoT Thingsboard platform.



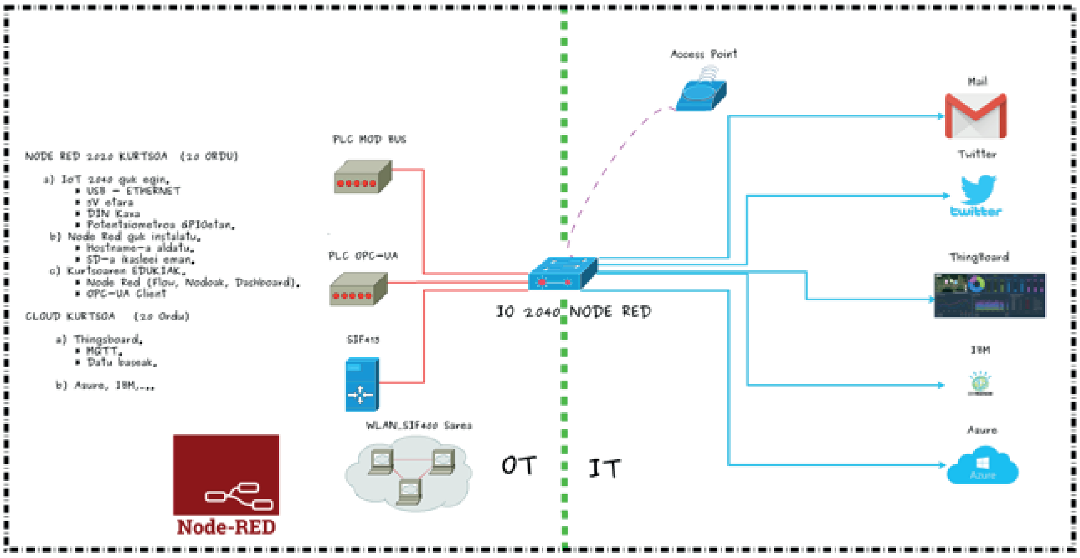
<table>
<tr><td>4.1</td><td>learning environment</td><td>purely physical (planning + execution)</td><td colspan="2">physical LF supported by digital factory (seeline “IT-Integration”)</td><td colspan="2">physical value stream of LF extended virtually</td><td>purely virtual (planning + execution)</td></tr>
<tr><td>4.2</td><td>environment scale</td><td colspan="3">scaled down</td><td colspan="3">life-size</td></tr>
<tr><td>4.3</td><td>work system levels</td><td>work place</td><td colspan="2">work system</td><td colspan="2">factory</td><td>network</td></tr>
<tr><td>4.4</td><td>enablers for changeability</td><td>mobility</td><td>modularity</td><td colspan="2">compatibility</td><td>scalability</td><td>universality</td></tr>
<tr><td>4.5</td><td>changeability dimensions</td><td>layout & logistics</td><td>product features</td><td colspan="2">product design</td><td>technology</td><td>product quantities</td></tr>
<tr><td>4.6</td><td>IT-integration</td><td colspan="2">IT before SOP (CAD, CAM, simulation)</td><td colspan="2">IT after SOP (PPS, ERP, MES)</td><td colspan="2">IT after production (CRM, PLM…)</td></tr>
</table>

For what purpose are different IT-integrations used:

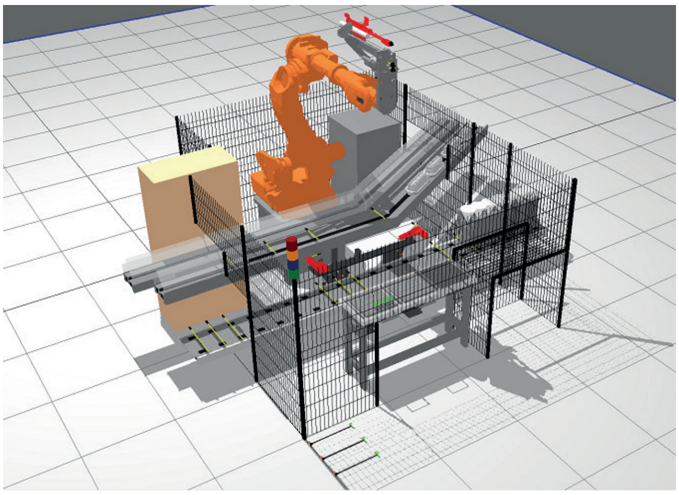
In the laboratory we can distinguish 2 parts: the OT part and the IT part.

In the OT part we have the cyber-physical system, SIF-400, which is designed to work with a large number of products and to be very modular, allowing great flexibility and product customization. The system has 2 modes of operation: single mode and integrated mode. In the integrated mode the whole process is controlled by an MES.

- SIF-401 - Pallet and container feeding station.
- SIF-402 - Container filling station - solid.
- SIF-403 - Container filling station - liquid.
- SIF-404 - Container filling station - customized product.
- SIF-405 - Capping station.
- SIF-406 - Container warehouse station.
- SIF-407 - Container labelling and dispatching station.
- SIF-408 - Container packing station.
- SIF-409 - Pack warehouse station.
- SIF-410 - Pack palletizing station.
- SIF-411 - Pack pallet labelling.
- SIF-412 - Pack pallet dispatching station.
- SIF-413 - Recycling station.
- SIF-414 - IAV - Mobile robot.



- The area of virtualization and process simulation known as digital twin.



PRODUCT

5.1	**materiality**	material (physical product)					immaterial (service)		
5.2	**form of product**	general cargo				bulk goods		flow products	
5.3	**product origin**	own development			development by participants			external development	
5.4	**marketability of product**	available on the market			available on the market but didactically simplified			not available on the market	
5.5	**functionality of product**	functional product			didactically adapted product with limited functionality			without function / application, for demonstration only	
5.6	**no. of different products**	1 product	2 products	3-4 products	> 4 products	flexible, developed by participants		acceptance of real orders	
5.7	**no. of variants**	1 variant	2-4 variants	4-20 variants	...	flexible, depending on participants		determined by real orders	
5.8	**no. of components**	1 comp.	2-5 comp.	6-20 comp.		21-50 comp.	51-100 comp.		> 100 comp.
5.9	**further product use**	re-use / re-cycling		exhibition / display		give-away	sale		disposal

Further description of the products manufactured in the LAB

In the laboratory we can differentiate the following types of products and services:

1.SIF-400 allows the production of unit containers and packs of containers. For unit containers, the customer places an order for X containers, assigning a recipe to each container. For packs of containers, the customer places the order for X packs with the specific containers of his choice. SIF-400 can ship unit containers, packs of containers and pallets of packs.

THE PRODUCTS

- Multiple product configurations are possible:
- Container shape: square section and circular section.
- Type of content: solid, liquid and customized.
- Content configuration: color, filling level, mixing ratio..
- Number of containers in each pack.
- Number of packs in the final pallet.

2. IoM2040:
this development is completely open and can be used to train students in the field of IIoT or as a gateway to collect data in the laboratories of vocational training centers.

3. Data analytics for VET LABs:
although we are still deploying it and it is not fully functonal, next year we want to pilot with a small number of VET centers an IoT platform where they can connect the machines in their LABs.

DIDACTICS

<table>
<tr><td>6.1</td><td>competence classes</td><td colspan="2">technical and methodological competencies</td><td colspan="2">social & communication competencies</td><td colspan="2">personal competencies</td><td colspan="3">activity and implementation oriented competencies</td></tr>
<tr><td>6.2</td><td>dimensions learn. targets</td><td colspan="2">cognitive</td><td colspan="3">affective</td><td colspan="4">psycho-motorical</td></tr>
<tr><td>6.3</td><td>learn. scenario strategy</td><td>instruction</td><td colspan="3">demonstration</td><td colspan="2">closed scenario</td><td colspan="3">open scenario</td></tr>
<tr><td>6.4</td><td>type of learn. environment</td><td colspan="4">greenfield (development of factory environment)</td><td colspan="5">brownfield (improvement of existing factory environment)</td></tr>
<tr><td>6.5</td><td>communication channel</td><td colspan="4">onsite learning (in the factory environment)</td><td colspan="5">remote connection (to the factory environment)</td></tr>
<tr><td>6.6</td><td>degree of autonomy</td><td colspan="2">instructed</td><td colspan="3">self-guided / self-regulated</td><td colspan="4">self-determined/ Selforganized</td></tr>
<tr><td>6.7</td><td>role of the trainer</td><td>presenter</td><td colspan="2">moderator</td><td colspan="3">coach</td><td colspan="3">instructor</td></tr>
<tr><td>6.8</td><td>type of training</td><td>tutorial</td><td colspan="2">practical lab course</td><td colspan="2">seminar</td><td colspan="2">workshop</td><td colspan="2">project work</td></tr>
<tr><td>6.9</td><td>standardization of trainings</td><td colspan="4">standardized trainings</td><td colspan="5">customized trainings</td></tr>
<tr><td>6.10</td><td>theoretical foundation</td><td>prerequisite</td><td colspan="2">in advance (en bloc)</td><td colspan="2">alternating with practical parts</td><td colspan="2">based on demand</td><td colspan="2">afterwards</td></tr>
<tr><td>6.11</td><td>evaluation levels</td><td>feedback of participants</td><td colspan="2">learning of participants</td><td colspan="2">transfer to the real factory</td><td colspan="2">economic impact of trainings</td><td colspan="2">return on trainings / ROI</td></tr>
<tr><td>6.12</td><td>learning success evaluation</td><td>knowledge test (written)</td><td colspan="2">knowledge test (oral)</td><td>written report</td><td colspan="2">oral presentation</td><td colspan="2">practical exam</td><td>none</td></tr>
</table>

Specific competencies trained in the lab/trained with the technologies in the LAB:

Skills trained in the lab/trained with the technologies in the LAB:

Learning outcomes:

Most of the training is designed using blended learning. This type of learning aims to use two strategies, face-to-face and virtual, taking the best of both at all times. Flipped Classroom (FC) or webinar tools such as "Zoom" or "Google Meet" are used to move the work of certain learning processes outside the classroom and class time is used, together with the teacher's experience, to facilitate and enhance other processes of knowledge acquisition and practice within the classroom, usually related to transversal competencies, such as the ability to diagnose, relate, solve problems, make decisions, communicate, organize their work, manage time, adapt to different cultural environments, manage stress, and have a teamwork attitude.

As mentioned above, the results of the projects worked on in Tknika in the form of knowledge transfer are aimed at training VET teachers who teach at EFQ levels 5,, so all training is adapted to these levels.

On the other hand, in Tknika we have an area specialized in methodology called "Learning and High Performance" that promotes collaborative learning based on challenges, so the training is also adapted to this working method.

METRICS

7.1	**no. of participants per training**	1-5 participants	5-10 participants	10-15 participants	15-30 participants	30> participants	
7.2	**no. of standardized trainings**	1 training	2-4 trainings	5-10 trainings		> 10 trainings	
7.3	**aver. duration of a single**	≤ 1 day	> 1 day until ≤ 2 days	> 2 days until ≤ 5 days	> 5 days until ≤ 10 days	> 10 days until ≤ 20 days	> 20 days
7.4	**participants per year**	< 50 participants	50-200 participants	201-500 participants	501-1000 participants	> 1000 participants	
7.5	**capacity utilization**	< 10%	> 10 until ≤ 20%	> 20%until ≤ 50%	> 50%until ≤ 75%	> 75%	
7.6	**size of LF**	≤ 100 sqm	> 100 sqm bis ≤ 300sqm	> 300sqm bis ≤ 500sqm	>500 sqm bis ≤ 1000sqm	> 1000 sqm	
7.7	**FTE in LF**	< 1	02-abr	05-sep	oct-15	> 15	

In the laboratory we have two types of knowledge transfer, one aimed at VET teachers and the other aimed at a more general public who usually visit Tknika to see what we work on and how we do it.

In the first one the transfer is usually of advanced type and with a longer duration that can range from 5 days to more than 20, depending on the topic we are dealing with. And in the second the visits are usually of a duration of less than 1 day.

FURTHER INFORMATION & ASPECTS TO IMPROVE

8.1	**Further information**	photographs	video
8.2	**Aspect to improve**	technical	methodological

Further information (link to video):

https://youtu.be/tXKAPhRrB_g

Industry 4.0 Factory LAB 2

Name of the lab:

Industrial Cybersecurity lab

General aim/purpose (short summary):

Research in the field of Cybersecurity, training of VET teachers

Year of inauguration:

2020

LAB size (square metres):

45

General information - summary table

Tknika is a centre promoted by the Deputy Ministry of Vocational Education and Training of the Education Department of the Basque Government. Innovation and applied research are at the core of Tknika in its ongoing efforts to place Basque Vocational Training at the European forefront. Through networking and direct involvement by the Basque Vocational Training teaching staff, the Centre develops innovative projects in the areas of technology, education and management. In Tknika there are different labs where applied innovation projects related to the industry are developed.

In the Industrial Cybersecurity Lab, we develop research projects related to cybersecurity in industrial environments. Finally, the results obtained are transferred to the rest of the education and vocational training centers, with teacher training being the main tool so that the knowledge acquired in the projects can reach companies.

The summary table below is established to present general information about the Industry 4.0 Factory Lab . Further information about this LAB in question, will be described additionally by the tables in the subsequent section.

General information - summary table

GENERAL INFORMATION	Name of the LAB	**Industrial Cybersecurity Lab**	MAIN PURPOSE	
	VET/HVET centre	TKNIKA, Applied Research Centre	Education	X
	Floor space of the lab (sqm)	45	Training	X
	Main topic/learning content	-	Research/Applied innovation	X
	I4.0 related technologies	-		
PURPOSE	Learning content	Industrial cybersecurity research		
	Secondary purpose	Teacher training		
	LAB type	Specific	Mixed	Learning Factory

		Name of the programmes carried out on the Lab	EQF Level	Lab hours	Nº subjects on the lab	Hour/Week x nº of weeks	Nº students (3)
LEARNING CONTENTS	Learning programmes/study programmes/levels	-	-	-	-	-	-
		-	-	-	-	-	-
		-	-	-	-	-	-
		-	-	-	-	-	-
		-	-	-	-	-	-
		-	-	-	-	-	–

SETTINGS	Nº of cell	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5	Cell 6	Cell 7	Cell 8	Cell 9
	Category of cell	Learning Factory	X	X	X	X	X	X	X	X
	Nº machines	3	Y	Y	Y	Y	Y	Y	Y	Y
	I4.0 Enabler technologies used and implementation level	Robotics	Additive Manufacturing	Cloud	CPS	Mobile/Tablet	AR/VR	Big data analytics	Ai	IoT/IIoT
		Sensors/Actuators	RFID	M2M	Cybersecurity	Digital twin				

Specific lab: : A lab designed and set up to teach/learn a specific technology. This could be the case for Additive manufacturing labs, Robotics labs, IoT labs (didactic labs by Festo, SMC and others) etc

Mixed lab: The main purpose of the lab is not a (i4.0) specific technology but those technologies that are implemented to complement the main activity. It could be: Machining labs with retrofitted machines with sensors and data acquisition systems included, metal forming labs where cobots/robots are implemented etc

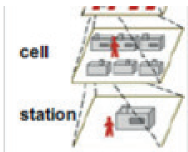
Learning Factory:

Study programmes: The learning activities carried out in the labs are usually a part of a wider programme. The name of the programme and its EQF level is marked. The hours are referred to the hours spent on activities in the lab.

The number of subjects is referred to the different subjects or areas that could be covered by a group in the lab. They can be considered as the number of separate training activities.

Nº students and groups per week in the lab. 3x20 means 3 groups of 20 students each. The timetable and schedule would be distributed in different days/hours in the lab in a period. This is the max number of students/groups that can be working simultaneously in the labs.

Cell/area: Part of the lab that groups a number of machines. Cells can be divided in 2 types:



a) Cells with machines with similar characteristics.

b) Cells with a sequenced number of machines where consecutive operations are carried out.

Usage level: Fully implemented | Implemented to certain degree | Planned to implement | Not implemented

Principle Layout of the Research Lab:

OPERATIONAL MODEL

1.1	operator	academic institution				non-academic institution							profit-oriented operator	
		university	college		BA	vocational school / high school			chamber	union	employers´ association	industrial network	consulting	producing company
1.2	trainer	professor	researcher		student assistant				technical expert /int. Specialist			consultant	educationalist	
1.3	development	own development					external assisted development					external development		
1.4	initial funding	internal funds					public funds					company funds		
1.5	ongoing funding	internal funds					public funds					company funds		
1.6	funding continuity	short term funding (e.g. single events)					mid term funding (projects and programs < 3 years)					long term funding (projects and programs > 3 years)		
1.7	business model for trainings	open models						closed models (training program only for single company)						
		club model		course fees										

Tknika is a publicly funded research center promoted by the Vice-Ministry of Vocational Training of the Department of Education of the Basque Government. Through networking and direct involvement by the Basque Vocational Training teaching staff, the Centre develops innovative projects in the areas of technology, education and management.

PURPOSE AND TARGETS

2.1	**main purpose**	education	vocational training	research								
2.2	**secondary purpose**	test environment / pilot environment	industrial production	innovation transfer	advertisement for production							
2.3	**target groups for education & training**	pupils	students	employees						entrepreneurs	freelancer	unemployed
			bachelor	master	phd students	apprentices	skilled worker	semi-skilled workers	unskilled	managers		open public
										lower mgmt	middle mgmt	top mgmt
2.4	**group constellation**	homogeneous	heterogeneous (knowledge level, hierarchy, students + employees, etc.)									
2.5	**targeted industries**	mechanical & plant eng.	automotive	logistics	transportation	FMCG	aerospace					
		chemical industry	electronics	construction	insurance / banking	textile industry	...					
2.6	**subject-rel. learning contents**	prod. Mgmgt & org.	resource efficiency	lean mgmt	automation	CPPS	work system design	HMI	design	Intralogistics design & mgmt	...	
2.7	**role of LF for research**	research object	research enabler									
2.8	**research topics**	production management & organization	resource efficiency	lean mgmt	automation	CPPS	changeability	HMI	didactics	...		

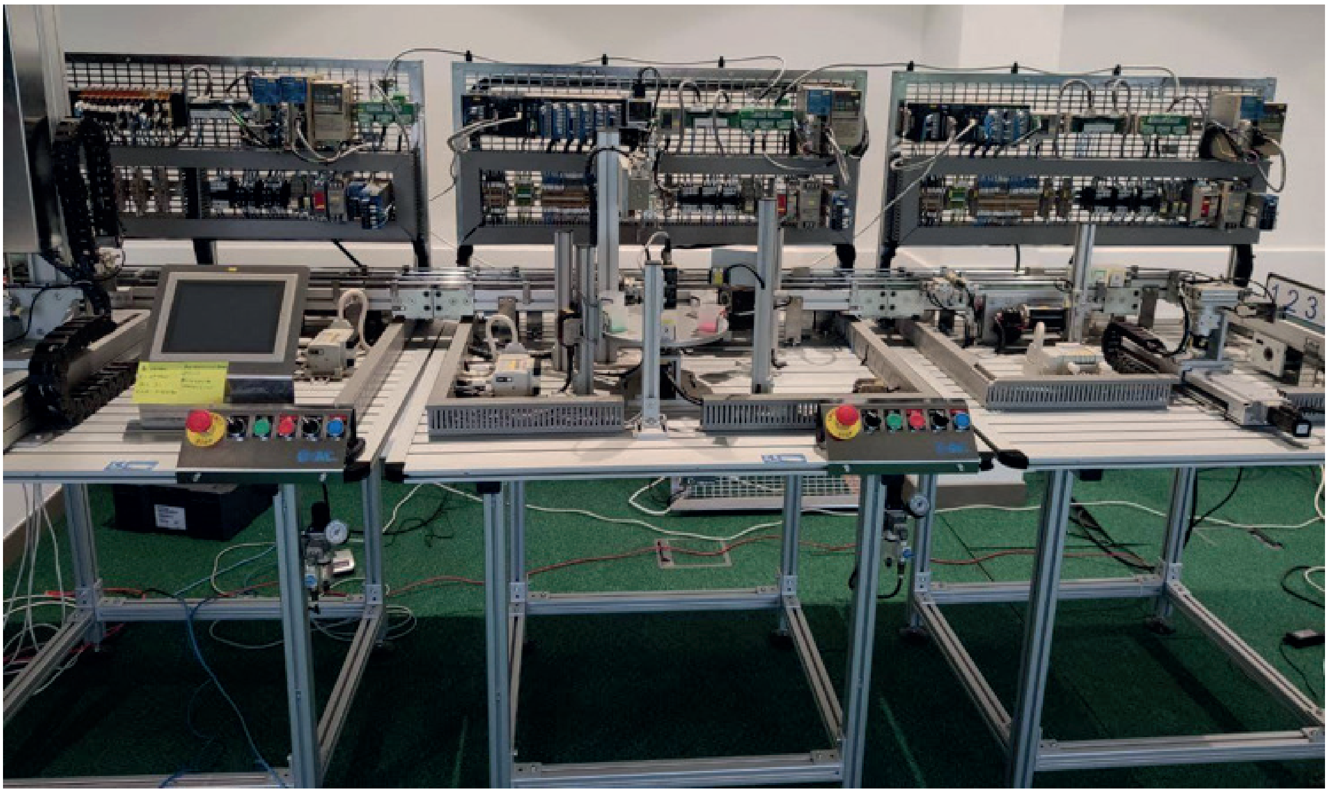
Tknika's main objective is to reduce the gap between educational needs and the constant evolution of technology. To do so, we believe that teacher training and networking are the main tools to be used. Since 2005, Tknika has played a key role in this field, involving high schools in large national and international projects and working with all kinds of new technologies. The way of working is through projects, where a group of teachers are released to develop and didactify these new technologies. First it is developed in Tknika and, once consolidated, it is transferred to the centers.

In this area of research we work with different layouts to simulate different cybersecurity levels in industry (IT/OT segmented or not, firewalls...) with the aim of acquiring and transferring this knowledge. In order to achieve this layouts, the lab includes the following technologies:

In this Lab we have been working in 3 main research topics:

- Rack with firewalls and switches
- IT zone, 3 PC-s
- OT zone, 3 Cells with different processes, Omron PLC-s
    - Storage simulating zone
    - Identification zone
    - Classification zone
- OT zone, DIN rail with 2 Siemens PLC and a signal tower
- Honeypot system

1. DEVELOPMENT OF CYBERSECURITY IN OT, OMRON CASE:



In this area of research we collaborate closely with SMC International Training in the development and testing of its training equipment for Industry 4.0 (SIF-400). This equipment includes the following technologies:

- Product traceability systems: RFID.

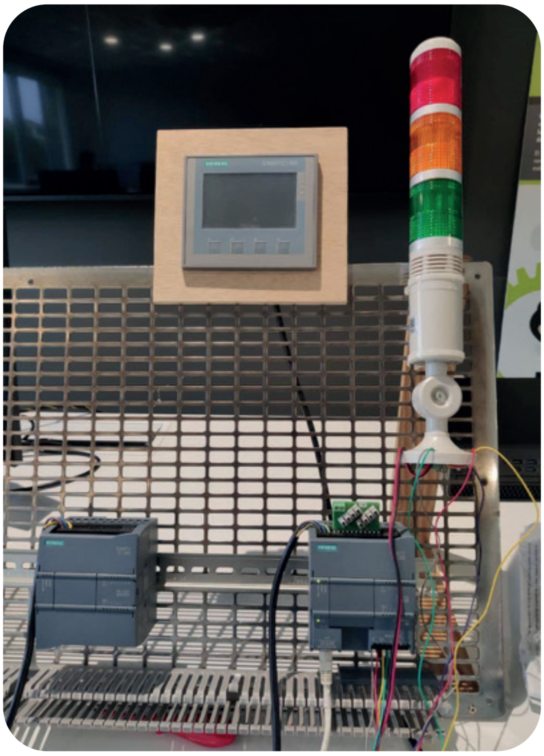
- PLC-s with possibility of inserting scripts to store data directly in DB

Application:

- **Teacher training:** At this moment we are already in the phase of transferring the knowledge acquired in the project.

- **Visits:** The laboratory has been intensively used in visits to Tknika. The system has made it easy to clearly and quickly explain the concept of Industrial Cybersecurity to visitors.

2. DEVELOPMENT OF CYBERSECURITY IN OT, SIEMENS CASE:



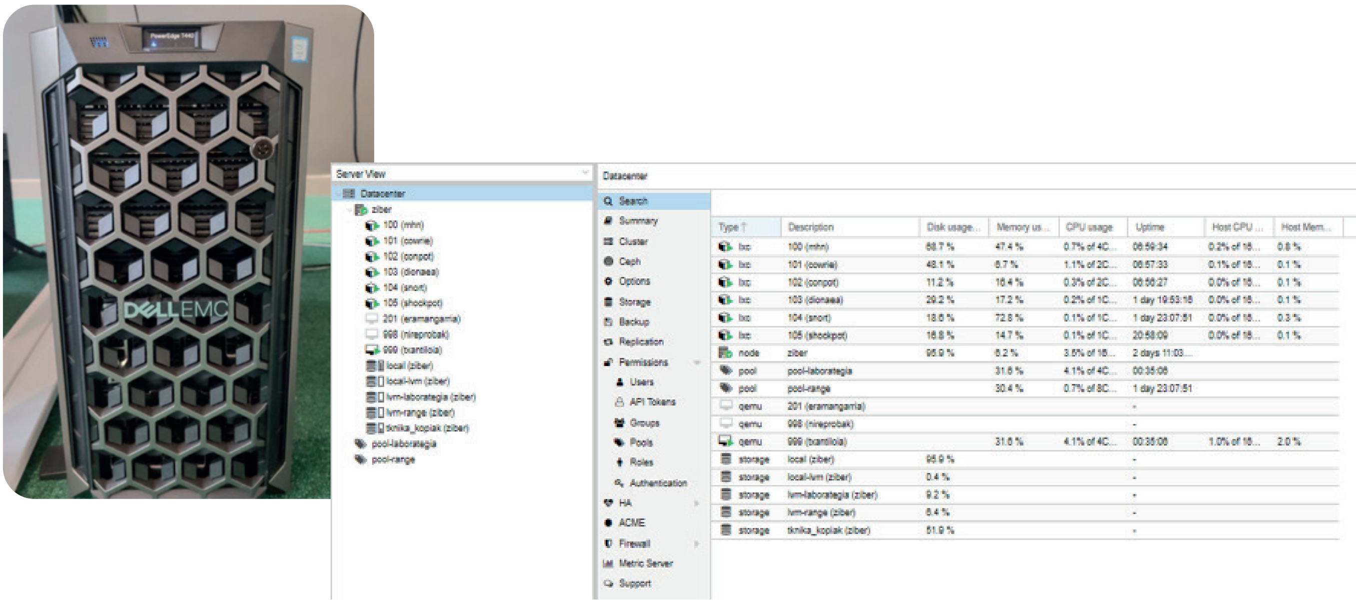
In this area of research we work researching the vulnerability of the system, specifically Siemens, to train in development of secure systems. Although this is not a cell, it is enough to develop secure systems, research about different siemens protocols.

Application:

- **Teacher training:** At this moment we are already in the phase of transferring the knowledge acquired in the project.

- **Visits:** The laboratory has been intensively used in visits to Tknika. The system has made it easy to clearly and quickly explain the concept of Industrial Cybersecurity to visitors.

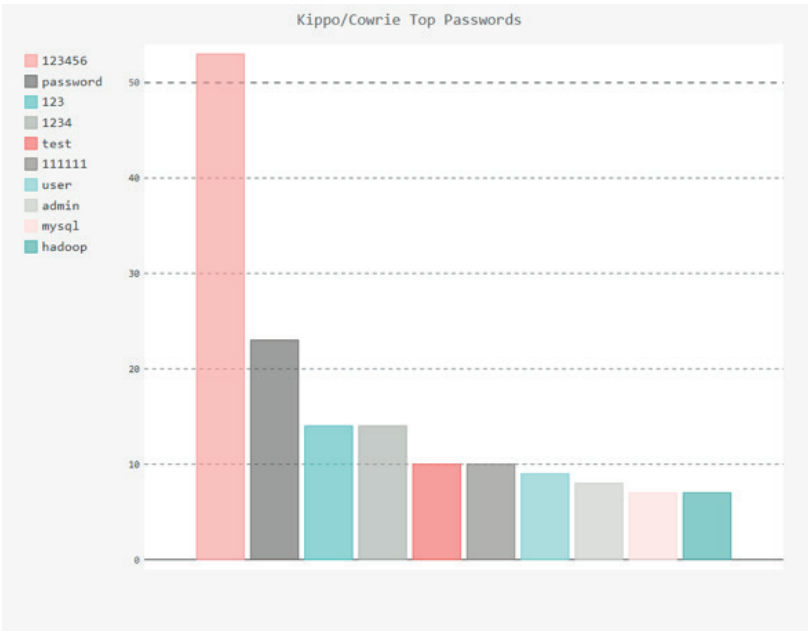
3. HONEYPOT:



In this area of research we work researching the vulnerability of IT systems, to train in development of secure IT systems.

Application:

- **Teacher training:** Recover information about actual attacks to prevent and identify system vulnerabilities and also collect all the vulnerable passwords and user/password combinations to show, prevent and share these information with VET teachers.



4. IT ZONE

In this area of research we work researching the vulnerability of IT systems, to train in development of secure IT systems.

Application:

Develop protection against attacks in IT systems such as DDOS, malware, ransomware...

PROCESS

<table>
<tr><td>3.1</td><td>product life cycle</td><td>product planning</td><td>product development</td><td>product design</td><td>rapid prototyping</td><td>manufacturing</td><td colspan="2" rowspan="4">assembly</td><td rowspan="4">logistics</td><td colspan="2">service</td><td>recycling</td></tr>
<tr><td>3.2</td><td>factory life cycle</td><td>investment planning</td><td>factory concept</td><td>process planning</td><td>ramp-up</td><td>manufacturing</td><td colspan="2">maintenance</td><td>recycling</td></tr>
<tr><td>3.3</td><td>order life cycle</td><td>configuration & order</td><td>order sequencing</td><td colspan="2">production planning and scheduling</td><td>manufacturing</td><td colspan="2">picking, packaging</td><td>shipping</td></tr>
<tr><td>3.4</td><td>technology life cycle</td><td>planning</td><td>development</td><td colspan="2">virtual testing</td><td>manufacturing</td><td colspan="2">maintenance</td><td>modernization</td></tr>
<tr><td>3.5</td><td>indirect functions</td><td>SCM</td><td>sales</td><td colspan="2">purchasing</td><td>HR</td><td colspan="3">finance / controlling</td><td colspan="3">QM</td></tr>
<tr><td>3.6</td><td>material flow</td><td colspan="4">continuous production</td><td colspan="7">discrete production</td></tr>
<tr><td>3.7</td><td>process type</td><td colspan="2">mass production</td><td colspan="2">serial production</td><td colspan="5">small series production</td><td colspan="2">one-off production</td></tr>
<tr><td>3.8</td><td>manufact. organization</td><td colspan="2">fixed-site manufacturing</td><td colspan="2">work bench manufacturing</td><td colspan="5">workshop manufacturing</td><td colspan="2">flow production</td></tr>
<tr><td>3.9</td><td>degree of automation</td><td colspan="2">manual</td><td colspan="5">partly automated / hybrid automation</td><td colspan="4">fully automated</td></tr>
<tr><td>3.10</td><td>manufact. Methods</td><td>cutting</td><td colspan="2">trad. primary shaping</td><td>additive manufact.</td><td colspan="2">forming</td><td>joining</td><td>coating</td><td colspan="3">change material properties</td></tr>
<tr><td>3.11</td><td>manufact. Technology</td><td colspan="3">physical</td><td colspan="4">chemical</td><td colspan="4">biological</td></tr>
</table>

Specific equipment used in the LAB:

• **CYBER PHYSICAL SYSTEM FOR CYBERSECURITY, USING SMC´S ITS-200 - INNOVATIVE TRAINING SYSTEM:**

• Cell 1, ITS-201: Automatic warehouse:

Storage simulation zone. This first station represents an automatic warehouse where the containers are stored and picked up.

Material movement is selected by a HMI (Human-Machine Interface). It extracts products from the warehouse and transfers them to the conveyor belt or vice versa. The part is a moulded-plastic container, which includes a number code and an identifying colour. Inside is an RFID tag and coloured nylon blocks.

ITS-201: Automatic warehouse

• Cell 2, ITS-202: Inspection

Identification zone. This second station inspects the different workpieces. The results of this inspection are transferred to the RFID memory inside each product.

• Cel 3, ITS-203: Classification and delivery -

Classification zone. - The third and last station classifies the different products and dispatches them depending on the data stored in the RFID memory.

All the stations have the following common features: *Extruded aluminium base structure, stainless steel front with on / off switch and emergency push button, electric actuators, industrial controller.*

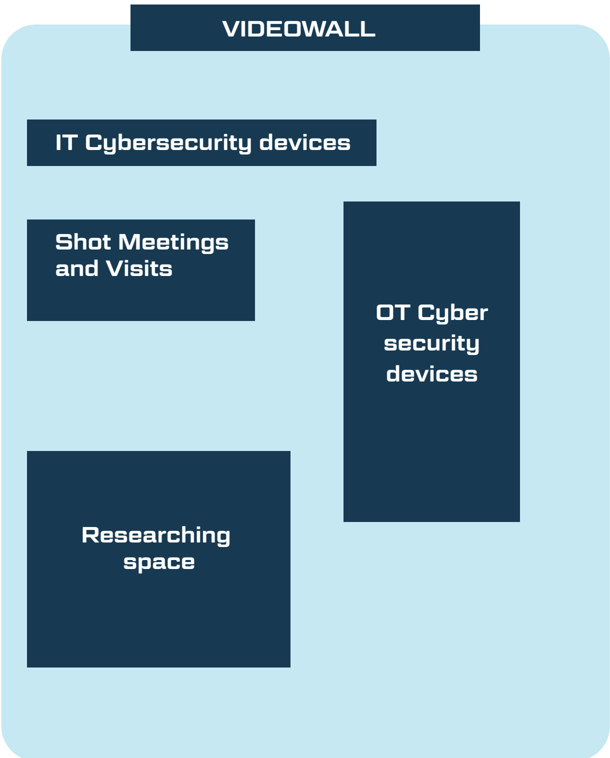
SETTING

4.1	learning environment	purely physical (planning + execution)	physical LF supported by digital factory (seeline "IT-Integration")		physical value stream of LF extended virtually		purely virtual (planning + execution)
4.2	environment scale	scaled down			life-size		
4.3	work system levels	work place	work system		factory		network
4.4	enablers for changeability	mobility	modularity	compatibility		scalability	universality
4.5	changeability dimensions	layout & logistics	product features	product design		technology	product quantities
4.6	IT-integration	IT before SOP (CAD, CAM, simulation)		IT after SOP (PPS, ERP, MES)		IT after production (CRM, PLM…)	

For what purpose are different IT-integrations used:

The laboratory is well suited both for research purposes and as a showroom. As you enter the lab, you can see the research and working space, but the great video wall and IT and OT spaces get the attention sooner than later.

As the visitor enters the room, he will see live online cyberattack attempts from all over the world, as the video wall shows our honeypots' live events. After showing IT related issues, focus is set on the OT devices, and after a brief explanation about how it works, we show how the devices can be compromised.



5.1	materiality	material (physical product)					immaterial (service)	
5.2	form of product	general cargo				bulk goods	flow products	
5.3	product origin	own development			development by participants		external development	
5.4	marketability of product	available on the market			available on the market but didactically simplified		not available on the market	
5.5	functionality of product	functional product			didactically adapted product with limited functionality		without function / application, for demonstration only	
5.6	no. of different products	1 product	2 products	3-4 products	> 4 products	flexible, developed by participants	acceptance of real orders	
5.7	no. of variants	1 variant	2-4 variants	4-20 variants	...	flexible, depending on participants	determined by real orders	
5.8	no. of components	1 comp.	2-5 comp.	6-20 comp.	21-50 comp.	51-100 comp.	> 100 comp.	
5.9	further product use	re-use / re-cycling		exhibition / display	give-away	sale		disposal

Further description of the products manufactured in the LAB

In the laboratory we can differentiate the following types of products and services:

1.IT cybersecurity services:

On the one hand, we research and identify common vulnerabilities of IT systems, create and transfer knowhow about IT cybersecurity to train in development of secure IT systems, and create and deploy different premade scenarios in order to support these trainings.

On the other hand, we use the different premade scenarios to explain quickly and clearly the IT cybersecurity state of the art to different visitors in real time.

2. OT cybersecurity Services

Same concept applies to the OT cybersecurity services. On the one hand, we research and identify common vulnerabilities of the OT systems that get, then create and transfer knowhow about them.

On the other hand, we also use the different pre-made scenarios to explain quickly and clearly the OT cybersecurity state of the art to different visitors in real time.

6.1	competence classes	technical and methodological competencies	social & communication competencies	personal competencies	activity and implementation oriented competencies		
6.2	dimensions learn. targets	cognitive	affective	psycho-motorical			
6.3	learn. scenario strategy	instruction	demonstration	closed scenario	open scenario		
6.4	type of learn. environment	greenfield (development of factory environment)	brownfield (improvement of existing factory environment)				
6.5	communication channel	onsite learning (in the factory environment)	remote connection (to the factory environment)				
6.6	degree of autonomy	instructed	self-guided / self-regulated	self-determined/ Selforganized			
6.7	role of the trainer	presenter	moderator	coach	instructor		
6.8	type of training	tutorial	practical lab course	seminar	workshop	project work	
6.9	standardization of trainings	standardized trainings	customized trainings				
6.10	theoretical foundation	prerequisite	in advance (en bloc)	alternating with practical parts	based on demand	afterwards	
6.11	evaluation levels	feedback of participants	learning of participants	transfer to the real factory	economic impact of trainings	return on trainings / ROI	
6.12	learning success evaluation	knowledge test (written)	knowledge test (oral)	written report	oral presentation	practical exam	none

Specific competencies trained in the lab/trained with the technologies in the LAB:
Skills trained in the lab/trained with the technologies in the LAB:

Learning outcomes:

Most of the training is designed using blended learning. This type of learning aims to use two strategies, face-to-face and virtual, taking the best of both at all times. Flipped Classroom (FC) or webinar tools such as "Zoom" or "Google Meet" are used to move the work of certain learning processes outside the classroom and class time is used.

Also Moodle and google drive is used to share information and provide the students with the information, app and notifications of the transfer or webinar.

As mentioned above, the results of the projects worked on in Tknika in the form of knowledge transfer are aimed at training VET teachers who teach at EFQ levels 5,, so all training is adapted to these levels.

On the other hand, in Tknika we have an area specialized in methodology called "Learning and High Performance" that promotes collaborative learning based on challenges, so the training is also adapted to this working method.

METRICS

7.1	**no. of participants per training**	1-5 participants	5-10 participants	10-15 participants	15-30 participants	30> participants	
7.2	**no. of standardized trainings**	1 training	2-4 trainings	5-10 trainings		> 10 trainings	
7.3	**aver. duration of a single training**	≤ 1 day	> 1 day until ≤ 2 days	> 2 days until ≤ 5 days	> 5 days until ≤ 10 days	> 10 days until ≤ 20 days	> 20 days
7.4	**participants per year**	< 50 participants	50-200 participants	201-500 participants	501-1000 participants	> 1000 participants	
7.5	**capacity utilization**	< 10%	> 10 until ≤ 20%	> 20%until ≤ 50%	> 50%until ≤ 75%	> 75%	
7.6	**size of LF**	≤ 100 sqm	> 100 sqm bis ≤ 300sqm	> 300sqm bis ≤ 500sqm	>500 sqm bis ≤ 1000sqm	> 1000 sqm	
7.7	**FTE in LF**	< 1	02-abr	05-sep	oct-15	> 15	

In the laboratory we have two types of knowledge transfer, one aimed at VET teachers involved in IT and the other one involved in OT.

Both of them are usually of advanced type and with a long duration that can range from 2 days to 10, although shorter and 1 day transfer can be done depending on the topic we are dealing with.

FURTHER INFORMATION & ASPECTS TO IMPROVE

8.1	**Further information**	photographs	video
8.2	**Aspect to improve**	technical	methodological

Further information (link to video):

https://youtu.be/tXKAPhRrB_g

Industry 4.0 Factory LAB 3

Name of the lab:

Welding and Additive Manufacturing (WAAM-Plasma) Lab

General aim/purpose (short summary):
Lab dedicated to automated welding and the Research in the field of Additive Manufacturing applications based in wire and arc processes. Training of VET teachers.

Year of inauguration:

2007

LAB size (square metres):

210

General information - summary table

Name of the lab: Metal Additive Manufacturing – WAAM Plasma Lab

General aim/purpose:

Tknika is a centre promoted by the Deputy Ministry of Vocational Education and Training of the Education Department of the Basque Government. Innovation and applied research are at the core of Tknika in its ongoing efforts to place Basque Vocational Training at the European forefront. Through networking and direct involvement by the Basque Vocational Training teaching staff, the Centre develops innovative projects in the areas of technology, education and management. In Tknika there are different labs where applied innovation projects related to the industry are developed.

Tknika is behind a drive to create an area of expertise, which apart from Tknika's own processes, includes projects related to Additive Manufacturing in different vocational training centres.

This involves the development of the following:

- **At Elgoibar IMH [Institute of machinery and tools]:**
LMD (Laser Metal Deposition) technology, consisting of the fusion, using a laser, of metallic material in powder form supplied through a coaxial head, which provides the material in the area where the laser beam is acting along the routes set for the production of the part.

- **At Goierri Eskola in Ordizia:**
SLM (Selective Laser Melting) technology, consisting of the selective fusion of thin layers of powder that have previously been deposited, over which a laser beam melts only the required section in each layer.

- **At Tknika:**
arc plasma technology with the contribution of a thread belonging to the DED (Direct Energy Deposition) group, which basically consists of the ordered provision of material in a molten bath format, as a result of fusing a metal wire resulting from a plasma electric arc.

GENERAL INFORMATION	Name of the LAB	**Welding and Additive Manufacturing Lab**	MAIN PURPOSE	
	VET/HVET centre	TKNIKA, Applied Research Centre	Education	
	Floor space of the lab (sqm)	210	Training	X
	Main topic/learning content	Arc and Wire Additive Manufacturing Directed Energy Deposition Processes (WAAM additive Manufacturing) – Automated welding processes	Research/Applied innovation	X
	I4.0 related technologies	Monitoring and process control, data analytics, robotics		
PURPOSE	Learning content	Applied Research		
	Secondary purpose	Teacher training		
	LAB type	Specific	Mixed	Learning Factory

		Name of the programmes carried out on the Lab	EQF Level	Lab hours	Nº subjects on the lab	Hour/Week x nº of weeks	Nº students (3)
LEARNING CONTENTS	Learning programmes/study programmes/levels	Robot programming and WAAM Applications	5	20	2	-	12
		Off-line robot programming software	5	30	2	-	12
		Introduction to Additive Manufacturing technologies, applications, and standards	5	20	3	-	12

SETTINGS	Nº of cell	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5	Cell 6	Cell 7	Cell 8	Cell 9
	Category of cell	Robot Welding Cell	WAAM Plasma machine	X	X	X	X	X	X	X
	Nº machines	3	2	Y	Y	Y	Y	Y	Y	Y
	I4.0 Enabler technologies used and implementation level	Robotics	Additive Manufacturing	Cloud	CPS	Mobile/Tablet	AR/VR	Big data analytics	Ai	IoT/IIoT
		Sensors/Actuators	RFID	M2M	Cybersecurity	Digital twin				

Specific lab: : A lab designed and set up to teach/learn a specific technology. This could be the case for Additive manufacturing labs, Robotics labs, IoT labs (didactic labs by Festo, SMC and others) etc

Mixed lab: The main purpose of the lab is not a (i4.0) specific technology but those technologies that are implemented to complement the main activity. It could be: Machining labs with retrofitted machines with sensors and data acquisition systems included, metal forming labs where cobots/robots are implemented etc

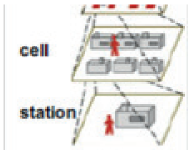
Learning Factory:

Study programmes: The learning activities carried out in the labs are usually a part of a wider programme. The name of the programme and its EQF level is marked. The hours are referred to the hours spent on activities in the lab.

The number of subjects is referred to the different subjects or areas that could be covered by a group in the lab. They can be considered as the number of separate training activities.

Nº students and groups per week in the lab. 3x20 means 3 groups of 20 students each. The timetable and schedule would be distributed in different days/hours in the lab in a period. This is the max number of students/groups that can be working simultaneously in the labs.

Cell/area: Part of the lab that groups a number of machines. Cells can be divided in 2 types:

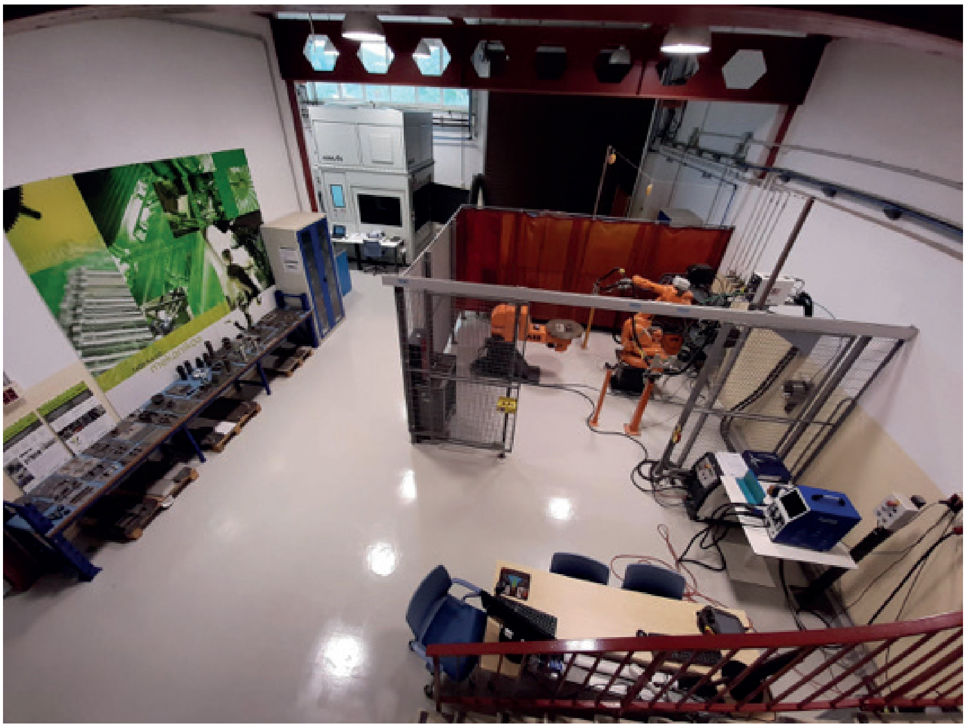


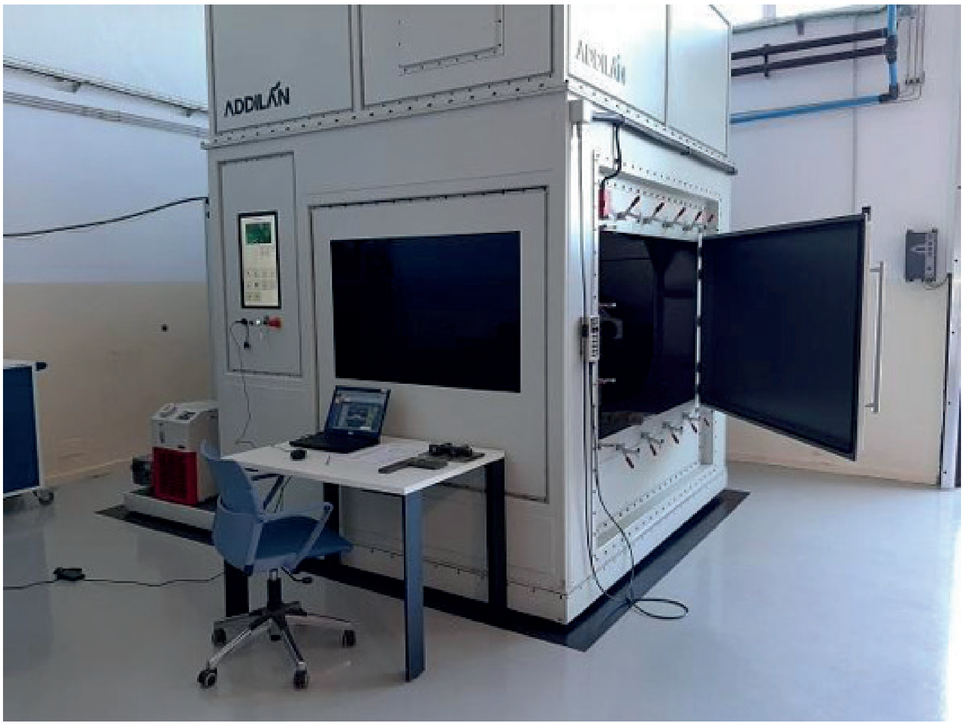
a) Cells with machines with similar characteristics.

b) Cells with a sequenced number of machines where consecutive operations are carried out.

Usage level:	Fully implemented	Implemented to certain degree	Planned to implement	Not implemented

Lab overview:





OPERATIONAL MODEL

1.1	**operator**	academic institution				non-academic institution							profit-oriented operator	
		university	college		BA	vocational school / high school			chamber	union	employers´ association	industrial network	consulting	producing company
1.2	**trainer**	professor	researcher		student assistant				technical expert /int. Specialist			consultant	educationalist	
1.3	**development**	own development					external assisted development					external development		
1.4	**initial funding**	internal funds					public funds					company funds		
1.5	**ongoing funding**	internal funds					public funds					company funds		
1.6	**funding continuity**	short term funding (e.g. single events)					mid term funding (projects and programs < 3 years)					long term funding (projects and programs > 3 years)		
1.7	**business model for trainings**	open models						closed models (training program only for single company)						
		club model		course fees										

Tknika is a publicly funded research centre promoted by the Vice-Ministry of Vocational Training of the Department of Education of the Basque Government.

It is a technical body responsible for research and applied innovation, and the transfer of the results of R&D&I projects to all centres providing vocational education and training in the Basque Country. The purposes are the following:

- To research vocational training and applied innovation, encouraging centres that provide vocational training to enter into relationships with companies, technological centres and different university and non-university research departments.
- To train professors at centres who provide vocational training on different technologies that arise in different production sectors.
- To make progress in new settings that improve different learning processes, driving internationalisation of vocational training and permanently improving vocational training.
- To promote entrepreneurial activity with students, through the centres providing vocational training.

PURPOSE AND TARGETS

2.1	**main purpose**	education	vocational training	research												
2.2	**secondary purpose**	test environment / pilot environment	industrial production	innovation transfer	advertisement for production											
2.3	**target groups for education & training**	pupils	students			employees							entrepreneurs	freelancer	unemployed	open public
			bachelor	master	phd students	apprentices	skilled workers	semi-skilled workers	unskilled	managers						
										lower mgmt	middle mgmt	top mgmt				
2.4	**group constellation**	homogeneous	heterogeneous (knowledge level, hierarchy, students + employees, etc.)													
2.5	**targeted industries**	mechanical & plant eng.	automotive	logistics	transportation	FMCG	aerospace									
		chemical industry	electronics	construction	insurance / banking	textile industry	…									
2.6	**subject-rel. learning contents**	prod. Mgmgt & org.	resource efficiency	lean mgmt	automation	CPPS	work system design	HMI	design	Intralogistics design & mgmt	…					
2.7	**role of LF for research**	research object	research enabler													
2.8	**research topics**	production management & organization	resource efficiency	lean mgmt	automation	CPPS	changeability	HMI	didactics	…						

Tknika's main objective is to reduce the gap between educational needs and the constant evolution of technology. To do so, we believe that teacher training and networking are the main tools to be used. Since 2005, Tknika has played a key role in this field, involving high schools in large national and international projects and working with all kinds of new technologies. The way of working is through projects, where a group of teachers are released to develop and didactify these new technologies. First it is developed in Tknika and, once consolidated, it is transferred to the centres.

One of the technologies we have been working on in recent years is Metal Additive Manufacturing.

GENERAL AIM/PURPOSE:

Additive Manufacturing is a technology that is currently undergoing major development and one that is associated with different lines of development, some of which we are working on and interested in:

- The development of practical cases of application in industry, defining manufacturing strategies and procedures.
- The design, simulation and CAM softwares, according to the needs of each process.
- The monitoring technology, process control.
- To metallurgical behaviour of the materials, treatments and residual stresses.

The overall objective of this project is to promote the development of Additive Manufacturing in the Basque Country, as one of the key aspects in advanced "manufacturing". As a result, we at Tknika need to do the following:

- Be familiar with the state of the art related to the Additive Manufacturing processes.
- Achieve mastery of the plasma Additive Manufacturing process, to become a reference point for vocational training centres.
- Develop and expand the use of Additive Manufacturing and its associated solutions, among the VET centres and via this latter, onto the companies.

Areas of competence:

- Welding processes MIG-MAG, TIG and Plasma
- Wire and Arc Additive Manufacturing (WAAM) process in a robot cell
- Wire and Arc Additive Manufacturing (WAAM) process in a additive specific machine
- Robot and machine programming for general purpose and for WAAM application.

PROCESS

3.1	**product life cycle**	product planning	product development	product design	rapid prototyping	manufacturing	assembly		logistics	service		recycling
3.2	**factory life cycle**	investment planning	factory concept	process planning	ramp-up					maintenance		recycling
3.3	**order life cycle**	configuration & order	order sequencing	production planning and scheduling						picking, packaging		shipping
3.4	**technology life cycle**	planning	development	virtual testing						maintenance		modernization
3.5	**indirect functions**	SCM	sales	purchasing		HR	finance / controlling			QM		
3.6	**material flow**	continuous production				discrete production						
3.7	**process type**	mass production		serial production		small series production					one-off production	
3.8	**manufact. organization**	fixed-site manufacturing		work bench manufacturing		workshop manufacturing					flow production	
3.9	**degree of automation**	manual		partly automated / hybrid automation					fully automated			
3.10	**manufact. Methods**	cutting	trad. primary shaping		additive manufact.	forming		joining	coating		change material properties	
3.11	**manufact. Technology**	physical			chemical				biological			

Specific equipment used in the LAB:

• Robot cell

The robotic cell is composed of an industrial arm with a reach of 1.45 meters and a two-axis positioner with a capacity of 250 kg.

The robotic cell can work independently with the following two welding processes:

- MIG-MAG process
- Plasma arc process

• Specific WAAM machine - ADDILAN A0.1 machine for WAAM-Plasma within Fronius welding machine:

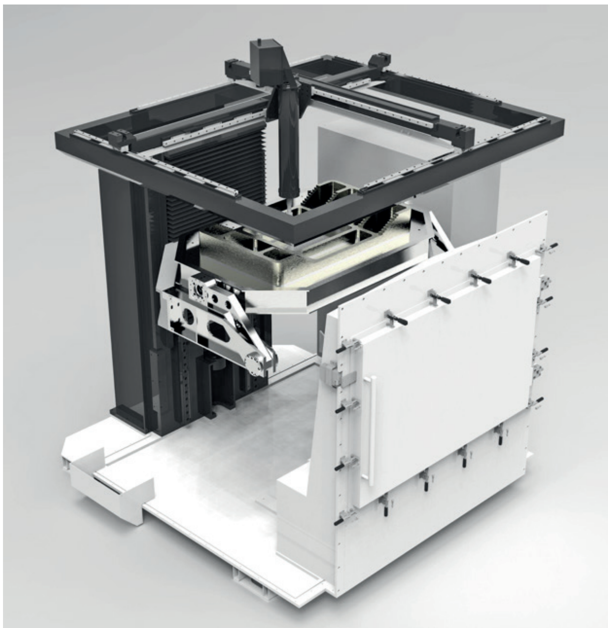
- This machine is based on WAAM technology and are designed to offer a competitive alternative to manufacturers of high added value components.

- They are fitted with a closed loop control system and an inert chamber with a special loading and unloading system.

- The unit guarantees top-quality of the piece during the manufacturing process.

- Among the materials we work with at ADDILAN are steel, titanium alloys, superalloys and aluminium alloys.

https://www.addilan.com/en/



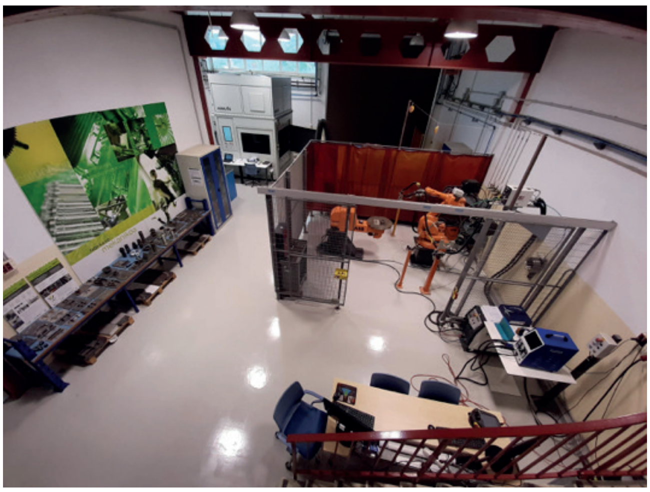
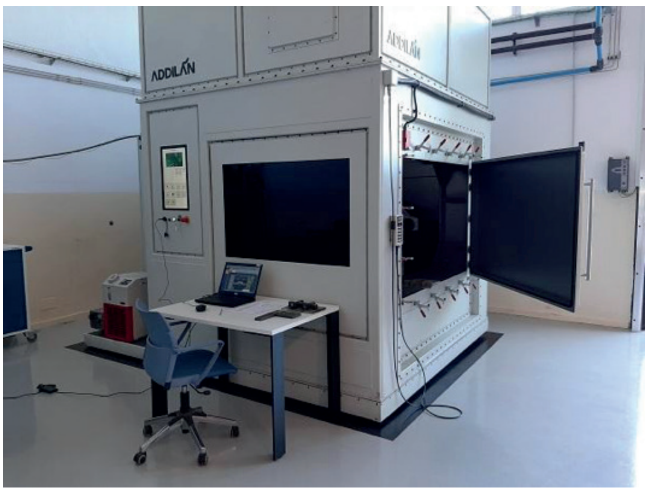
SETTING

4.1	**learning environment**	purely physical (planning + execution)	physical LF supported by digital factory (seeline "IT-Integration")		physical value stream of LF extended virtually		purely virtual (planning + execution)
4.2	**environment scale**	scaled down			life-size		
4.3	**work system levels**	work place	work system		factory		network
4.4	**enablers for changeability**	mobility	modularity	compatibility		scalability	universality
4.5	**changeability dimensions**	layout & logistics	product features	product design		technology	product quantities
4.6	**IT-integration**	IT before SOP (CAD, CAM, simulation)		IT after SOP (PPS, ERP, MES)		IT after production (CRM, PLM…)	

The additive manufacturing and welding workshop is a space of approximately 210 m2, organized in three areas:

- The first area is occupied by the robot and positioning cell, where welding and wire and arc additive manufacturing (WAAM) solutions are developed.
- The second space is occupied by the metal additive manufacturing Addilan machine for the manufacture of large-format parts.
- The third and last space is a multipurpose space, where we can find different welding processes and machines: MIG-MAG and TIG.

Below we can see two images of the described workshop:

For what purpose are different IT-integrations used:

WAAM machine:

- Welding vision camera – process control and register
- Pyrometers – temperature control
- csv files analysis - process control, data analytics and machine learning

Robot cell:

- Simulation and off-line programming software

PRODUCT

5.1	**materiality**	material (physical product)					immaterial (service)		
5.2	**form of product**	general cargo				bulk goods		flow products	
5.3	**product origin**	own development			development by participants			external development	
5.4	**marketability of product**	available on the market			available on the market but didactically simplified			not available on the market	
5.5	**functionality of product**	functional product			didactically adapted product with limited functionality			without function / application, for demonstration only	
5.6	**no. of different products**	1 product	2 products	3-4 products	> 4 products	flexible, developed by participants		acceptance of real orders	
5.7	**no. of variants**	1 variant	2-4 variants	4-20 variants	…	flexible, depending on participants		determined by real orders	
5.8	**no. of components**	1 comp.	2-5 comp.	6-20 comp.		21-50 comp.	51-100 comp.		> 100 comp.
5.9	**further product use**	re-use / re-cycling		exhibition / display		give-away	sale		disposal

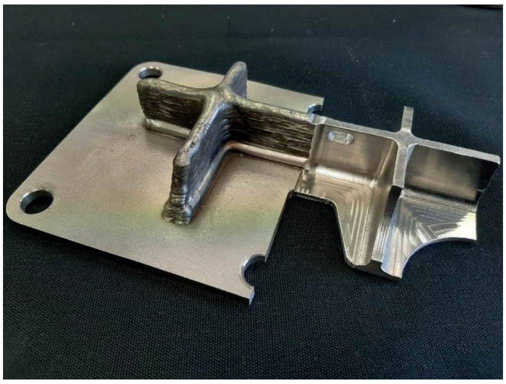
The wire and arc additive manufacturing (WAAM) process is a process still under development that is having an important boom in recent years. It is especially interesting for the manufacture of medium and large format pieces with high added value materials.

There are many application sectors for which these types of parts can be manufactured: aeronautical, space, oil and gas, etc.

The main outcomes generated in this project line are:

- Demonstrative WAAM parts (different applications, geometries, size, and materials).
- Knowledge related to the WAAM process.
- Courses focused on VET system teachers.

Below we can see several examples of the manufactured parts:



Case study published for ADDIMAT, the Additive & 3D Manufacturing Technologies Association of Spain:

https://www.addimat.es/gestor/recursos/uploads/archivos/casestudies/EN/2021/manufacturing-of-a-demonstrator-using-WAAM-technology-on-the-Addilan-V01-machine.pdf

6.1	**competence classes**	technical and methodological competencies	social & communication competencies	personal competencies	activity and implementation oriented competencies		
6.2	**dimensions learn. targets**	cognitive	affective	psycho-motorical			
6.3	**learn. scenario strategy**	instruction	demonstration	closed scenario	open scenario		
6.4	**type of learn. environment**	greenfield (development of factory environment)	brownfield (improvement of existing factory environment)				
6.5	**communication channel**	onsite learning (in the factory environment)	remote connection (to the factory environment)				
6.6	**degree of autonomy**	instructed	self-guided / self-regulated	self-determined/ Selforganized			
6.7	**role of the trainer**	presenter	moderator	coach	instructor		
6.8	**type of training**	tutorial	practical lab course	seminar	workshop	project work	
6.9	**standardization of trainings**	standardized trainings	customized trainings				
6.10	**theoretical foundation**	prerequisite	in advance (en bloc)	alternating with practical parts	based on demand	afterwards	
6.11	**evaluation levels**	feedback of participants	learning of participants	transfer to the real factory	economic impact of trainings	return on trainings / ROI	
6.12	**learning success evaluation**	knowledge test (written)	knowledge test (oral)	written report	oral presentation	practical exam	none

Specific competencies trained in the lab/trained with the technologies in the LAB:

Skills trained in the lab/trained with the technologies in the LAB:

Learning outcomes:

Tknika, being a research centre where applied innovation projects are developed aimed at updating the knowledge of teachers of the Basque Vocational Training system, works on projects related to new areas of knowledge such as Industry 4.0, Cybersecurity, Additive Manufacturing, 3D Printing or Virtual and Augmented Reality.

Although in these types of specialization technical knowledge has a special relevance, in the training that we carry out derived from the projects we apply new training methodologies that improve the learning results. The results of the project are usually designed as an easy tool for teachers to integrate into the classroom, thus facilitating their integration within the modules they teach as much as possible.

The results of the projects worked on in Tknika in the form of knowledge transfer aim at training VET teachers who teach classes at EFQ levels 4 and 5, so all training is adapted to those levels.

Some of the learning outcomes that we are working on are described in the VET curricula and most of them are related with the welding processes and robotic and automation technologies for these applications. Apart from that are considered aspects related with materials, post processing operations and quality control.

https://ivac-eei.eus/es/familias-profesionales/fabricacion-mecanica-fme/ciclos-formativos/tecnico-superior-en-construcciones-metalicas.html

On the other hand, in Tknika we have an area specialized in methodology called "Learning and High Performance" that promotes collaborative learning based on challenges, so the training is also adapted to this working method.

METRICS

7.1	**no. of participants per training**	1-5 participants	5-10 participants	10-15 participants	15-30 participants	30> participants	
7.2	**no. of standardized trainings**	1 training	2-4 trainings	5-10 trainings		> 10 trainings	
7.3	**aver. duration of a single training**	≤ 1 day	> 1 day until ≤ 2 days	> 2 days until ≤ 5 days	> 5 days until ≤ 10 days	> 10 days until ≤ 20 days	> 20 days
7.4	**participants per year**	< 50 participants	50-200 participants	201-500 participants	501-1000 participants	> 1000 participants	
7.5	**capacity utilization**	< 10%	> 10 until ≤ 20%	> 20%until ≤ 50%	> 50%until ≤ 75%	> 75%	
7.6	**size of LF**	≤ 100 sqm	> 100 sqm bis ≤ 300sqm	> 300sqm bis ≤ 500sqm	>500 sqm bis ≤ 1000sqm	> 1000 sqm	
7.7	**FTE in LF**	< 1	02-abr	05-sep	oct-15	> 15	

In the laboratory we have two types of knowledge transfer, one aimed at VET teachers and the other aimed at a more general public who usually visit Tknika to see what we work on and how we do it.

In the first one the transfer is usually of advanced type and with a longer duration that can range from 1 day to 4 or 5, depending on the topic we are dealing with. And in the second the visits are usually of a duration of less than 1 day.

FURTHER INFORMATION & ASPECTS TO IMPROVE

8.1	**Further information**	photographs	video
8.2	**Aspect to improve**	technical	methodological

Further information (link to video):

- https://youtu.be/tXKAPhRrB_g
- WAAM demonstrative part images and process videos

Aspects to improve:

- New CAM programming solutions
- Post-process operations and treatments
- Material characterisation and testing - part properties
- WAAM process simulation software solutions
- Monitoring technologies
- Machine and WAAM process learning
- MIG process based WAAM solutions

Industry 4.0 Factory LAB 4

Name of the lab:

IKASLAB 3D Printing LAB

General aim/purpose (short summary):

Research in the field of additive manufacturing and reverse engineering, training of VET teachers

Year of inauguration:

2014

LAB size (square metres):

150

General information - summary table

Tknika is a centre promoted by the Deputy Ministry of Vocational Education and Training of the Education Department of the Basque Government. Innovation and applied research are at the core of Tknika in its ongoing efforts to place Basque Vocational Training at the European forefront. Through networking and direct involvement by the Basque Vocational Training teaching staff, the centre develops innovative projects in the areas of technology, education and management. In Tknika there are different labs where applied innovation projects related to the industry are developed.

The IKASLAB lab in Tknika is part of a net of labs in Basque VET system practising with additive manufacturing (AM) technologies, with the difference of working on advanced applications and using industrial equipment.

As we are a net, we share our experiences and equipment with other centers of the system, so we can also profit from experiences of the others and the integration of AM results faster and better.

Particularly in the lab of Tknika, this knowledge in advanced applications is developed by the use of Stratasys and HP additive manufacturing technologies, by digitalisation and reverse engineering processes and by the creation of biomodels in collaboration with hospitals.

The summary table below is established to present general information about the IKASLAB Lab. Further information about this lab in question, will be described additionally by the tables in the subsequent section.

GENERAL INFORMATION	Name of the LAB	IKASLAB	MAIN PURPOSE	
	VET/HVET centre	TKNIKA, Applied Research Centre	Education	
	Floor space of the lab (sqm)	180	Training	X
	Main topic/learning content	Additive Manufacturing technologies and applications	Research/Applied innovation	X
	I4.0 related technologies	Additive Manufacturing, Digitalisation technologies		
PURPOSE	Learning content	Applied Research		
	Secondary purpose	Teacher training		
	LAB type	Specific	Mixed	Learning Factory

LEARNING CONTENTS		Name of the programmes carried out on the Lab	EQF Level	Lab hours	Nº subjects on the lab	Hour/Week x nº of weeks	Nº students (3)
	Learning programmes/study programmes/levels	Polyjet Advanced applications	5	20	2	-	12
		Scan and Reverse Engineering	5	30	2	-	12
		Introduction to Additive Manufacturing technologies, applications, and standards	5	20	3	-	12

SETTINGS	Nº of cell	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5	Cell 6	Cell 7	Cell 8	Cell 9
	Category of cell	Fused Deposition Modeling (FDM)	Polyjet	Multijet Fusion	Scan	X	X	X	X	X
	Nº machines	3	2	Y	Y	Y	Y	Y	Y	Y
	I4.0 Enabler technologies used and implementation level	Robotics	Additive Manufacturing	Cloud	CPS	Mobile/Tablet	AR/VR	Big data analytics	Ai	IoT/IIoT
		Sensors/Actuators	RFID	M2M	Cybersecurity	Digital twin				

Specific lab: : A lab designed and set up to teach/learn a specific technology. This could be the case for Additive manufacturing labs, Robotics labs, IoT labs (didactic labs by Festo, SMC and others) etc

Mixed lab: The main purpose of the lab is not a (i4.0) specific technology but those technologies that are implemented to complement the main activity. It could be: Machining labs with retrofitted machines with sensors and data acquisition systems included, metal forming labs where cobots/robots are implemented etc

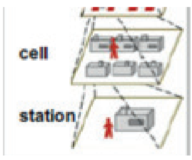
Learning Factory:

Study programmes: The learning activities carried out in the labs are usually a part of a wider programme. The name of the programme and its EQF level is marked. The hours are referred to the hours spent on activities in the lab.

The number of subjects is referred to the different subjects or areas that could be covered by a group in the lab. They can be considered as the number of separate training activities.

Nº students and groups per week in the lab. 3x20 means 3 groups of 20 students each. The timetable and schedule would be distributed in different days/hours in the lab in a period. This is the max number of students/groups that can be working simultaneously in the labs.

Cell/area: Part of the lab that groups a number of machines. Cells can be divided in 2 types:

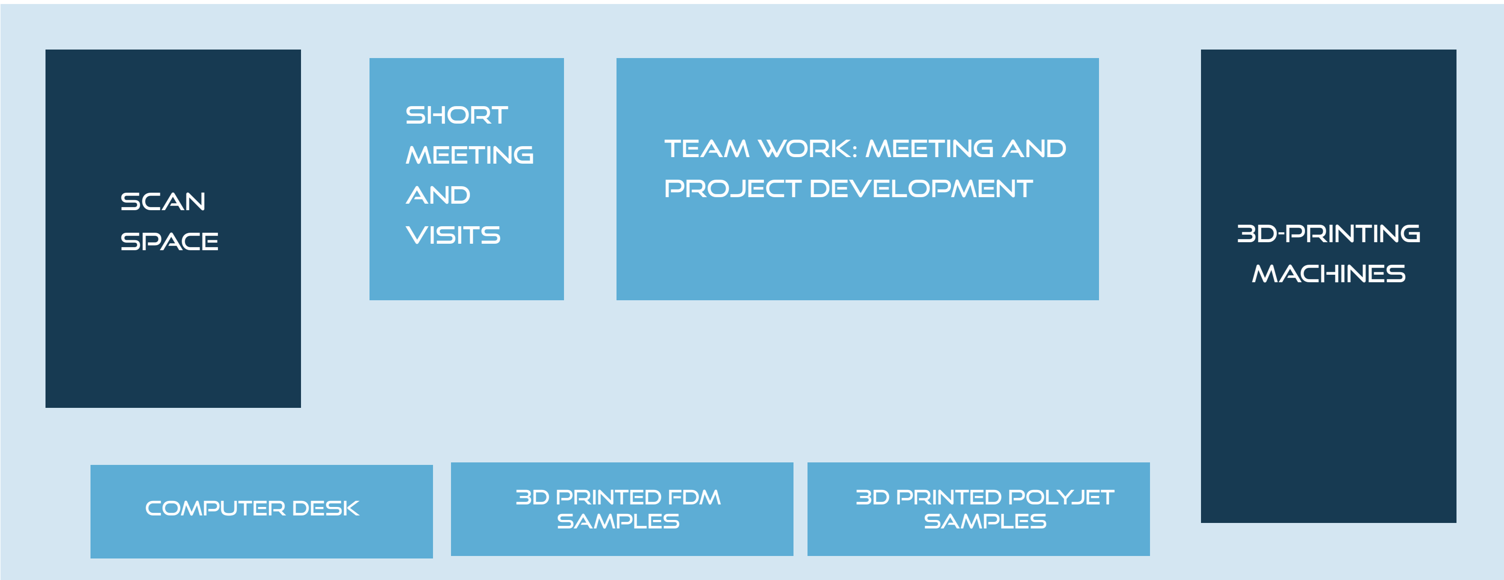


a) Cells with machines with similar characteristics.

b) Cells with a sequenced number of machines where consecutive operations are carried out.

Usage level: Fully implemented | Implemented to certain degree | Planned to implement | Not implemented

Principle Layout of the Research Lab:



OPERATIONAL MODEL

1.1	operator	academic institution			non-academic institution					profit-oriented operator	
		university	college	BA	vocational school / high school	chamber	union	employers´ association	industrial network	consulting	producing company
1.2	trainer	professor	researcher	student assistant		technical expert /int. Specialist			consultant	educationalist	
1.3	development	own development			external assisted development				external development		
1.4	initial funding	internal funds			public funds				company funds		
1.5	ongoing funding	internal funds			public funds				company funds		
1.6	funding continuity	short term funding (e.g. single events)			mid term funding (projects and programs < 3 years)				long term funding (projects and programs > 3 years)		
1.7	business model for trainings	open models			closed models (training program only for single company)						
		club model	course fees								

Tknika TKNIKA is a publicly funded research centre promoted by the Vice-Ministry of Vocational Training of the Department of Education of the Basque Government.

It is a technical body responsible for research and applied innovation, and the transfer of the results of R&D&I projects to all centres providing vocational education and training in the Basque Country. The purposes are the following:

- To research vocational training and applied innovation, encouraging centres that provide vocational training to enter into relationships with companies, technological centres and different university and non-university research departments.
- To train professors at centres who provide vocational training on different technologies that arise in different production sectors.
- To make progress in new settings that improve different learning processes, driving internationalisation of vocational training and permanently improving vocational training.
- To promote entrepreneurial activity with students, through the centres providing vocational training.

PURPOSE AND TARGETS

2.1	main purpose	education	vocational training	research								
2.2	secondary purpose	test environment / pilot environment	industrial production	innovation transfer	advertisement for production							
2.3	target groups for education & training	pupils	students	employees	entrepreneurs	freelancer	unemployed	open public				
			bachelor	master	phd students	apprentices	skilled workers	semi-skilled workers	unskilled	managers: lower mgmt	middle mgmt	top mgmt
2.4	group constellation	homogeneous	heterogeneous (knowledge level, hierarchy, students + employees, etc.)									
2.5	targeted industries	mechanical & plant eng.	automotive	logistics	transportation	FMCG	aerospace					
		chemical industry	electronics	construction	insurance / banking	textile industry	…					
2.6	subject-rel. learning contents	prod. Mgmgt & org.	resource efficiency	lean mgmt	automation	CPPS	work system design	HMI	design	Intralogistics design & mgmt	…	
2.7	role of LF for research	research object	research enabler									
2.8	research topics	production management & organization	resource efficiency	lean mgmt	automation	CPPS	changeability	HMI	didactics	…		

Tknika's main objective is to reduce the gap between educational needs and the constant evolution of technology. To do so, we believe that teacher training and networking are the main tools to be used. Since 2005, Tknika has played a key role in this field, involving high schools in large national and international projects and working with all kinds of new technologies. The way of working is through projects, where a group of teachers are released to develop and didactify these new technologies. As a first step it is developed in Tknika and, once consolidated, it is transferred to VET centers.

One of the technologies we have been working on in recent years is the concept of Additive Manufacturing. On the one hand there is a net of laboratories where students and teachers are trained to become 3d printer users, and on the other hand industrial equipment and software allow us to learn and experiment with advanced applications.

In this Lab we have been working in 3 main research topics:

- **1.Reverse Engineering:** scanning and reverse engineering processes now take more relevance as digitalization is now more and more demanded, combined or not with AM.
- **2.AM advanced processes:** Industrial AM technologies require their users a lot of dedication so this area of work needs to be developed as well.
- **3.BIomodel production for hospital applications:** in collaboration with hospitals, 3D biomodels are produced in 3D printers so surgeons can use them to improve their work in the hospital.

PROCESS

3.1	product life cycle	product planning	product development	product design	rapid prototyping	manufacturing	assembly		logistics	service		recycling
3.2	factory life cycle	investment planning	factory concept	process planning	ramp-up					maintenance		recycling
3.3	order life cycle	configuration & order	order sequencing	production planning and scheduling						picking, packaging		shipping
3.4	technology life cycle	planning	development	virtual testing						maintenance		modernization
3.5	indirect functions	SCM	sales	purchasing		HR	finance / controlling			QM		
3.6	material flow	continuous production				discrete production						
3.7	process type	mass production		serial production		small series production					one-off production	
3.8	manufact. organization	fixed-site manufacturing		work bench manufacturing		workshop manufacturing					flow production	
3.9	degree of automation	manual		partly automated / hybrid automation					fully automated			
3.10	manufact. Methods	cutting	trad. primary shaping		additive manufact.	forming		joining	coating		change material properties	
3.11	manufact. Technology	physical			chemical				biological			

The team of teachers participating in the lab develop projects that demonstrate the advantages of using these new technologies, by the design and manufacture of parts or assemblies. Additive manufacturing technologies and scanning processes are part of Industry 4.0 technologies, as they allow new scenarios in industry processes.

These are some of the best advantages:

- Prototyping faster and cheaper
- Lighter and more complex design
- Generative design and lattice structures design
- Custom design
- Reduction of parts in assemblies
- Material and energy waste reduction
- Inventory reduction
- Digitalization of complex surfaces' parts

As the equipment in the lab is shared with the network of laboratories of the Basque VET system, projects developed in other centers can also be materialised in the industrial machines of Tknika.

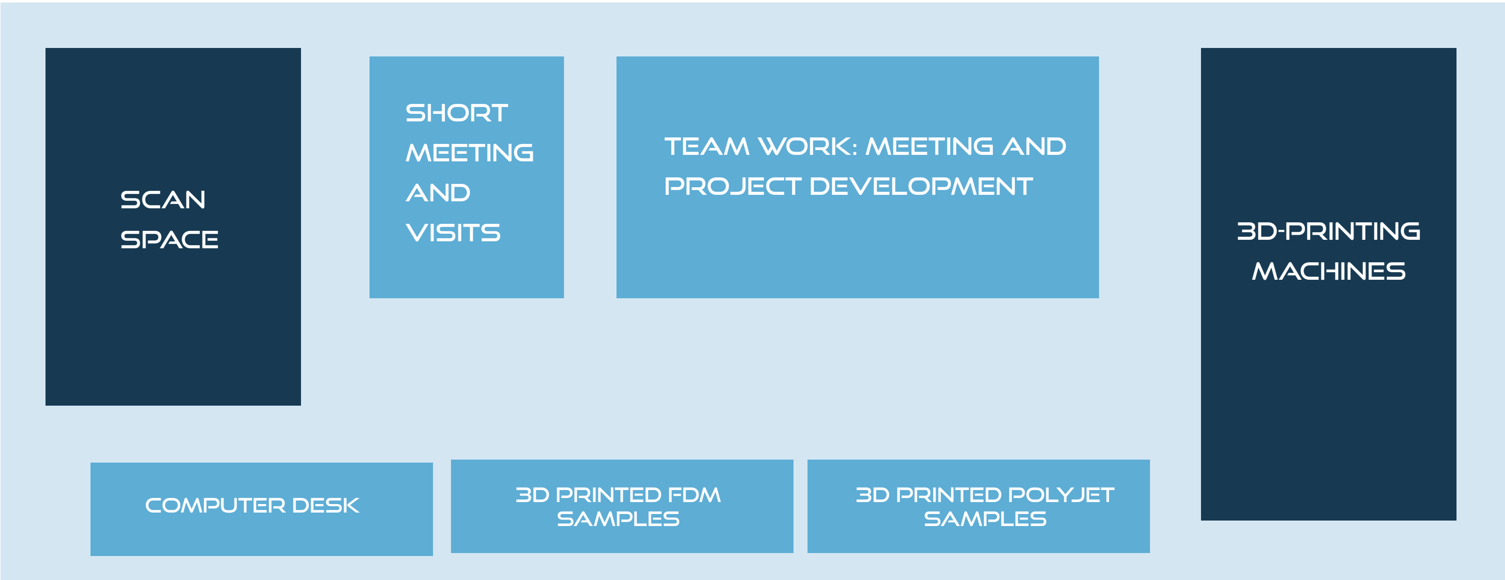
The process of work with each technology that is acquired for the lab would be the next:

- Training for the use of the machine and its software, for the teachers in Tknika.
- Practice with the technology and materials by the development of suitable projects, which includes design, manufacture and post-processes. The project must justify the use of this particular technology.
- Transfer of knowledge to the rest of teachers of the VET system, by the use of different channels.
- Use of the technology, by more and more teachers of the system.

SETTING

<table>
<tr><td>4.1</td><td>learning environment</td><td>purely physical (planning + execution)</td><td colspan="2">physical LF supported by digital factory (seeline “IT-Integration”)</td><td colspan="2">physical value stream of LF extended virtually</td><td>purely virtual (planning + execution)</td></tr>
<tr><td>4.2</td><td>environment scale</td><td colspan="3">scaled down</td><td colspan="3">life-size</td></tr>
<tr><td>4.3</td><td>work system levels</td><td>work place</td><td colspan="2">work system</td><td colspan="2">factory</td><td>network</td></tr>
<tr><td>4.4</td><td>enablers for changeability</td><td>mobility</td><td>modularity</td><td colspan="2">compatibility</td><td>scalability</td><td>universality</td></tr>
<tr><td>4.5</td><td>changeability dimensions</td><td>layout & logistics</td><td>product features</td><td colspan="2">product design</td><td>technology</td><td>product quantities</td></tr>
<tr><td>4.6</td><td>IT-integration</td><td colspan="2">IT before SOP (CAD, CAM, simulation)</td><td colspan="2">IT after SOP (PPS, ERP, MES)</td><td colspan="2">IT after production (CRM, PLM…)</td></tr>
</table>

This is the lay-out of the lab:



Apart from the Scanning and Additive Manufacturing spaces, the lab has deserved space for other functions:

- Team Work corner
- Short meeting space for providers, teachers, visits, etc.
- Work desk: machine management, design, etc.
- Sample corner to show different technologies and applications.

Specific equipment used in the LAB:

ADDITIVE MANUFACTURING EQUIPMENT:

- **Stratasys 450mc– FDM technology**
  Materials: thermoplastic (or thermoplastic & carbon fiber)
  Applications: prototypes, functional parts.

- **Makerbot Metal X - FDM technology**
  Materials: thermoplastic (including flexible)
  Applications: prototypes, functional parts.

- **Stratasys J750DAP – Polyjet technology**
  Materials: acrylic based resins, rigid and/or flexible, multi-coloured and transparent
  Applications: realistic prototypes, biomodels,small quantity moulds.

- **HP-4210-MJF – Multijet Fusion technology**
  Material: PA
  Applications: prototypes, functional parts.

- **Markforged Metal X – metal parts by FDM technology and sinter process.**
  Material: metal (inox, copper, tool steel)
  Applications: prototypes, functional parts.

SCANNING EQUIPMENT:

- **Creaform Go!Scan 3D** – surface and colour digitalisation by structured light projection.
- **Creaform HandyScan 700** – surface digitalisation by laser projection.
- **Creaform Academia 50** – surface and colour digitalisation by structured light projection
- **Solutionix Rexcan CS+** – surface digitalisation by structured light projection.

PRODUCT

<table>
<tr><td>5.3</td><td>product origin</td><td colspan="3">own development</td><td colspan="3">development by participants</td><td colspan="2">external development</td></tr>
<tr><td>5.4</td><td>marketability of product</td><td colspan="3">available on the market</td><td colspan="3">available on the market but didactically simplified</td><td colspan="2">not available on the market</td></tr>
<tr><td>5.5</td><td>functionality of product</td><td colspan="3">functional product</td><td colspan="3">didactically adapted product with limited functionality</td><td colspan="2">without function / application, for demonstration only</td></tr>
<tr><td>5.6</td><td>no. of different products</td><td>1 product</td><td>2 products</td><td>3-4 products</td><td>> 4 products</td><td colspan="2">flexible, developed by participants</td><td colspan="2">acceptance of real orders</td></tr>
<tr><td>5.7</td><td>no. of variants</td><td>1 variant</td><td>2-4 variants</td><td>4-20 variants</td><td>...</td><td colspan="2">flexible, depending on participants</td><td colspan="2">determined by real orders</td></tr>
<tr><td>5.8</td><td>no. of components</td><td>1 comp.</td><td>2-5 comp.</td><td colspan="2">6-20 comp.</td><td>21-50 comp.</td><td colspan="2">51-100 comp.</td><td>> 100 comp.</td></tr>
<tr><td>5.9</td><td>further product use</td><td colspan="2">re-use / re-cycling</td><td colspan="2">exhibition / display</td><td>give-away</td><td colspan="2">sale</td><td>disposal</td></tr>
</table>

Further description of the products manufactured in the LAB:

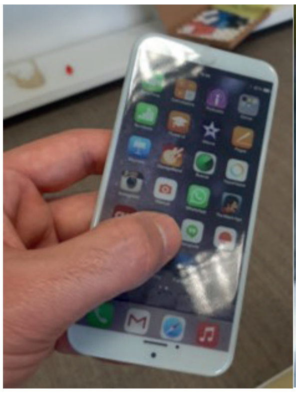
The produced parts are basically demonstrative, to show the possibilities of different AM technologies and applications.

Each year different projects are selected and developed to test the machines and learn from the working process. They can come from a need or proposition of one of the schools of the system or they can be created by the team.

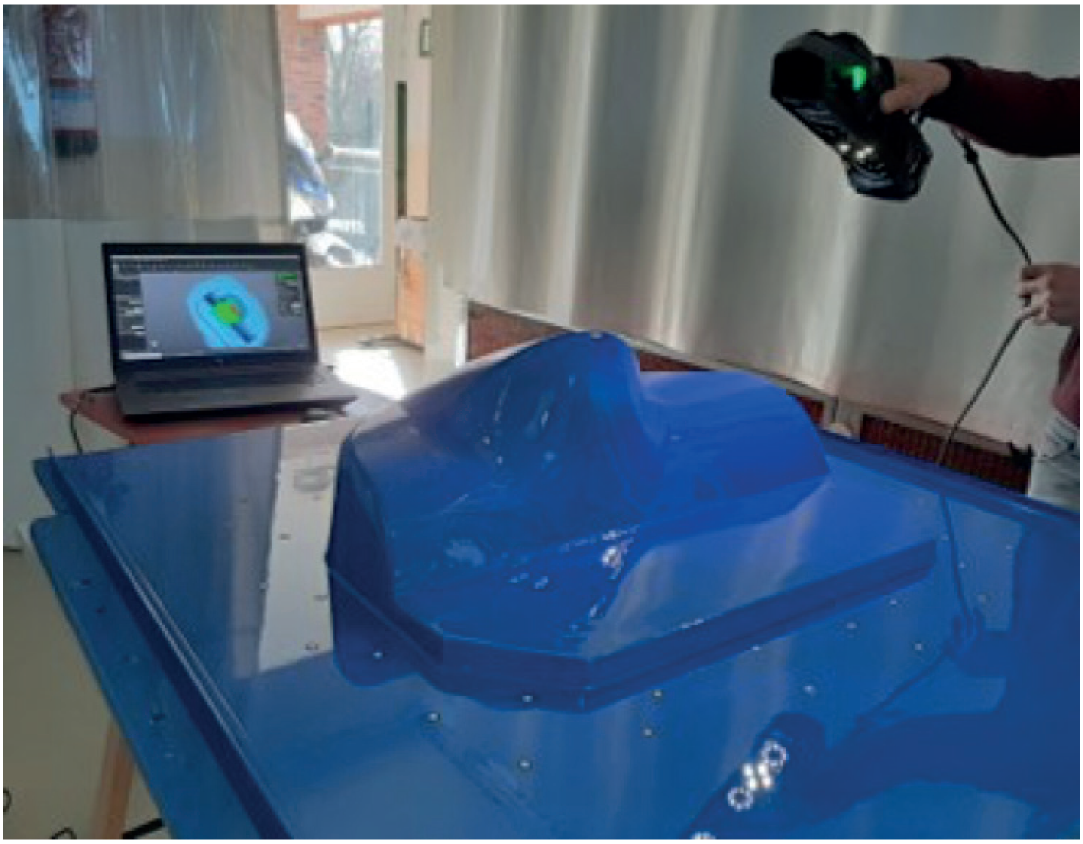
The next parts are examples developed by the team:

1.- Cover of an engine, made with HP Multijet Fusion technology. You can see a part on the left as it is after 3d printing, and the one on the right has a black colouring post-process.

2.- Polyjet technology allows different colour mixing on the same printing process. It is very useful to make realistic parts, consumer products, etc.. On the next images you can find a mobile and its surface finishing process, to make it look real. Also transparent parts are possible with this technology.



3.- Scanning processes allow you to digitalise parts: more complex the surface is, better to choose scanning instead of CAD designing.



DIDACTICS

6.1	**competence classes**	technical and methodological compentencies	social & communication competencies	personal competencies	activity and implementation oriented competencies		
6.2	**dimensions learn. targets**	cognitive	affective	psycho-motorical			
6.3	**learn. scenario strategy**	instruction	demonstration	closed scenario	open scenario		
6.4	**type of learn. environment**	greenfield (development of factory environment)	brownfield (improvement of existing factory environment)				
6.5	**communication channel**	onsite learning (in the factory environment)	remote connection (to the factory environment)				
6.6	**degree of autonomy**	instructed	self-guided / self-regulated	self-determined/ Selforganized			
6.7	**role of the trainer**	presenter	moderator	coach	instructor		
6.8	**type of training**	tutorial	practical lab course	seminar	workshop	project work	
6.9	**standardization of trainings**	standardized trainings	customized trainings				
6.10	**theoretical foundation**	prerequisite	in advance (en bloc)	alternating with practical parts	based on demand	afterwards	
6.11	**evaluation levels**	feedback of participants	learning of participants	transfer to the real factory	economic impact of trainings	return on trainings / ROI	
6.12	**learning success evaluation**	knowledge test (written)	knowledge test (oral)	written report	oral presentation	practical exam	none

Specific competencies trained in the lab/trained with the technologies in the LAB:

Skills trained in the lab/trained with the technologies in the LAB:

Learning outcomes:

In this Ikaslab project Additive Manufacturing as well as Reverse Engineering are focused from a global view, where these new technologies and applications are shown by examples and exercises, and teachers from the VET system can have access to them.

From this point of view, these teachers and the Centres they belong to, receive an input of new technologies on the market and applications that can change manufacturing processes in industry.

Considering that the technologies developed in this project can be useful in such different areas of industry, our learners, who are teachers in these areas, will evaluate the applicability in their specific area of work.

As mentioned above, the results of the projects worked in Tknika aim to transfer knowledge to VET teachers who teach at EFQ levels 5, so all training is adapted to these levels.

METRICS

7.1	**no. of participants per training**	1-5 participants	5-10 participants	10-15 participants	15-30 participants	30> participants	
7.2	**no. of standardized trainings**	1 training	2-4 trainings	5-10 trainings		> 10 trainings	
7.3	**aver. duration of a single training**	≤ 1 day	> 1 day until ≤ 2 days	> 2 days until ≤ 5 days	> 5 days until ≤ 10 days	> 10 days until ≤ 20 days	> 20 days
7.4	**participants per year**	< 50 participants	50-200 participants	201-500 participants	501-1000 participants	> 1000 participants	
7.5	**capacity utilization**	< 10%	> 10 until ≤ 20%	> 20%until ≤ 50%	> 50%until ≤ 75%	> 75%	
7.6	**size of LF**	≤ 100 sqm	> 100 sqm bis ≤ 300sqm	> 300sqm bis ≤ 500sqm	>500 sqm bis ≤ 1000sqm	> 1000 sqm	
7.7	**FTE in LF**	< 1	02-abr	05-sep	oct-15	> 15	

In the laboratory we have two types of knowledge transfer, one aimed at VET teachers and the other aimed at a more general public who usually visit Tknika to see what we work on and how we do it.

In the first one the transfer is usually of advanced type and with a longer duration that can range from 1 day to 5, depending on the topic we are dealing with.

And in the second the visits are usually of a duration of less than 1 day.

FURTHER INFORMATION & ASPECTS TO IMPROVE

8.1	**Further information**	photographs	video
8.2	**Aspect to improve**	technical	methodological

Further information (link to video):

- https://www.youtube.com/watch?v=XIyfXLZYbzU

Machining LAB

Introduction:

This model is elaborated by partners of the consortium with support from companies and associated partners and the model for describing learning factories (Abele, Metternich and Tisch 2019), in order to describe existing and future learning cyber-physical spaces, AM LABs 4.0, and its characteristics.

The model has been developed to create a common structure for descriptions of AM LABs 4.0. The description model includes aspects of the LABs such as physical characteristics, equipment, ICT applications, I4.0 technologies, methodologies, learning strategies, etc.

Partners, organisations, and institutions can take advantage of the descriptions of AM LABs 4.0 by evaluating information regarding different learning cyber-physical spaces.

All consortium partners described their AM LABs 4.0 via the model in order to have a standardized structure for describing cyber-physical spaces, beneficial for VET/HVET and stakeholder all over Europe. The structure makes the model readable for users, external from the EXAM 4.0 consortium, and it is simple for other users to use when describing their/new AM LABs 4.0.

In the following sections, a detailed description of a number of reference LABs is shown. All the LABs are described with the following structure:

- General information
- Operational model
- Purpose and targets
- Process
- Setting
- Product
- Didactics
- Metrics
- Further information & aspects to improve

- **Name of the lab:**

Machining and mechanical assembly LAB

- **General aim/purpose (short summary):**

The general objective of this lab is to plan, schedule and control the manufacturing by machining and assembly of capital goods, based on the documentation of the process and the specifications of the products to be manufactured, ensuring the quality of management and products, as well as the supervision of the systems of prevention of labour risks and environmental protection. All of these incorporate digitization skills and industry 4.0 methodologies that more clearly align with the demands of the industry.

This objective would entail tasks such as:

- Prepare the procedures for the assembly and maintenance of equipment, defining the resources, the necessary times, and the control systems.

- Supervise and / or execute the machining, assembly, and maintenance processes, controlling the times and the quality of the results.

- Supervise the programming and tuning of numerical control machines, robots, and manipulators for machining.

- Schedule production using computerized management techniques and tools.
- Determine the necessary provisioning through an intelligent warehouse.
- Ensure that manufacturing processes conform to established procedures.
- Manage the maintenance of resources in my area.

The LAB can be used simultaneously by students from different programmes. Students from the following programmes are the main users:

- Higher Technician in Production Scheduling in Mechanical Manufacturing (EQF 5),
- Higher Technician in Manufacturing design Mechanics (EQF 5)
- Higher Technician in Industrial Mechanics (EQF level 5).
- Technician in machining (EQF level 4),

In the machining lab, besides the initial training, is also used for:

- Specialization programmes
- Training for employment
- Tailor-made training for SMEs
- Improvement and recycling programmes
- Tkgune - Applied innovation and technical services to SMEs
- Showroom for companies

LAB size (square metres): 2000

In the following sections, a detailed description of the LABs is shown with the following structure:

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

Further information and aspects to improve

General information - summary table

GENERAL INFORMATION	Name of the LAB	**Machining Lab**	MAIN PURPOSE	
	VET/HVET centre	Miguel Altuna LHII	Education	X
	Floor space of the lab (sqm)	2000	Training	X
	Main topic/learning content	Machining, CNC machining	Research/Applied innovation	
	I4.0 related technologies	CPS, data acquisition, RFID, IIoT		
PURPOSE	Learning content	Machining on: Conventional lathe machining, milling, CNC machining, END, Grinding Set up of metal forming presses Mechanical and electric assembly		
	Secondary purpose	Production management, Safety, I4.0 related topics, smart maintenance		
	LAB type	Specific	Mixed	Learning Factory

LEARNING CONTENTS	Learning programmes/study programmes/levels					
Name of the programmes carried out on the Lab	EQF Level	Lab hours	Nº subjects on the lab	Hour/Week x nº of weeks	Nº students (3)
Production management on Mechanical Manufacturing	5	198 126	2	6x33 6x21	3x20 3x20
Machining technician	4	330 165 210	3	10x33 5x33 10x21	2x20 2x20
Industrial mechatronics	5	165 168	2	5x33/8x21	2x21 2x21
Design in mechanical manufacturing	5	198	1	6x33	1x15
Precision cold forging	5	_	1	_	1x12
_	_	_	_	_	_

SETTINGS									
Nº of cell	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5	Cell 6	Cell 7	Cell 8	Cell 9
Category of cell	CNC	Lathes	Mills	END	Grinding	Metal formig	Mechanical assembly	Electric assembly	_
Nº machines	12	20	21	4	6	12	5	6	_
I4.0 Enabler technologies used and implementation level	Robotics	Additive Manufacturing	Cloud	CPS	Mobile/Tablet	AR/VR	Big data analytics	Ai	IoT/IIoT
	Sensors/Actuators	RFID	M2M	Cybersecurity	Digital twin				

OPERATIONAL MODEL

1.1	**Operator**	academic institution: university, college, BA	non-academic institution: vocational school / high school, chamber, union, employers´ association, industrial network	profit-oriented operator: consulting, producing company
1.2	**Trainer**	professor, researcher, student assistant	technical expert /int. Specialist	consultant, educationalist
1.3	**Development**	own development	external assisted development	external development
1.4	**Initial funding**	internal funds	public funds	company funds
1.5	**Ongoing funding**	internal funds	public funds	company funds
1.6	**Funding continuity**	short term funding (e.g., single events)	midterm funding (projects and programmes < 3 years)	long term funding (projects and programmes > 3 years)
1.7	**Business model for trainings**	open models: club model, course fees	closed models (training programme only for single company)	

Note: in 1.7 Business models for training there are different modalities: For students in the initial training model, the programmes are state funded. For tailored training for companies, it is course fee. We also use closed models.

This laboratory is within a VET centre that imparts institutionalized, intentional, and planned learning processes and whose results are accredited

Description of funding methods

Miguel Altuna LHII being a public VET centre belonging to the Basque Country Education ministry so that the activities of the centre are mainly funded by the VET department of education.

Miguel Altuna LHII plans and monitors its own budget, deciding independently how to use the resources.

- Miguel Altuna LHII is funded mainly by the government. However, it is allowed to earn and retain income (for example, by selling training services).to fund investments, research, or other activities.

- Miguel Altuna LHII being a public body has to some degree, the authority to enter independently into contracts with other organisations such as businesses, training providers and donors e.g., to buy or sell services or equipment. There is limitation in the maximum amount of the contracts and also the nature of them.

- However, Miguel Altuna LHII has not the authority to take out loans, for example, to fund investment.

PURPOSE AND TARGETS

2.1	**Main purpose**	education	vocational training	research							
2.2	**Secondary purpose**	test environment / pilot environment	industrial production	innovation transfer	advertisement for production						
2.3	**Target groups for education & training**	pupils	students	employees	entrepreneurs	freelancer	unemployed	open public			
			bachelor	master	phd students	apprentices	skilled workers	semi-skilled workers	unskilled	managers	
										lower mgmt	middle mgmt
										top mgmt	
2.4	**Group constellation**	homogeneous	heterogeneous (knowledge level, hierarchy, students + employees, etc.)								
2.5	**Targeted industries**	mechanical & plant eng.	automotive	logistics	transportation	FMCG	aerospace				
		chemical industry	electronics	construction	insurance / banking	textile industry	...				
2.6	**Subject-rel. learning contents**	prod. Mgmt & org.	resource efficiency	lean mgmt	automation	CPPS	work system design	HMI	design	Intralogistics design & mgmt	...
2.7	**Role of LAB for research**	research object	research enabler								
2.8	**Research topics**	production management & organization	resource efficiency	lean mgmt	automation	CPPS	changeability	HMI	didactics	...	

The general objective of this lab is to plan, schedule and control the manufacturing by machining and assembly of capital goods, based on the documentation of the process and the specifications of the products to be manufactured, ensuring the quality of management and products, as well as the supervision of the systems of prevention of labour risks and environmental protection. All of this incorporates digitization skills and industry 4.0 methodologies that more clearly align with the demands of the industry.

This objective would entail tasks such as:

- Prepare the procedures for the assembly and maintenance of equipment, defining the resources, the necessary times, and the control systems.
- Supervise and / or execute the machining, assembly, and maintenance processes, controlling the times and the quality of the results.
- Supervise the programming and tuning of numerical control machines, robots, and manipulators for machining.

- Schedule production using computerized management techniques and tools.
- Determine the necessary provisioning through an intelligent warehouse.
- Ensure that manufacturing processes conform to established procedures.
- Manage the maintenance of resources in my area.

The LAB can be used simultaneously by students from different programmes. Students from the following programmes are the main users:

- Higher Technician in Production Scheduling in Mechanical Manufacturing (EQF level 5).
- Higher Technician in Manufacturing design Mechanics (EQF level 5).
- Higher Technician in Industrial Mechanics (EQF level 5).
- Technician in machining (EQF level 4).

In the machining lab, besides the initial training, is also used for:

- Specialization programmes
- Training for employment
- Tailor-made training for SMEs
- Improvement and recycling programmes
- Tkgune - Applied innovation and technical services to SMEs
- Showroom for companies

Description of the relation between each study programme and the LAB

All the lab's users must use the IoT system to book machines and equipment, check availability of the facilities and use the correspondent tooling sets. The use of RFID cards is compulsory for all users, including trainers and staff. All students must use it as well, independently of the EQF level of their programmes or even trainees from companies attending continuous training programmes.

The use of the machining lab's equipment can be different for each group linked to different study programmes.

Generally speaking, students from EQF4, they work on the preparation of competences related to produce parts by machining, using different procedures and equipment, from conventional machining to CNC.

For EQF5 levels programmes, besides the tasks related to machining, they also perform management and planning tasks as

- Schedule productions, production planning, quality control and measurement procedures, maintenance planning,
- Prepare the procedures for the assembly and maintenance of equipment, defining the resources, the necessary times, and the control systems.
- Supervise and / or execute the machining, assembly, and maintenance processes, controlling the times and the quality of the results.
- Supervise the programming and tuning of numerical control machines, robots, and manipulators for machining.
- Determine the necessary provisioning through an intelligent warehouse.
- Ensure that manufacturing processes conform to established procedures. Applied metrology
- Manage the maintenance of resources in their area.

PROCESS

<table>
<tr><td>3.1</td><td>Product life cycle</td><td>product planning</td><td>product development</td><td>product design</td><td>rapid prototyping</td><td>manufacturing</td><td colspan="2">assembly</td><td>logistics</td><td colspan="2">service</td><td>recycling</td></tr>
<tr><td>3.2</td><td>LAB life cycle</td><td>investment planning</td><td>factory concept</td><td>process planning</td><td>ramp-up</td><td>manufacturing</td><td colspan="2">assembly</td><td>logistics</td><td colspan="2">maintenance</td><td>recycling</td></tr>
<tr><td>3.3</td><td>Order life cycle</td><td>configuration & order</td><td>order sequencing</td><td colspan="2">production planning and scheduling</td><td>manufacturing</td><td colspan="2">assembly</td><td>logistics</td><td colspan="2">picking, packaging</td><td>shipping</td></tr>
<tr><td>3.4</td><td>Technology life cycle</td><td>planning</td><td>development</td><td colspan="2">virtual testing</td><td>manufacturing</td><td colspan="2">assembly</td><td>logistics</td><td colspan="2">maintenance</td><td>modernization</td></tr>
<tr><td>3.5</td><td>Indirect functions</td><td>SCM</td><td>sales</td><td colspan="2">purchasing</td><td>HR</td><td colspan="3">finance / controlling</td><td colspan="3">QM</td></tr>
<tr><td>3.6</td><td>Material flow</td><td colspan="4">continuous production</td><td colspan="7">discrete production</td></tr>
<tr><td>3.7</td><td>Process type</td><td colspan="2">mass production</td><td colspan="2">serial production</td><td colspan="5">small series production</td><td colspan="2">one-off production</td></tr>
<tr><td>3.8</td><td>Manufact. organization</td><td colspan="2">fixed-site manufacturing</td><td colspan="2">work bench manufacturing</td><td colspan="5">workshop manufacturing</td><td colspan="2">flow production</td></tr>
<tr><td>3.9</td><td>Degree of automation</td><td colspan="2">manual</td><td colspan="5">partly automated / hybrid automation</td><td colspan="4">fully automated</td></tr>
<tr><td>3.10</td><td>Manufact. Methods</td><td>cutting</td><td colspan="2">trad. primary shaping</td><td>additive manufact.</td><td colspan="2">forming</td><td>joining</td><td colspan="2">coating</td><td colspan="2">change material properties</td></tr>
<tr><td>3.11</td><td>Manufact. Technology</td><td colspan="3">physical</td><td colspan="4">chemical</td><td colspan="4">biological</td></tr>
</table>

The lab is distributed in cells where different configurations are available. In 2000 square metres different process flow can be arranged depending on the objectives of the courses.

Specific equipment used in the LAB, Addressing Industry 4.0:

The idea of the workshop is to be fully digitized at least to the same level that the industry is digitizing its production plants. This offers a fully digitized TVET training space designed to the same industry standards.

Among others, the workshop includes the following characteristics:

Communication between all machines and installations. For this, the workshop has a WI-FI system that connects with different PLCs connected to the machines. The Wi-Fi is sent through a beacon system and the PLCs have the receivers.

Cybersecurity. To avoid external intrusions, the lab's WI-FI system is totally independent from the rest of the school.

Centralized reservation system and control of use. Through screens installed at strategic points, the possibility of reserving the machines is enabled. The teacher determines the machines that the student can reserve. Without a reservation it is impossible to start a machine and in order to reserve it is essential to ensure that you have the PPE. In this way, it is controlled to what capacity the lab is working, an adequate distribution of the machines is made, and safety is increased. The reservation is made by RFID HF.

Smart warehouse to control the use of tools. The general tools are arranged in an intelligent warehouse where, by means of RFID UHF, the entrance of the person is controlled and which tools they take out, since each tool has its corresponding RFID UHF. Also inside there is a computer that, through different filters, indicates in which location each tool is or if it is outside the warehouse and who has it.

RFID card. Depending on the function to be performed in the workshop, a UHF or HF RFID system is required. In our case, both technologies have been inserted into a single user card.

Big data analytics. Through the identification, the students, and the level of use of their machine are tracked since the reservation time and the use time can be known. You can track energy efficiency, create smart maintenance systems, and monitor and utilize this data.

Open-source enterprise resource planning (ERP) system to manage the entire system.

Screens on the machines to view technical information that the user has left in the cloud for use on the machines. In this way you can view plans, processes, ... without the need to carry papers. Decreasing the use of paper and movement times.

4.1	**Learning environment**	purely physical (planning + execution)	physical supported by digital factory (see line “IT-Integration”)		Physical, extended virtually		purely virtual (planning + execution)
4.2	**Environment scale**	scaled down			life-size		
4.3	**Work system levels**	workplace	work system		factory		network
4.4	**Enablers for changeability**	mobility	modularity	compatibility		scalability	universality
4.5	**Changeability dimensions**	layout & logistics	product features	product design		technology	product quantities
4.6	**IT-integration**	IT before SOP (CAD, CAM, simulation)		IT after SOP (PPS, ERP, MES)		IT after production (CRM, PLM…)	

For what purpose are different IT-integrations used:

The items integrated in the lab are related to the digitalization of the processes. Machine communication and data acquisition. The Specific equipment used in the LAB, Addressing Industry 4.0 has been explained in the previous section, 3.

The purpose of those equipment and the associated IT resources is to get the student from all programmes used to work on digitalized environments. The data created during the learning process is analysed and used by the students as a learning activity to improve the overall process. Students become familiar to use data analytic tools and to make decisions based on real results.

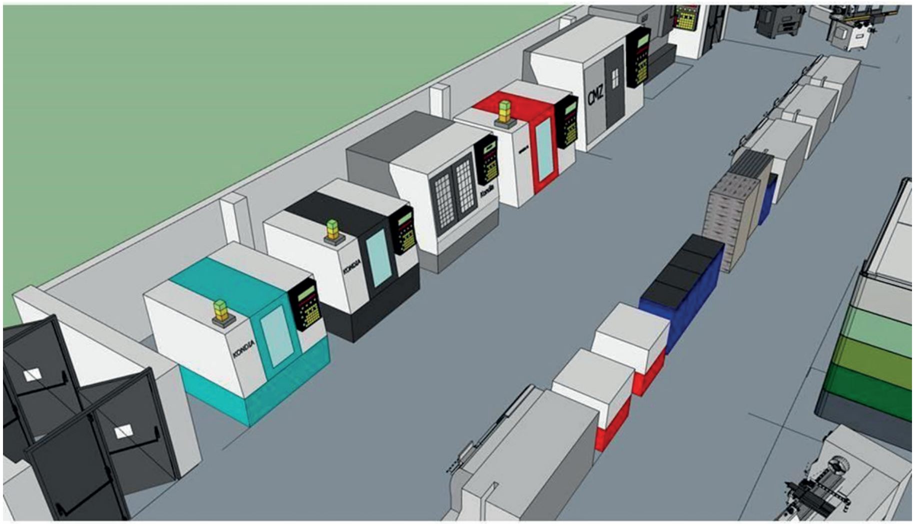
Students from mechanical programmes understood the automation architecture, the function of different devices, the communication protocols and other features concerning Industry 4.0

General setting of the equipment

This workshop occupies a space of 2000m2 in which 165 students can work at the same time. The space is divided into 8 different cells which are made up of 86 different machines. The cells that we can find are CNC, Lathes, Strawberries, END, Grinding, Metal forming, Mechanical Assembly and Electrical Assembly.

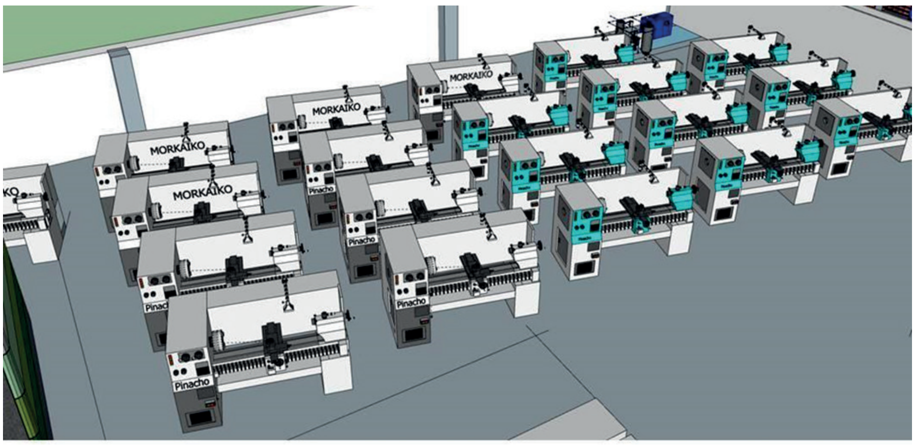
The CNC area is completed with 12 machines, which are:

- 1 Kondia B-500
- 1 Kondia B-640
- 1 Kondia HM1060
- 1 Kondia A6
- 1 CMZ TC 20YS
- 1 Lealde
- 4 Smart-200
- 2 Emco Mill 105



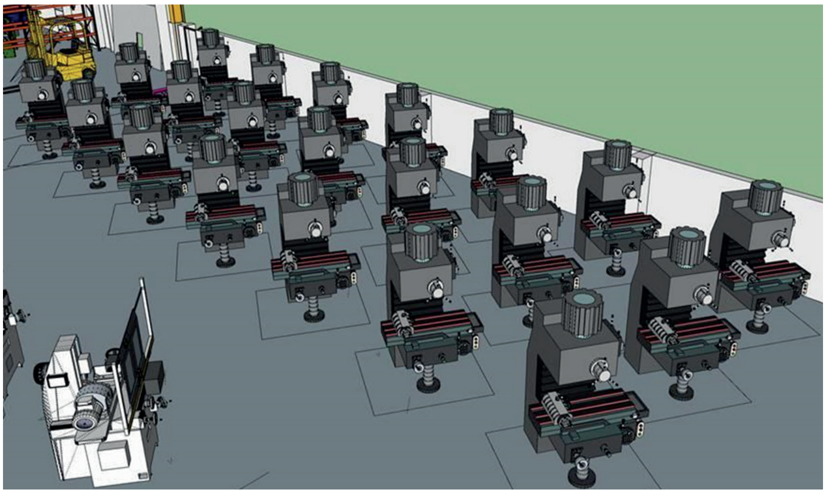
The Lathes area is completed with 20 machines, which are:

- 10 Pinacho S 90/200
- 5 Pinacho SC 200
- 5 Morkaiko 400 M



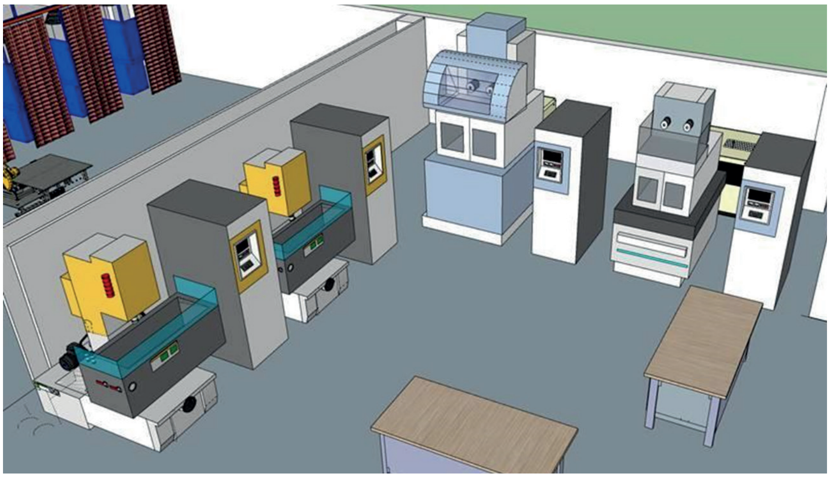
The Mills area is completed with 21 machines, which are:

- 2 Lagun FTV 1
- 2 Lagun FTV 2-S
- 6 Lagun FTV 4-SP
- 2 Lagun FV-125
- 1 Lagun MEC
- 7 Kondia FV-1
- 1 CME FV-15



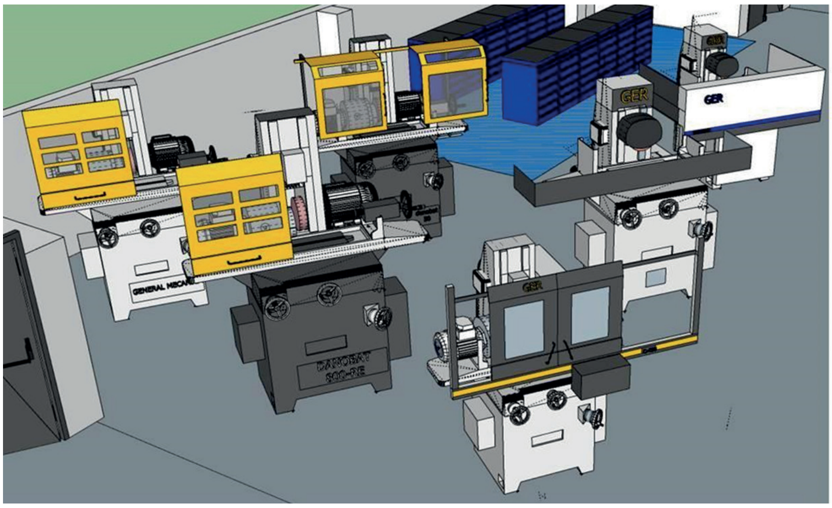
The END area is completed with 4 machines, which are:

- 1 Ona Datic S30
- 1 Onadatic F30
- 1 Aricut
- 1 Prima



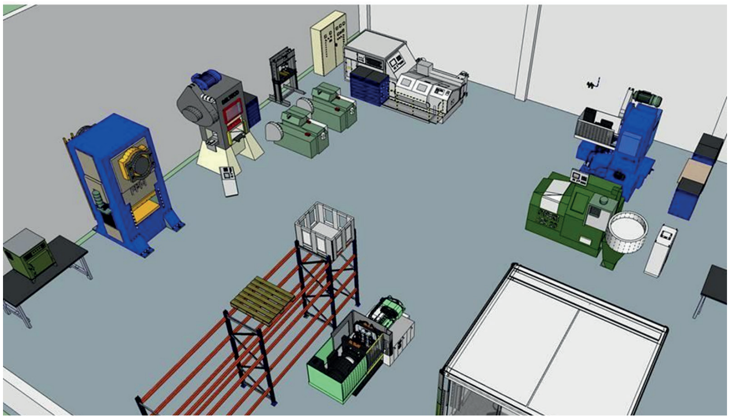
The Grinding area is completed with 6 machines, which are:

- 1 GER G450
- 1 GER S40/20
- 1 GER MH
- 1 Danobat 500
- 1 Danobat 800R
- 1 GM OHX



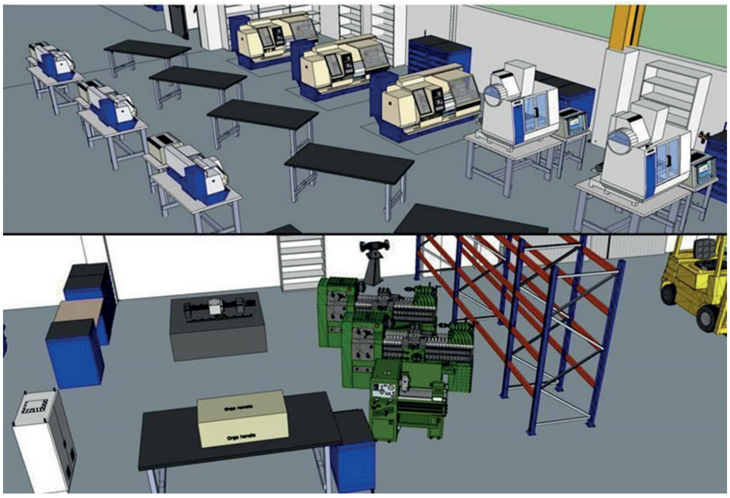
The Metal Forming area is completed with 7 machines, which are:

- 1 Dellavia 300Tn
- 1 Delteco 65Tn
- 2 National Kaiser
- 1 Sacma SP260
- 1 Schuller
- 1 Diregi DK7



The Mechanical / Electrical Assembly area is completed with 10 machines, which are:

- 2 Pinacho Fanuc
- 1 Pinacho Fagor
- 2 Supernona mills
- 3 Alecoop Magnum didactic lathe



PRODUCT

5.1	**Materiality**	material (physical product)					immaterial (service)		
5.2	**Form of product**	general cargo				bulk goods		flow products	
5.3	**Product origin**	own development			development by participants			external development	
5.4	**Marketability of product**	available on the market			available on the market but didactically simplified			not available on the market	
5.5	**Functionality of product**	functional product			didactically adapted product with limited functionality			without function / application, for demonstration only	
5.6	**No. of different products**	1 product	2 products	3-4 products	> 4 products	flexible, developed by participants		acceptance of real orders	
5.7	**No. of variants**	1 variant	2-4 variants	4-20 variants	…	flexible, depending on participants		determined by real orders	
5.8	**No. of components**	1 comp.	2-5 comp.	6-20 comp.		21-50 comp.	51-100 comp.		> 100 comp.
5.9	**Further product use**	re-use / re-cycling		exhibition / display		give-away	sale		disposal

Further description of the products manufactured in the LAB

This lab cannot be considered a Learning Factory. Unless some production processes are implemented and simple products are used in means of using the equipment, the overall approach of the lab is not around the production and assembly of a product or a family of products.

The methodology used for learning activities is “Challenge based collaborative learning”. Those challenges are in most of the cases the design, manufacturing, and assembly of products. The cases can be “services” automation of lines, equipment maintenance projects, problem solving challenges etc. In a way, those challenges can be also managed as products. However, the challenges can vary from team to team, from group to group. The sequence and objectives of the challenges are also diverse, always with the aim of fulfilling a learning process and to complete a set of skills acquisitions. So, different arrangements of the lab are used.

So, the information of the table must be filtered and interpreted in the singular context of this Lab.

6.1	**Competence classes**	technical and methodological competencies	social & communication competencies	personal competencies	activity and implementation-oriented competencies		
6.2	**Dimensions learn. targets**	cognitive	affective	psycho-motorial			
6.3	**Learn. scenario strategy**	instruction	demonstration	closed scenario	open scenario		
6.4	**Type of learn. environment**	greenfield (development of factory environment)	brownfield (improvement of existing factory environment)				
6.5	**Communication channel**	onsite learning (in the factory environment)	remote connection (to the factory environment)				
6.6	**Degree of autonomy**	instructed	self-guided / self-regulated	self-determined/ Self organized			
6.7	**Role of the trainer**	presenter	moderator	coach	instructor		
6.8	**Type of training**	tutorial	practical lab course	seminar	workshop	project work	
6.9	**Standardization of trainings**	standardized trainings	customized trainings				
6.10	**Theoretical foundation**	prerequisite	in advance (in bloc)	alternating with practical parts	based on demand	afterwards	
6.11	**Evaluation levels**	feedback of participants	learning of participants	transfer to the real factory	economic impact of trainings	return on trainings / ROI	
6.12	**Learning success evaluation**	knowledge test (written)	knowledge test (oral)	written report	oral presentation	practical exam	none

Specific competencies addressed in the lab and Curriculum used:

Of the training programmes offered at the centre, the use of this lab is made by 4 programmes: Technician in machining (EQF level 4), Senior Technician in Production Scheduling in Mechanical Manufacturing (EQF 5), Senior Technician in Manufacturing design Mechanics (EQF 5) and Higher Technician in Industrial Mechanics (EQF level 5).

The Machining Technician programme makes the use of the lab on 3 of its modules. In the 1st year Manufacturing by chip removal (363h) and in the 2nd year CNC (252h) and Manufacturing by abrasion, EDM, cutting and forming, additive manufacturing and by special processes (210h).

The programme of Higher Technician in Programming of production in mechanical manufacturing makes use of the lab on 3 of its modules. In the 1st year Mechanical Manufacturing Techniques (198h) and in the 2nd year CNC (240h) and CAM (40h).

The programme of Higher Technician in Design in Mechanical Manufacturing makes use of the lab on 1 of its modules. In the 1st year Mechanical Manufacturing Techniques (198h).

The programme of Superior Technician in Industrial Mechatronics (superior, level 5) makes use of the lab on 2 of its modules. In the 1st year Manufacturing processes (165h) and in the 2nd year Configuration of mechatronic systems (160h).

All these modules, in addition to achieving the general skills required within mechanical manufacturing, are prepared to work on different skills related to I4.0. They are between them:

- Programme simulation: by computer, machine, CAM integrated in machine, 3D simulation, virtual, etc.

- Integration of data acquisition systems. Artificial vision cameras.

- Integration of radio frequency identification systems.

- Correction in real time of the deviations of the machined parts (dimensional, geometric, and surface tolerances).

- Use of computer tools and software to access and manage the necessary and generated documentation (PC, tablet, smartphone, machine interface, integrated CAD / CAM / ERP systems, PLM, etc.).

- Registration of the programme and the documentation generated in folder structure, CAD / CAM / ERP integrated systems, PLM, etc.

- Machining strategies: high performance, high feed, adaptive machining, ...).

- Programming of robots (industrial and collaborative) for manipulation and machining.

- Monitoring of computer security regulations and procedures (cybersecurity).

- Analysis of process data in real time (Big Data, Smart Data, ...).

Learning Methodology

The central element on which the whole learning model is articulated is COLLABORATIVE LEARNING BASED ON CHALLENGES.

The presentation of a problematic situation, its transformation to a challenge, as well as the whole process until obtaining a result, is structured based on both the technical and specific competences of each programme, as well as those transversal competences that are currently strategical, such as: autonomous learning, teamwork, orientation towards extraordinary results, digital competences, etc …

Problematic situations, in all cases, are raised to a class configured in teams, where the work process has to enable the students to live the situation as a challenge and, from there, they have to have the opportunity to generate the necessary knowledge that provides the best solutions.

The approach of the model through challenges needs a reinterpretation of the mechanics of learning. The interpretation that best fits the model is to understand learning as a process of evolution, where the students are responsible for it. Challenge-based learning allows a scenario in which students individually and team levels are put into action and produce a result. This result is interpreted, analysed, and discussed upon to make necessary changes to approach higher objectives in the next challenge.

The main idea of this methodology is to create teams and for them to establish a contract in which they include the commitments acquired by the members of each team. These contracts will evolve and transform as teams incorporate experience. When working in the workshop, these teams will have to manage themselves by dividing up the tasks in order to overcome the challenge. Generally, the use of machines is individual or in pairs.

This methodology enables us to work intramedullary in a way that students can work on transversal competences through challenges that are close to a business reality. The next step would be to create a Learning Factory, simulating the operation of the workshop to a real workshop.

METRICS

7.1	**No. of participants per training**	1-5 participants	5-10 participants	10-15 participants	15-30 participants	30> participants	
7.2	**No. of standardized trainings**	1 training	2-4 trainings	5-10 trainings		> 10 trainings	
7.3	**Aver. duration of a single training**	≤ 1 day	> 1 day until ≤ 2 days	> 2 days until ≤ 5 days	> 5 days until ≤ 10 days	> 10 days until ≤ 20 days	> 20 days
7.4	**Participants per year**	< 50 participants	50-200 participants	201-500 participants	501-1000 participants	> 1000 participants	
7.5	**Capacity utilization**	< 10%	> 10 until ≤ 20%	> 20%until ≤ 50%	> 50%until ≤ 75%	> 75%	
7.6	**Size of LAB**	≤ 100 sqm	> 100 sqm bis ≤ 300 sqm	> 300sqm bis ≤ 500sqm	>500 sqm bis ≤ 1000 sqm	> 1000 sqm	
7.7	**FTE in LAB**	< 1	2-4	5-9	10-15	> 15	

This is a lab in which 20 students, grouped in 5 islands.

FURTHER INFORMATION & ASPECTS TO IMPROVE

8.1	**Further information**	photographs	video
8.2	**Aspect to improve**	technical	methodological

Aspects to improve:

One of the features that we have taken care of is the scalability of the system. We believe that the market and industry will demand many new capabilities to implement in a learning space as this one. We have created a solid basis to continue growing and implementing new unforeseen technologies. They are using mostly industrial hardware that make it possible to continue growing.

The implementation of Industry 4.0 related technologies and features are an ongoing process. In a short and medium term many new implementation and investments are foreseen

- Creation of modular cells.
- Retrofitting of CNC machines as learning cells where to implement and experiment with I4.0 devices and communication protocols.
- Smart maintenance system
- Metrology in line processes
- Virtualization of LABs. Digital twin of the lab
- Integration of cobots in CNC machine feeding and assembly lines
- Energy efficiency modules
- Product's traceability systems. Stocks control
- Management of systems using ERP, linking different LABs and departments

Strength and weaknesses of the LAB. Lessons learned

Concerning the current implementation stage, the areas to improve are to increase the flexibility of the systems. We are designing an organizational model to diverse trainings running simultaneously in the same lab. That creates complex organizational planning and scheduling needs. To overcome this issue, we need to implement modular and flexible cells where to easily change configurations and or schedules.

During the planning and implementation of this lab we realized about the importance of creating awareness among the teachers. To create a "culture of I40" is the first step in this process. It is crucial to engage trainers and teachers to the I40 mind set. The culture of digitalization and the use of data generated on our own processes must be understood as a learning /teaching primary need.

In order to clearly show the benefits of the system and in order to make the users interiorize the advantages of the automation, we had to reinforce the communication channels and politics.

Specific train the trainers actions were put in place. We took care about all the staff feeling comfortable with the new system.

Concerning pedagogical aspects, we are building the lab embedded in our journey towards the learning factory approach. Besides the technology, implemented pedagogical changes are also taking place. Both aspects go together. Indeed, all the changes made will make sense as long as they improve the students' learning process. In this sense, we must work on both aspects simultaneously.

We understand that before undertaking digital transformation actions, in this case in the manufacturing workshop, we have to be clear about what we want to achieve from this transformation in terms of improving the learning process.

Robotic LAB

Introduction:

This model is elaborated by partners of the consortium with support from companies and associated partners and the model for describing learning factories (Abele, Metternich and Tisch 2019), in order to describe existing and future learning cyber-physical spaces, AM LABs 4.0, and its characteristics.

The model has been developed to create a common structure for descriptions of AM LABs 4.0. The description model includes aspects of the LABs such as physical characteristics, equipment, ICT applications, I4.0 technologies, methodologies, learning strategies, etc.

Partners, organisations, and institutions can take advantage of the descriptions of AM LABs 4.0 by evaluating information regarding different learning cyber-physical spaces.

All consortium partners described their AM LABs 4.0 via the model in order to have a standardized structure for describing cyber-physical spaces, beneficial for VET/HVET and stakeholder all over Europe. The structure makes the model readable for users, external from the EXAM 4.0 consortium, and it is simple for other users to use when describing their/new AM LABs 4.0.

In the following sections, a detailed description of a number of reference LABs is shown. All the LABs are described with the following structure:

- General information
- Operational model
- Purpose and targets
- Process
- Setting
- Product
- Didactics
- Metrics
- Further information & aspects to improve

- **Name of the lab:**

  Automation and Robotics LAB

- **General aim/purpose (short summary):**

  Develop and manage projects for the assembly and maintenance of automatic installations

- **Year of inauguration:**

  2000

- **LAB size (square metres):**

  130

In the following sections, a detailed description of a number of reference labs is shown. All the labs are described with the following structure:

General information - summary table

GENERAL INFORMATION	Name of the LAB	**Robotic lab**	MAIN PURPOSE	
	VET/HVET centre	Migeul Altuna LHII	Education	X
	Floor space of the lab (sqm)	130	Training	X
	Main topic/learning content	Automatic installations	Research/Applied innovation	
	I4.0 related technologies	CPS, robotic, RFID, Cybersecurity components, data adquisition		
PURPOSE	Learning content	Develop and manage projects for the assembly and maintenance of automatic installations.		
	Secondary purpose	Production automation, Safety, I4.0 related topics, smart maintenance		
	LAB type	Specific	Mixed	Learning Factory

		Name of the programmes carried out on the Lab	EQF Level	Lab hours	Nº subjects on the lab	Hour/Week x nº of weeks	Nº students (3)
LEARNING CONTENTS	Learning programmes/study programmes/levels	Automation and Industrial Robotics	5	120	5	6x20	20
		_	_	100	_	5x20	20
		_	_	140	_	7x20	20
		_	_	140	_	7x20	20
		_	_	50	_	25x2	20
		_	_	_	_	_	_

SETTINGS	Nº of cell	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5	Cell 6	Cell 7	Cell 8	Cell 9
	Category of cell	_	_	_	_	_	_	_	_	_
	Nº machines	32	_	_	_	_	_	_	_	_
	I4.0 Enabler technologies used and implementation level	Robotics	Additive Manufacturing	Cloud	CPS	Mobile/Tablet	AR/VR	Big data analytics	Ai	IoT/IIoT
		Sensors/Actuators	RFID	M2M	Cybersecurity	Digital twin				

The second section – detailed description

OPERATIONAL MODEL

1.1	Operator	academic institution			non-academic institution					profit-oriented operator	
		university	college	BA	vocational school / high school	chamber	union	employers´ association	industrial network	consulting	producing company
1.2	Trainer	professor	researcher	student assistant	technical expert /int. Specialist	consultant	educationalist				
1.3	Development	own development	external assisted development	external development							
1.4	Initial funding	internal funds	public funds	company funds							
1.5	Ongoing funding	internal funds	public funds	company funds							
1.6	Funding continuity	short term funding (e.g., single events)	midterm funding (projects and programmes < 3 years)	long term funding (projects and programmes > 3 years)							
1.7	Business model for trainings	open models		closed models (training programme only for single company)							
		club model	course fees								

Note: in 1.7 Business models for training there are different modalities: For students in the initial training model, the programs are state funded. For tailored training for companies, it is course fee.

This laboratory is within a VET that imparts institutionalized, intentional, and planned learning processes and whose results are accredited...

Description of funding methods

Miguel Altuna LHII being a public VET centre belonging to the Basque Country Education ministry so that the activities of the centre are mainly funded by the VET department of education.

Miguel Altuna LHII plans and monitors its own budget, deciding independently how to use the resources.

- Miguel Altuna LHII is funded mainly by the government. However, it is allowed to earn and retain income (for example, by selling training services).to fund investments, research, or other activities.
- Miguel Altuna LHII being a public body has to some degree, the authority to enter independently into contracts with other organisations such as businesses, training providers and donors e.g., to buy or sell services or equipment. There are limitations in the maximum amount of the contracts and also the nature of them.

However, Miguel Altuna LHII has not the authority to take out loans, for example, to fund investment.

PURPOSE AND TARGETS

2.1	Main purpose	education	vocational training	research								
2.2	Secondary purpose	test environment / pilot environment	industrial production	innovation transfer	advertisement for production							
2.3	Target groups for education & training	pupils	students	employees	entrepreneurs	freelancer	unemployed	open public				
			bachelor	master	phd students	apprentices	skilled workers	semi-skilled workers	unskilled	managers		
										lower mgmt	middle mgmt	top mgmt
2.4	Group constellation	homogeneous	heterogeneous (knowledge level, hierarchy, students + employees, etc.)									
2.5	Targeted industries	mechanical & plant eng.	automotive	logistics	transportation	FMCG	aerospace					
		chemical industry	electronics	construction	insurance / banking	textile industry	...					
2.6	Subject-rel. learning contents	prod. Mgmt & org.	resource efficiency	lean mgmt	automation	CPPS	work system design	HMI	design	Intralogistics design & mgmt	...	
2.7	Role of LAB for research	research object	research enabler									
2.8	Research topics	production management & organization	resource efficiency	lean mgmt	automation	CPPS	changeability	HMI	didactics	...		

The Robotics Lab was opened in 2000. It has been updated continuously. In 2019, when Miguel Altuna LHII moved its location, the lab was redesigned, and new equipment was introduced.

The general objective of this lab is to develop and manage projects for the assembly and maintenance of automatic measurements, regulation, and process control facilities in the new industrial systems as well as to supervise or carry out the assembly, maintenance, and commissioning of systems, respecting the criteria of quality, safety and respect for the environment and design for all. All of this, incorporating digitization skills and industry 4.0 methodologies that align with the demands of industry.

This objective involves tasks such as:

- Develop management and control programmes for communication networks.
- Prepare roadmaps, using office automation tools specific to the automatic system devices, to define the assembly protocol, tests, and guidelines for commissioning.
- Define logistics, using warehouse management computer tools, to manage the supply and storage of materials and equipment.
- Execute the assembly of automatic control installations and communication infrastructures.
- Diagnose breakdowns and malfunctions, using appropriate diagnostic and testing tools, to monitor and / or maintain associated facilities and equipment.
- Check the operation of the control programmes, using industrial programmable devices, to verify compliance with the established functional conditions.
- Analyse and use the resources and learning opportunities related to the scientific, technological, and organizational evolution of the sector and the information and communication technologies, to maintain the spirit of updating and adapt to new work and personal situations.
- Apply communication strategies and techniques, adapting to the content to be transmitted, the purpose and the characteristics of the recipients, to ensure the effectiveness of communication processes.
- Evaluate situations of prevention of occupational risks and environmental protection, proposing and applying prevention measures.
- Identify and propose the professional actions necessary to respond to universal accessibility and "design for all".

Study programs and the EQF level of each program related to the LAB:

The main use is for students in 2nd year of “automatization and robotics” EQF5

The robotics lab, besides the mentioned program is also used for:

- Specialization programmes
- Training for employment
- Tailor-made training for SMEs
- Improvement and recycling programmes
- Tkgune - Applied innovation and technical services for SMEs
- Showroom for companies

PROCESS

3.1	**Product life cycle**	product planning	product development	product design	rapid prototyping	manufacturing	assembly		logistics	service		recycling
3.2	**LAB life cycle**	investment planning	factory concept	process planning	ramp-up	manufacturing	assembly		logistics	maintenance		recycling
3.3	**Order life cycle**	configuration & order	order sequencing	production planning and scheduling		manufacturing	assembly		logistics	picking, packaging		shipping
3.4	**Technology life cycle**	planning	development	virtual testing		manufacturing	assembly		logistics	maintenance		modernization
3.5	**Indirect functions**	SCM	sales	purchasing		HR	finance / controlling			QM		
3.6	**Material flow**	continuous production				discrete production						
3.7	**Process type**	mass production		serial production		small series production					one-off production	
3.8	**Manufact. organization**	fixed-site manufacturing		work bench manufacturing		workshop manufacturing					flow production	
3.9	**Degree of automation**	manual		partly automated / hybrid automation					fully automated			
3.10	**Manufact. Methods**	cutting	trad. primary shaping		additive manufact.	forming		joining	coating		change material properties	
3.11	**Manufact. Technology**	physical			chemical				biological			

Specific equipment used in the LAB:

The idea of the lab is to be fully digitized at least to the same level as the industry is digitizing its production plants. This offers a fully digitized TVET training space designed to the same industry standards.

Addressing industry 4.0, the robotics lab works now mainly on M2M, CPS, sensor / actuators, RFID and Robotic, although adding nuances of cyber security and big data:

- **M2M**: After designing automated systems with the stations, we work on communication between them through different industrial communication systems such as ASI bus, Profibus bus and Ethernet-Profinet bus.

- **CPS**: The physical elements available in the classroom can be used for training with their corresponding simulation software. Modern PC technology allows us to create realistic 3D simulations even for the most complex automation systems. Participants discover the kinetic dynamism of mechatronic systems using virtual reality – without any risk to human or machine. This allows users to take a step into automation technology without any worries, providing a great motivational boost. For this different software's such as CIROS Mechatronics, CIROS Robotics, CIROS Studio, Robotstudio and URSIM are used.

- **Sensor, Actuators and RFID**: there are different sensors, RFID devices and readers in the lab for programming and later incorporating them into an automated system.

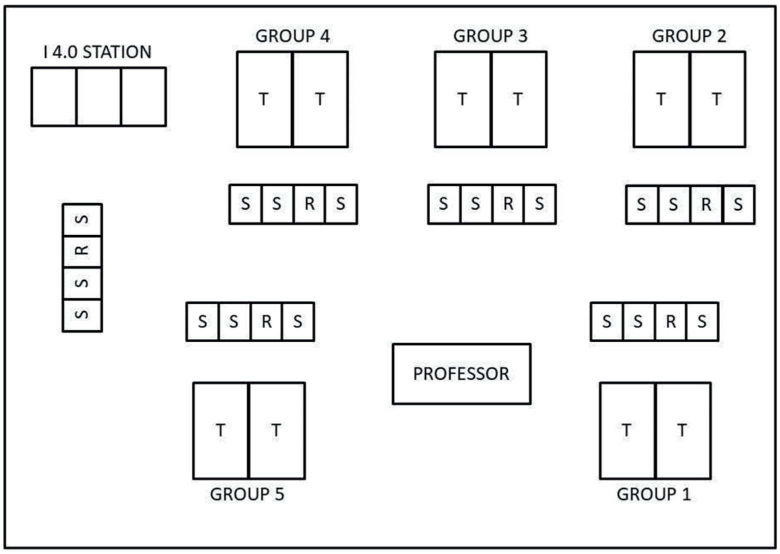
- **Robotics**: The different robots and their corresponding software are used for learning how to programme them. In addition, sets are assembled with the stations to recreate different automated facilities.

SETTING

<table>
<tr><td>4.1</td><td>Learning environment</td><td>purely physical (planning + execution)</td><td colspan="2">physical supported by digital factory (see line "IT-Integration")</td><td colspan="2">Physical, extended virtually</td><td>purely virtual (planning + execution)</td></tr>
<tr><td>4.2</td><td>Environment scale</td><td colspan="3">scaled down</td><td colspan="3">life-size</td></tr>
<tr><td>4.3</td><td>Work system levels</td><td>workplace</td><td colspan="2">work system</td><td colspan="2">factory</td><td>network</td></tr>
<tr><td>4.4</td><td>Enablers for changeability</td><td>mobility</td><td>modularity</td><td colspan="2">compatibility</td><td>scalability</td><td>universality</td></tr>
<tr><td>4.5</td><td>Changeability dimensions</td><td>layout & logistics</td><td>product features</td><td colspan="2">product design</td><td>technology</td><td>product quantities</td></tr>
<tr><td>4.6</td><td>IT-integration</td><td colspan="2">IT before SOP (CAD, CAM, simulation)</td><td colspan="2">IT after SOP (PPS, ERP, MES)</td><td colspan="2">IT after production (CRM, PLM…)</td></tr>
</table>

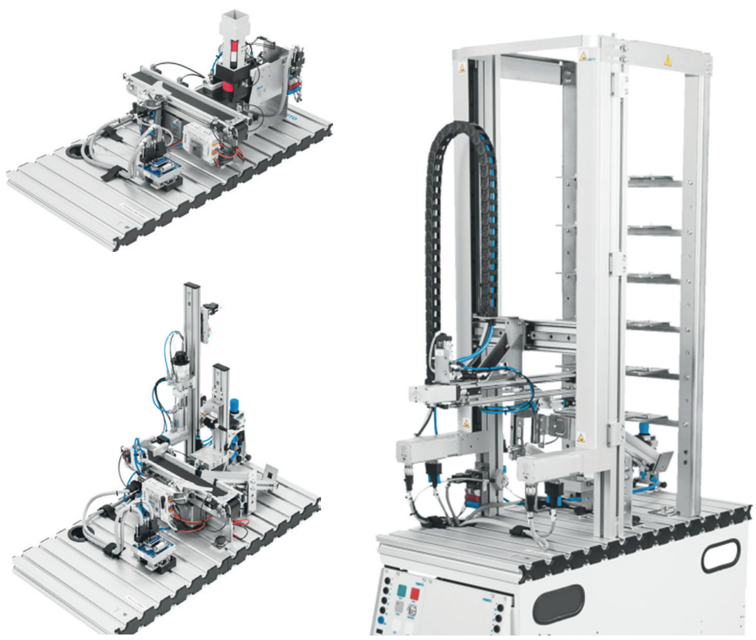
For what purpose are different IT-integrations used:

This lab occupies an area of 130m2, in which 20 students, grouped in 5 islands, can work at the same time. The area of the lab is designed as a dynamic space where there are 20 stations, 4 robots (2 industrial and 2 collaborative), 2 artificial vision cameras and 6 frequency inverters that can be moved and grouped in different ways to simulate different real production processes. Each of the stations is governed by an industrial automaton (Siemens, Omron, etc.) and they are communicated with the rest of the stations through an industrial communications bus (Profibus, Ethernet, etc).

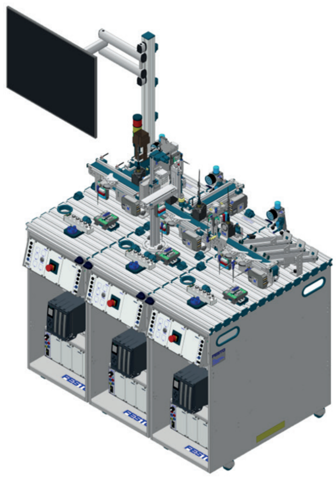


Regarding the stations, the laboratory is made up of the following 20 stations:

- 2 Distribution / Conveyor station
- 2 Sorting station
- 2 Measuring station
- 2 Pick and Place station
- 2 Separating station
- 1 Storage station
- 1 Fluid muscle press station
- 1 Packaging station
- 1 Programming station
- 1 Pneumatic handling
- 1 Electric handling
- 1 Lung station
- 1 Processing station
- 1 Storing station



- 1 I4.0 station



Regarding the robots, the laboratory is made up of the following 4:

- 2 Industrial Robots:

  - Robot ABB IRB120 (3 kg)
  - Robot Mitsubishi RV-2SDB

- 2 Collaborative Robots:

  - Universal Robot: UR3. (3kg)
  - Universal Robot: UR5 (5kg)

Regarding the artificial vision camera, the laboratory is made up of the following one:

- 2 Cognex Insight 5100

Regarding the frequency inverters, the laboratory is made up of the following 6:

- 3 Siemens Sinamics G120C. Profinet-Profibus
  3 Siemens Sinamics G120. Profinet-Profibus

PRODUCT

5.1	**Materiality**	material (physical product)					immaterial (service)		
5.2	**Form of product**	general cargo				bulk goods		flow products	
5.3	**Product origin**	own development			development by participants			external development	
5.4	**Marketability of product**	available on the market			available on the market but didactically simplified			not available on the market	
5.5	**Functionality of product**	functional product			didactically adapted product with limited functionality			without function / application, for demonstration only	
5.6	**No. of different products**	1 product	2 products	3-4 products	> 4 products	flexible, developed by participants		acceptance of real orders	
5.7	**No. of variants**	1 variant	2-4 variants	4-20 variants	…	flexible, depending on participants		determined by real orders	
5.8	**No. of components**	1 comp.	2-5 comp.	6-20 comp.		21-50 comp.	51-100 comp.		> 100 comp.
5.9	**Further product use**	re-use / re-cycling		exhibition / display		give-away	sale		disposal

Further description of the products manufactured in the LAB

This lab cannot be considered a Learning Factory. Unless some production processes are implemented and simple products are used in means of using the equipment, the overall approach of the lab is not around the production and assembly of a product or a family of products.

The methodology used for learning activities is “Challenge based collaborative learning”. Those challenges can be in many cases considered products. However, the challenges can vary from team to team, from group to group. The sequence and objectives of the challenges are also diverse, always with the aim of fulfilling a learning process and to complete a set of skills acquisitions. So, different arrangements of the lab are used.

Some of the modules of the Lab e.g., Festo didactics modules are indeed scaled learning Factories. In those modules the produced are small components with different attributes where different data is recorded in RFID chips.

So, the information of the table must be filtered and interpreted in the singular context of this Lab.

6.1	**Competence classes**	technical and methodological competencies	social & communication competencies	personal competencies	activity and implementation-oriented competencies		
6.2	**Dimensions learn. targets**	cognitive	affective	psycho-motorial			
6.3	**Learn. scenario strategy**	instruction	demonstration	closed scenario	open scenario		
6.4	**Type of learn. environment**	greenfield (development of factory environment)	brownfield (improvement of existing factory environment)				
6.5	**Communication channel**	onsite learning (in the factory environment)	remote connection (to the factory environment)				
6.6	**Degree of autonomy**	instructed	self-guided / self-regulated	self-determined/ Self organized			
6.7	**Role of the trainer**	presenter	moderator	coach	instructor		
6.8	**Type of training**	tutorial	practical lab course	seminar	workshop	project work	
6.9	**Standardization of trainings**	standardized trainings	customized trainings				
6.10	**Theoretical foundation**	prerequisite	in advance (in bloc)	alternating with practical parts	based on demand	afterwards	
6.11	**Evaluation levels**	feedback of participants	learning of participants	transfer to the real factory	economic impact of trainings	return on trainings / ROI	
6.12	**Learning success evaluation**	knowledge test (written)	knowledge test (oral)	written report	oral presentation	practical exam	none

Specific competencies trained in the lab/trained with the technologies in the LAB:

The central element on which the whole learning model is articulated is COLLABORATIVE LEARNING BASED ON CHALLENGES.

The presentation of a problematic situation, its transformation to a challenge, as well as the whole process until obtaining a result, is structured based on both the technical and specific competences of each programme, as well as those transversal competences that are currently strategical, such as: autonomous learning, teamwork, orientation towards extraordinary results, digital competences, etc …

Problematic situations, in all cases, are raised to a class configured in teams, where the work process has to enable the students to live the situation as a challenge and, from there, they have to have the opportunity to generate the necessary knowledge that provides the best solutions.

The approach of the model through challenges needs a reinterpretation of the mechanics of learning. The interpretation that best fits the model is to understand learning as a process of evolution, where the students are responsible for it. Challenge-based learning allows a scenario in which students individually and team levels are put into action and produce a result. This result is interpreted, analysed, and discussed upon to make necessary changes to approach higher objectives in the next challenge.

The main idea of this methodology is to create teams and for them to establish a contract in which they include the commitments acquired by the members of each team. These contracts will evolve and transform as teams incorporate experience. When working in the workshop, these teams will have to manage themselves by dividing up the tasks to overcome the challenge. Generally, the use of machines is individual or in pairs.

This methodology enables us to work intermodular in a way that students can work on transversal competences through challenges that are close to a business reality. The next step would be to create a Learning Factory, simulating the operation of the workshop to a real workshop.

Curriculum used:

In this lab we work on the curriculum correspondent to the program for “Higher Technician in Automation and Industrial Robotics” EQF5

Bearing in mind initial training taught at school, the use of this laboratory is carried out by 1 cycle: Higher Technician in Automation and Industrial Robotics (level 5).

The cycle makes use of the laboratory in the 2nd year and with all its modules. The total hours used are 650h, which are distributed as follows: Advanced programmable systems (120h), Industrial Robotics (100h), Industrial Communications (140h), Integration of industrial automation systems (140h), Industrial Automation and Robotics Project (50), Technical English (40) and Business and Entrepreneurship (60h). Even so, the specific use of the workshop is only done by the first 5 subjects.

Skills trained in the lab/trained with the technologies in the LAB

The program, in addition to achieving the general skills required within automation and robotics, is prepared to work on different skills related to I4.0. such as:

- Configuration and programming of BCR, QR, Data matrix, RFID readers, etc.
- Configuration and programming of artificial vision cameras, mobile devices, tablets, etc.
- Identification through monitoring.
- Software virtualization. Virtual machine.
- Program monitoring.
- Robot programming (industrial / collaborative) with integrated vision.
- Data digitization and analysis.
- Internet of things, IoT.
- Cybersecurity in the industrial environment.
- Simulation of the process using a twin or mirror image.
- Data acquisition and monitoring locally and in the cloud.

METRICS

7.1	**No. of participants per training**	1-5 participants	5-10 participants	10-15 participants	15-30 participants	30> participants	
7.2	**No. of standardized trainings**	1 training	2-4 trainings	5-10 trainings		> 10 trainings	
7.3	**Aver. duration of a single training**	≤ 1 day	> 1 day until ≤ 2 days	> 2 days until ≤ 5 days	> 5 days until ≤ 10 days	> 10 days until ≤ 20 days	> 20 days
7.4	**Participants per year**	< 50 participants	50-200 participants	201-500 participants	501-1000 participants	> 1000 participants	
7.5	**Capacity utilization**	< 10%	> 10 until ≤ 20%	> 20%until ≤ 50%	> 50%until ≤ 75%	> 75%	
7.6	**Size of LAB**	≤ 100 sqm	> 100 sqm bis ≤ 300 sqm	> 300sqm bis ≤ 500sqm	>500 sqm bis ≤ 1000 sqm	> 1000 sqm	
7.7	**FTE in LAB**	< 1	2-4	5-9	10-15	> 15	

FURTHER INFORMATION & ASPECTS TO IMPROVE

8.1	**Further information**	photographs	video
8.2	**Aspect to improve**	technical	methodological

Aspects to improve:

The next step to take in improving the lab would be to create a Digital Twins to foresee the effect is of applying robots in production lines in the Fab lab. In this way, we would start connecting different equipment of the robotics lab with machining lab's machines.

On the one hand, in this way it could be possible to optimize processes, improve maintenance, etc. On the other hand, the students would have experiences of robotics and automation in a real machining space.

For further information, some photos have been included in the document with:

The technology used in the lab

The usage of the lab

The layout of the lab

DHBW – Germany

Name of the lab:

DHBW Automation Labs

General aim/purpose (short summary):

Industry related education, focused on industrial demands from companies in our region.

Year of inauguration:

2009

LAB size (square metres):

115

			MAIN PURPOSE	
GENERAL INFORMATION	Name of the LAB	**Automation lab**	MAIN PURPOSE	
	VET/HVET centre	DHBW-Heidenheim	Education	X
	Floor space of the lab (sqm)	115	Training	X
	Main topic/learning content	Robotics, learning factory	Research/Applied innovation	_
	I4.0 related technologies	Robotics, M2M, Mobile		
PURPOSE	Learning content	Robot Programming, Production Planning and optimizing, Automation systems with Field level M2M, MES		
	Secondary purpose	Production management, Safety, Smart maintenance, Lean Production		
	LAB type	Specific	Mixed	Learning Factory

		Name of the programmes carried out on the Lab	EQF Level	Lab hours	Nº subjects on the lab	Hour/Week x nº of weeks	Nº students (3)
LEARNING CONTENTS	Learning programmes/study programmes/levels	Robotics	6	80	1	12x16	8
		Production Systems	6	40	1	12x16	8
		Automation Systems	6	40	1	12x16	8
		_	_	_	_	_	_
		_	_	_	_	_	_
		_	_	_	_	_	_

	Nº of cell	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5	Cell 6	Cell 7	Cell 8	Cell 9
SETTINGS	Category of cell	Robotics	learning Factory	_	_	_	_	_	_	_
	Nº machines	3	2	_	_	_	_	_	_	_
	I4.0 Enabler technologies used and implementation level	Robotics	M2M							
		Sensors/Actuators	SCADA,MES							

<table>
<tr><td rowspan="2">1.1</td><td rowspan="2">Operator</td><td colspan="4">academic institution</td><td colspan="7">non-academic institution</td><td colspan="2">profit-oriented operator</td></tr>
<tr><td>university</td><td colspan="2">college</td><td>BA</td><td colspan="3">vocational school / high school</td><td>chamber</td><td>union</td><td>employers´ association</td><td>industrial network</td><td>consulting</td><td>producing company</td></tr>
<tr><td>1.2</td><td>Trainer</td><td>professor</td><td colspan="2">researcher</td><td colspan="4">student assistant</td><td colspan="3">technical expert /int. Specialist</td><td>consultant</td><td colspan="2">educationalist</td></tr>
<tr><td>1.3</td><td>Development</td><td colspan="5">own development</td><td colspan="5">external assisted development</td><td colspan="3">external development</td></tr>
<tr><td>1.4</td><td>Initial funding</td><td colspan="5">internal funds</td><td colspan="5">public funds</td><td colspan="3">company funds</td></tr>
<tr><td>1.5</td><td>Ongoing funding</td><td colspan="5">internal funds</td><td colspan="5">public funds</td><td colspan="3">company funds</td></tr>
<tr><td>1.6</td><td>Funding continuity</td><td colspan="5">short term funding (e.g., single events)</td><td colspan="5">midterm funding (projects and programmes < 3 years)</td><td colspan="3">long term funding (projects and programmes > 3 years)</td></tr>
<tr><td rowspan="2">1.7</td><td rowspan="2">Business model for trainings</td><td colspan="6">open models</td><td colspan="7" rowspan="2">closed models (training programme only for single company)</td></tr>
<tr><td colspan="2">club model</td><td colspan="4">course fees</td></tr>
</table>

Description of funding methods:

DHBW is a non-profit, free university from Germany, which in this case means that the regional government owns 100 % of the shares. It is possible for DHBW to have additional third-party projects with additional funding.

At the DHBW we have about 10 Campuses, Heidenheim is one of them. On this Campus we have a lot of different Labs separated in the Building. 3 of these LABs will be described in this description.

The Automation LAB, the Fab LAB, and the research LAB (Lab for structural Analysis).

Some smaller LABs, like the VR and Eye Tracking LAB and LABs for Medicine and Information technologies as well as LABs from other campuses are not included in this description.

PURPOSE AND TARGETS

2.1	Main purpose	education	vocational training	research													
2.2	Secondary purpose	test environment / pilot environment	industrial production	innovation transfer	advertisement for production												
2.3	Target groups for education & training	pupils	students			employees							entrepreneurs	freelancer	unemployed	open public	
			bachelor	master	phd students	apprentices	skilled workers	semi-skilled workers	unskilled	managers							
										lower mgmt	middle mgmt	top mgmt					
2.4	Group constellation	homogeneous	heterogeneous (knowledge level, hierarchy, students + employees, etc.)														
2.5	Targeted industries	mechanical & plant eng.	automotive	logistics	transportation	FMCG	aerospace										
		chemical industry	electronics	construction	insurance / banking	textile industry	...										
2.6	Subject-rel. learning contents	prod. Mgmt & org.	resource efficiency	lean mgmt	automation	CPPS	work system design	HMI	design	Intralogistics design & mgmt	...						
2.7	Role of LAB for research	research object	research enabler														
2.8	Research topics	production management & organization	resource efficiency	lean mgmt	automation	CPPS	changeability	HMI	didactics	...							

Study programs and the EQF level of each program related to the LAB:

Automation systems and production systems as part of the study program industrial Engineering, the ECF level of these programs are 6.

Mechanical Engineering Program, EQF level is 6.

Workshops for pupils, EQF level is 2.

Description of the relation between each study program and the LAB:

The programs that spend the most time in LAB are the Industrial Engineering programs and the Mechanical Engineering Program.

The Masters of all technical Programs have election courses within the LAB.

Other study programs such as Information technology programs and all Business Programs have access to the LAB as well, but do not use the LAB to the same extent as aforementioned programs.

PROCESS

<table>
<tr><td>3.1</td><td>Product life cycle</td><td>product planning</td><td>product development</td><td>product design</td><td>rapid prototyping</td><td>manufacturing</td><td colspan="2">assembly</td><td>logistics</td><td colspan="2">service</td><td>recycling</td></tr>
<tr><td>3.2</td><td>LAB life cycle</td><td>investment planning</td><td>factory concept</td><td>process planning</td><td>ramp-up</td><td>manufacturing</td><td colspan="2">assembly</td><td>logistics</td><td colspan="2">maintenance</td><td>recycling</td></tr>
<tr><td>3.3</td><td>Order life cycle</td><td>configuration & order</td><td>order sequencing</td><td colspan="2">production planning and scheduling</td><td>manufacturing</td><td colspan="2">assembly</td><td>logistics</td><td colspan="2">picking, packaging</td><td>shipping</td></tr>
<tr><td>3.4</td><td>Technology life cycle</td><td>planning</td><td>development</td><td colspan="2">virtual testing</td><td>manufacturing</td><td colspan="2">assembly</td><td>logistics</td><td colspan="2">maintenance</td><td>modernization</td></tr>
<tr><td>3.5</td><td>Indirect functions</td><td>SCM</td><td>sales</td><td colspan="2">purchasing</td><td>HR</td><td colspan="3">finance / controlling</td><td colspan="3">QM</td></tr>
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</table>

Specific equipment used in the LAB:

The DHBW Automation lab includes two technologies.

Robotics:

In Robotics we teach the standard use of Industrial Robots. One important aspect is dealing with functional safety. During additional workshops we have projects about Robot Cell layout planning an industrial process workflow.

Learning factory:

In this part of the LAB, we teach different levels of automation. Sensors Actors and Automation components like Transfer systems Storing Systems and Material handling are used in the field level.

In the Control level is PLC Technology, Fieldbuses and M2M communication used.

In the Management level we have SCADA Systems and Parts of an MES System as well as predictive Maintenance. We have no connection to the Enterprise EAI Level today.

SETTING

4.1	**Learning environment**	purely physical (planning + execution)	physical supported by digital factory (see line "IT-Integration")		Physical, extended virtually		purely virtual (planning + execution)
4.2	**Environment scale**	scaled down			life-size		
4.3	**Work system levels**	workplace	work system		factory		network
4.4	**Enablers for changeability**	mobility	modularity	compatibility		scalability	universality
4.5	**Changeability dimensions**	layout & logistics	product features	product design		technology	product quantities
4.6	**IT-integration**	IT before SOP (CAD, CAM, simulation)		IT after SOP (PPS, ERP, MES)		IT after production (CRM, PLM...)	

For what purpose are different IT-integrations used:

Students of the DHBW release projects in the area of advanced Manufacturing.

Some examples are Visualising Robot Paths with AR, implementing an OPC-Server for predictive Maintenance or an agent to optimize Order Management.

PRODUCT

5.1	**Materiality**	material (physical product)					immaterial (service)		
5.2	**Form of product**	general cargo				bulk goods		flow products	
5.3	**Product origin**	own development			development by participants			external development	
5.4	**Marketability of product**	available on the market			available on the market but didactically simplified			not available on the market	
5.5	**Functionality of product**	functional product			didactically adapted product with limited functionality			without function / application, for demonstration only	
5.6	**No. of different products**	1 product	2 products	3-4 products	> 4 products	flexible, developed by participants		acceptance of real orders	
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5.9	**Further product use**	re-use / re-cycling		exhibition / display		give-away	sale		disposal

6.1	Competence classes	technical and methodological competencies	social & communication competencies	personal competencies	activity and implementation-oriented competencies	
6.2	Dimensions learn. targets	cognitive	affective	psycho-motorial		
6.3	Learn. scenario strategy	instruction	demonstration	closed scenario	open scenario	
6.4	Type of learn. environment	greenfield (development of factory environment)	brownfield (improvement of existing factory environment)			
6.5	Communication channel	onsite learning (in the factory environment)	remote connection (to the factory environment)			
6.6	Degree of autonomy	instructed	self-guided / self-regulated	self-determined/ Self organized		
6.7	Role of the trainer	presenter	moderator	coach	instructor	
6.8	Type of training	tutorial	practical lab course	seminar	workshop	project work
6.9	Standardization of trainings	standardized trainings	customized trainings			
6.10	Theoretical foundation	prerequisite	in advance (in bloc)	alternating with practical parts	based on demand	afterwards
6.11	Evaluation levels	feedback of participants	learning of participants	transfer to the real factory	economic impact of trainings	return on trainings / ROI
6.12	Learning success evaluation	knowledge test (written)	knowledge test (oral)	written report	oral presentation	practical exam	none

Curriculum used:

Modulhandbuch Engineering and Management, Modulhandbuch Mechanical Engineering

https://www.dhbw.de/fileadmin/user/public/SP/HDH/Wirtschaftsingenieurwesen/Allgemeines_Wirtschaftsingenieurwesen.pdf

https://www.dhbw.de/fileadmin/user/public/SP/HDH/Maschinenbau/Allgemeiner_Maschinenbau.pdf

METRICS

7.1	**No. of participants per training**	1-5 participants	5-10 participants	10-15 participants	15-30 participants	30> participants	
7.2	**No. of standardized trainings**	1 training	2-4 trainings	5-10 trainings		> 10 trainings	
7.3	**Aver. duration of a single training**	≤ 1 day	> 1 day until ≤ 2 days	> 2 days until ≤ 5 days	> 5 days until ≤ 10 days	> 10 days until ≤ 20 days	> 20 days
7.4	**Participants per year**	< 50 participants	50-200 participants	201-500 participants	501-1000 participants	> 1000 participants	
7.5	**Capacity utilization**	< 10%	> 10 until ≤ 20%	> 20%until ≤ 50%	> 50%until ≤ 75%	> 75%	
7.6	**Size of LAB**	≤ 100 sqm	> 100 sqm bis ≤ 300 sqm	> 300sqm bis ≤ 500sqm	>500 sqm bis ≤ 1000 sqm	> 1000 sqm	
7.7	**FTE in LAB**	< 1	2-4	5-9	10-15	> 15	

FURTHER INFORMATION & ASPECTS TO IMPROVE

8.1	**Further information**	photographs	video
8.2	**Aspect to improve**	technical	methodological

Further information (link to video):

https://www.heidenheim.dhbw.de/virtueller-rundgang

https://my.matterport.com/show/?m=SCEKg6tnmtc&sr=2.96,-.94&ss=87

Aspects to improve:

The biggest restriction is the limitation in space. The Lab should be separated in two rooms.

Aspects like Virtualisation and Simulation should be included. The M2M between the Cells and Web should be improved.

Name of the lab:

DHBW Automation Labs

General aim/purpose (short summary):

Industry related education, focused on industrial demands from companies in our region.

Year of inauguration:

2009

LAB size (square metres):

115

General information - summary table

GENERAL INFORMATION	Name of the LAB	**FabLab**						MAIN PURPOSE		
	VET/HVET centre	DHBW-Heidenheim						Education		_
	Floor space of the lab (sqm)	115						Training		X
	Main topic/learning content	FabLab						Research/Applied innovation		X
	I4.0 related technologies	IoT, Robotics, Sensor-Actors, Additive Manufacturing, CPS, Identification, AI								
PURPOSE	Learning content	Embeded Systems, Real Time Systems, Product Development, AI								
	Secondary purpose	Product Development								
	LAB type	Specific			Mixed			Learning Factory		
LEARNING CONTENTS	Learning programmes/study programmes/levels	Name of the programmes carried out on the Lab				EQF Level	Lab hours	Nº subjects on the lab	Hour/Week x nº of weeks	Nº students (3)
		Robotics				6	40	1	12x16	8
		Embedded Systems				6	40	1	12x16	8
		Student Projects				6	80	1	12x16	8
		_				_	_	_	_	_
		_				_	_	_	_	_
		_				_	_	_	_	_
SETTINGS	Nº of cell	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5	Cell 6	Cell 7	Cell 8	Cell 9
	Category of cell	Mobile Robotics	Collaboration Robots	3d-Printing	Electronics develop Workspace	_	_	_	_	_
	Nº machines	3	2	3	2	_	_	_	_	_
	I4.0 Enabler technologies used and implementation level	Robotics	Robotics	Additive Manufacturing	Sensors/Actuators					
		Sensors/Actuators	Autonomous Systems	M2M	IOT, CPS					

OPERATIONAL MODEL

1.1	Operator	academic institution	non-academic institution	profit-oriented operator							
		university	college	BA	vocational school / high school	chamber	union	employers´ association	industrial network	consulting	producing company
1.2	Trainer	professor	researcher	student assistant	technical expert /int. Specialist	consultant	educationalist				
1.3	Development	own development	external assisted development	external development							
1.4	Initial funding	internal funds	public funds	company funds							
1.5	Ongoing funding	internal funds	public funds	company funds							
1.6	Funding continuity	short term funding (e.g., single events)	midterm funding (projects and programmes < 3 years)	long term funding (projects and programmes > 3 years)							
1.7	Business model for trainings	open models	closed models (training programme only for single company)								
		club model	course fees								

Description of funding methods:

DHBW is a non-profit, free university from Germany, which in this case means that the regional government owns 100 % of the shares. It is possible to have additional third-party Projects with additional funding.

PURPOSE AND TARGETS

2.1	Main purpose	education	vocational training	research							
2.2	Secondary purpose	test environment / pilot environment	industrial production	innovation transfer	advertisement for production						
2.3	Target groups for education & training	pupils	students	employees	entrepreneurs	freelancer	unemployed	open public			
			bachelor	master	phd students	apprentices	skilled workers	semi-skilled workers	unskilled	managers	
										lower mgmt	middle mgmt	top mgmt
2.4	Group constellation	homogeneous	heterogeneous (knowledge level, hierarchy, students + employees, etc.)								
2.5	Targeted industries	mechanical & plant eng.	automotive	logistics	transportation	FMCG	aerospace				
		chemical industry	electronics	construction	insurance / banking	textile industry	...				
2.6	Subject-rel. learning contents	prod. Mgmt & org.	resource efficiency	lean mgmt	automation	CPPS	work system design	HMI	design	Intralogistics design & mgmt	...
2.7	Role of LAB for research	research object	research enabler								
2.8	Research topics	production management & organization	resource efficiency	lean mgmt	automation	CPPS	changeability	HMI	didactics	...	

Study programs and the EQF level of each program related to the LAB:

Industrial Engineering, the ECF level of these programs are 6.

Mechanical Engineering Program, EQF level is 6.

Computer science Program, EQF level is 6.

Workshops for pupils EQF level is 2.

Description of the relation between each study program and the LAB:

The programs that spend the most time in LAB are the Industrial Engineering programs and the Mechanical Engineering Program as well as Computer science.

The Masters of all technical Programs have election Courses within the Lab

Other study programs such as business Informatics programs and all Business Programs have access to the Lab, but they do not use it so far now.

PROCESS

3.1	**Product life cycle**	product planning	product development	product design	rapid prototyping	manufacturing	assembly	logistics	service	recycling
3.2	**LAB life cycle**	investment planning	factory concept	process planning	ramp-up	manufacturing	assembly	logistics	maintenance	recycling
3.3	**Order life cycle**	configuration & order	order sequencing	production planning and scheduling		manufacturing	assembly	logistics	picking, packaging	shipping
3.4	**Technology life cycle**	planning	development	virtual testing		manufacturing	assembly	logistics	maintenance	modernization
3.5	**Indirect functions**	SCM	sales	purchasing		HR	finance / controlling		QM	
3.6	**Material flow**	continuous production				discrete production				
3.7	**Process type**	mass production		serial production		small series production			one-off production	
3.8	**Manufact. organization**	fixed-site manufacturing		work bench manufacturing		workshop manufacturing			flow production	
3.9	**Degree of automation**	manual		partly automated / hybrid automation				fully automated		
3.10	**Manufact. Methods**	cutting	trad. primary shaping		additive manufact.	forming	joining	coating	change material properties	
3.11	**Manufact. Technology**	physical			chemical			biological		

Specific equipment used in the LAB:

The DHBW FabLab includes multi-Technologies.

<u>Robotics</u>

In Robotics we Teach the use of Collaboration Robots. One important aspect is dealing with Human Robotics Interaction. Additional we have some Mobile Robots. We teach the levels of autonomous Systems and the necessary Sensor Systems like Cams, Lidar, Ultrasonic

<u>Learning Workspace</u>

In this part of the Lab is for developing IOT Projects with embedded Systems. The 3D Printers are Involved in this technology.

SETTING

<table>
<tr><td>4.1</td><td>Learning environment</td><td>purely physical (planning + execution)</td><td colspan="2">physical supported by digital factory (see line “IT-Integration”)</td><td colspan="2">Physical, extended virtually</td><td>purely virtual (planning + execution)</td></tr>
<tr><td>4.2</td><td>Environment scale</td><td colspan="3">scaled down</td><td colspan="3">life-size</td></tr>
<tr><td>4.3</td><td>Work system levels</td><td>workplace</td><td colspan="2">work system</td><td colspan="2">factory</td><td>network</td></tr>
<tr><td>4.4</td><td>Enablers for changeability</td><td>mobility</td><td>modularity</td><td colspan="2">compatibility</td><td>scalability</td><td>universality</td></tr>
<tr><td>4.5</td><td>Changeability dimensions</td><td>layout & logistics</td><td>product features</td><td colspan="2">product design</td><td>technology</td><td>product quantities</td></tr>
<tr><td>4.6</td><td>IT-integration</td><td colspan="2">IT before SOP (CAD, CAM, simulation)</td><td colspan="2">IT after SOP (PPS, ERP, MES)</td><td colspan="2">IT after production (CRM, PLM…)</td></tr>
</table>

For what purpose are different IT-integrations used:

Students of the DHBW realizes Projects in the area of IOT, CPS and Robotics

Some Projects are Realising mobile Robots ode special Handling devices for certain Processes. Equipment for Remote Operational of smart Systems like Home Farming.

PRODUCT

5.1	**Materiality**	material (physical product)					immaterial (service)		
5.2	**Form of product**	general cargo				bulk goods		flow products	
5.3	**Product origin**	own development			development by participants			external development	
5.4	**Marketability of product**	available on the market			available on the market but didactically simplified			not available on the market	
5.5	**Functionality of product**	functional product			didactically adapted product with limited functionality			without function / application, for demonstration only	
5.6	**No. of different products**	1 product	2 products	3-4 products	> 4 products	flexible, developed by participants		acceptance of real orders	
5.7	**No. of variants**	1 variant	2-4 variants	4-20 variants	...	flexible, depending on participants		determined by real orders	
5.8	**No. of components**	1 comp.	2-5 comp.	6-20 comp.		21-50 comp.	51-100 comp.		> 100 comp.
5.9	**Further product use**	re-use / re-cycling		exhibition / display		give-away	sale		disposal

Further description of the products manufactured in the LAB:

Small Giveaways with 3D Printer or Laser Cutter. Small differential Drive Robots based on Arduino or comparable Platform.

Prototypes for Robots to be tested and further developed.

6.1	**Competence classes**	technical and methodological competencies	social & communication competencies	personal competencies	activity and implementation-oriented competencies		
6.2	**Dimensions learn. targets**	cognitive	affective	psycho-motorial			
6.3	**Learn. scenario strategy**	instruction	demonstration	closed scenario	open scenario		
6.4	**Type of learn. environment**	greenfield (development of factory environment)	brownfield (improvement of existing factory environment)				
6.5	**Communication channel**	onsite learning (in the factory environment)	remote connection (to the factory environment)				
6.6	**Degree of autonomy**	instructed	self-guided / self-regulated	self-determined/ Self organized			
6.7	**Role of the trainer**	presenter	moderator	coach	instructor		
6.8	**Type of training**	tutorial	practical lab course	seminar	workshop	project work	
6.9	**Standardization of trainings**	standardized trainings	customized trainings				
6.10	**Theoretical foundation**	prerequisite	in advance (in bloc)	alternating with practical parts	based on demand	afterwards	
6.11	**Evaluation levels**	feedback of participants	learning of participants	transfer to the real factory	economic impact of trainings	return on trainings / ROI	
6.12	**Learning success evaluation**	knowledge test (written)	knowledge test (oral)	written report	oral presentation	practical exam	none

Curriculum used:

Modulhandbuch Engineering and Management, Modulhandbuch Mechanical Engineering

https://www.dhbw.de/fileadmin/user/public/SP/HDH/Wirtschaftsingenieurwesen/Allgemeines_Wirtschaftsingenieurwesen.pdf

https://www.dhbw.de/fileadmin/user/public/SP/HDH/Maschinenbau/Allgemeiner_Maschinenbau.pdf

METRICS

7.1	**No. of participants per training**	1-5 participants	5-10 participants	10-15 participants	15-30 participants	30> participants	
7.2	**No. of standardized trainings**	1 training	2-4 trainings	5-10 trainings		> 10 trainings	
7.3	**Aver. duration of a single training**	≤ 1 day	> 1 day until ≤ 2 days	> 2 days until ≤ 5 days	> 5 days until ≤ 10 days	> 10 days until ≤ 20 days	> 20 days
7.4	**Participants per year**	< 50 participants	50-200 participants	201-500 participants	501-1000 participants	> 1000 participants	
7.5	**Capacity utilization**	< 10%	> 10 until ≤ 20%	> 20%until ≤ 50%	> 50%until ≤ 75%	> 75%	
7.6	**Size of LAB**	≤ 100 sqm	> 100 sqm bis ≤ 300 sqm	> 300sqm bis ≤ 500sqm	>500 sqm bis ≤ 1000 sqm	> 1000 sqm	
7.7	**FTE in LAB**	< 1	2-4	5-9	10-15	> 15	

FURTHER INFORMATION & ASPECTS TO IMPROVE

8.1	**Further information**	photographs	video
8.2	**Aspect to improve**	technical	methodological

Aspects to improve:

The biggest restriction is the limitation in space.

Aspects like virtualisation and simulation should be included. A basic Framework and Infrastructure for CPS should be provided.

Da Vinci College – Netherlands

- **Name of the lab:**

  Sustainability factory (Duurzaamheidsfabriek)

- **General aim/purpose (short summary):**

  On these floors students are practically trained for their future profession. The way education of MBO (vocational training) in our Technical School department is formed is a hybrid way of learning. We try as much as possible to teach together with companies, or even more important, we try to work on real orders from companies. We believe that working together with companies will result in better skilled professionals.

- **Year of inauguration:**

  2010

- **LAB size (square metres):**

  1075 + 800

General information - summary table

GENERAL INFORMATION	Name of the LAB	**Duurzaamheidsfabriek 1st floor**							MAIN PURPOSE	
	VET/HVET centre	Davinci College							Education	X
	Floor space of the lab (sqm)	1075							Training	X
	Main topic/learning content	Machining, CNC machining, Additive Manufacturing, Welding, Proces engineering, Industrial 3D printing							Research/Applied innovation	_
	I4.0 related technologies	Additive Manufacturing, Mobile technologies, Robotics								
PURPOSE	Learning content	Conventional lathe/milling machining, CNC machining, Additive Manufacturing, Welding, Water cutting								
	Secondary purpose	Production, Safety, I4.0 related topics, smart maintenance								
	LAB type	Specific			Mixed				Learning Factory	
LEARNING CONTENTS	Learning programmes/study programmes/levels	Name of the programmes carried out on the Lab				EQF Level	Lab hours	Nº subjects on the lab	Hour/Week x nº of weeks	Nº students (3)
		Engineer MBO level (Middenkader engineer)				3/4	400	_	20x40	_
		Electrotechnical Engineer				3/4	400	_	20x40	_
		Installation techniques				3/4	400	_	20x40	_
		Metal and proces engineering				3/4	400	_	20x40	_
		_				_	_	_	_	_
		_				_	_	_	_	_
SETTINGS	Nº of cell	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5	Cell 6	Cell 7	Cell 8	Cell 9
	Category of cell	Lathes	Mills	Additive Manufacturing	Liquid Calibration station	Welding	Conventional machining machines	Water Cutting Machine	Arg Reality Welding	CNC
	Nº machines	7	3	4	1	8	10	1	10	5
	I4.0 Enabler technologies used and implementation level	Additive Manufacturing	Welding simulator	AR/VR						

GENERAL INFORMATION	Name of the LAB	Duurzaamheidsfabriek 2nd floor							MAIN PURPOSE	
	VET/HVET centre	Davinci College							Education	_
	Floor space of the lab (sqm)	800							Training	_
	Main topic/learning content	Smart Technology Lab, Drive Technology Lab, Control Technology Lab, LexLab							Research/Applied innovation	_
	I4.0 related technologies	Additive Manufacturing, Mobile technologies, Robotics								
PURPOSE	Learning content	Robots, Production Lane, Solar Panel Technology, IOT, Drive engines								
	Secondary purpose	Production, Safety, I4.0 related topics								
	LAB type	Specific			Mixed				Learning Factory	
LEARNING CONTENTS	Learning programmes/study programmes/levels	Name of the programmes carried out on the Lab				EQF Level	Lab hours	Nº subjects on the lab	Hour/Week x nº of weeks	Nº students (3)
		Engineer MBO level (Middenkader engineer)				3/4	400	_	20x40	_
		Electrotechnical Engineer				3/4	400	_	20x40	_
		Installation techniques				4	400	_	20x40	_
		Smart Technology				4	400	_	20x40	_
		House of Energy Transition				2/3/4	400	_	20x40	_
		_				_	_	_	_	_
SETTINGS	Nº of cell	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5	Cell 6	Cell 7	Cell 8	Cell 9
	Category of cell	Robotino	MPS Robot	Production Lane	PLC	Siemens logo	Pneumatic Feisto	Mech prod plate	Laser cutter	IoT/IIoT
	Nº machines	2	_	10	10	20	2	1	2	A lot
	I4.0 Enabler technologies used and implementation level									

OVERVIEW OF THE CONSORTIUM PARTNERS VET/VHET CENTRES' LABS

EXAM 4.0's final model for describing VET/HVET centres' AM LABs has been evaluated by Curt Nicolin Gymnasiet and Miguel Altuna LHII. The tables make the comparison of LABs less time consuming and it also makes the comparison between LABs and Learning factories easier.

Following is a thorough overview and comparison between Curt Nicolin Gymnasiet's and Miguel Altuna LHII's LABs. The following overview is determined to show the simplicity of comparison of LABs when using the tables in EXAM 4.0's final model for describing VET/HVET centres' AM LABs.

Operational model:

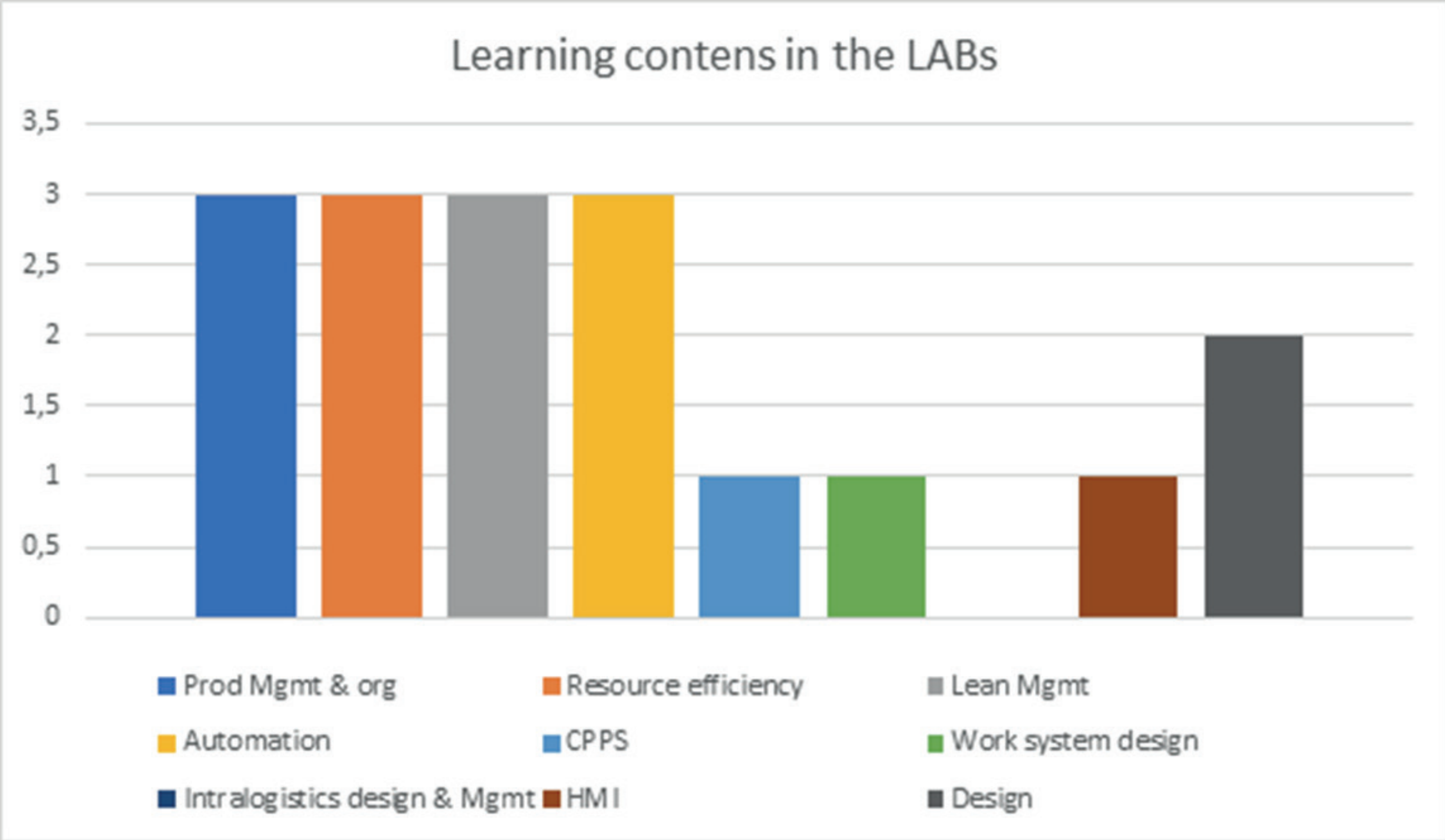
It is easily read in the first table of the model that both Curt Nicolin Gymnasiet and Miguel Altuna LHII are academic institutions and either a vocational school/gymnasiet or a college.

Curt Nicolin Gymnasiet uses all selectable funds in the table, thus internal-, public- and company funds, for both initial and ongoing funding. Miguel Altuna LHII Machining LAB uses internal- and public funds for initial funding and public- and company funding for ongoing funding. The funding continuity is for Curt Nicolin Gymnasiet short, mid, and long term. Long term funding is however the only method used at Miguel Altuna LHII.

Purpose and targets:

The main purpose for Curt Nicolin Gytmnasiet's LAB is education and vocational training. The main purpose for both of Miguel Altuna LHII's LABs are vocational training and research. The targeted groups for training and education are at Curt Nicolin Gymnasiet students and unemployed. The second table clearly shows that Miguel Altuna LHII has a wider target group including employees, skilled and unskilled workers, managers, entrepreneurs, and freelancers for instance.

The education in Curt Nicolin Gymnasiet's LAB is targeted towards mechanical and electronic industries. Miguel Altuna LHII Machining LAB targets their education towards mechanical, electronics, automotive and aerospace industries, and the robotic LAB towards mechanical, electronic, and automotive industries.



Process:

All LABs from Curt Nicolin Gymansiet and Miguel Altuna LHII have a physical discrete production. Curt Nicolin Gymnasiet has work bench manufacturing and workshop manufacturing as their manufacturing organization and the production is either manual or partly automated. Both of Miguel Altuna LHII's LABs have workshop manufacturing as their manufacturing organization. The machining LAB is either manually handled or partly automated and the robotic LAB is fully automated.

Setting:

Both Curt Nicolin Gymnasiet's LAB and Miguel Altuna LHII's Robotic LAB are physical LABs that are extended virtually, e.g., via VR or AR. The machining LAB is also physical but supported by a digital factory. The changeability enablers in CNG's LAB are mobility, modularity, and scalability. Miguel Altuna LHII's machining LAB have compatibility, scalability and universality and the Robotic LAB have mobility and modularity as their changeability enablers. The changeability dimensions for CNG's LAB and Miguel Altuna LHII's Robotic LAB are layout & logistics and technology. Miguel Altuna LHII's machining LAB has product features and product design. The most frequently used IT-integration in the LABs is IT before sop applications such as CAD and CAM, but IT after sop and production are also used in form of e.g., PPS, ERP and PLM.

Product:

CNG's LAB and Miguel Altuna LHII's machining LAB have physical products and the Robotic LAB has immaterial products, thus service. Neither of the products manufactured in the LABs are available on the market. The functionality of the products varies in CNG's LAB, functional, without function and with limited function. The products in Miguel Altunas LHII' LABs are however not functional. The further usage of the products from CNG's LAB are for display, as giveaway or for sale. The products from both of Miguel Altunas LHII' LAB is reused or displayed.

Didactics:

All LABs educate all competencies available in the table, thus technical, methodological, social, communication, personal, activity and implementation-oriented competencies. Competencies and skills are mainly educated via tutorials, seminars, through practical LAB courses and projects. The learning success evaluation in the LABs are knowledge test, written report, oral presentation, practical exam but also oral knowledge test.

Metrics:

CNG's LAB is over 1000 square metres, takes between 200-500 learners every year and the number of participants in each training can vary from 5 to over 30. Both of Miguel Altunas LHII' LABs are from 100 to 300 square metres; take less than 50 learners every year and each training have from 15 to 30 participants.

EXAM 4.0 affiliated partners' LABs

CIFP Bidasoa LHII - Basque Country, Spain

Machining LAB

- **General aim/purpose (short summary):**

The machining workshop, with advanced machinery and resources, was re-inaugurated in 2015 to meet the following needs:

1. Teach mechanical manufacturing VET programmes' practical subjects.

2. Offer initial training courses and advanced machining specialization courses for workers and unemployed, as well as customized courses for small and medium-sized companies (SMEs).

3. Provide applied innovation, prototyping, research, and manufacturing services (TKGUNE programme - http://y2u.be/AiRYtJe5NcE) to small and medium-sized companies (SMEs).

- **Year of inauguration:**

2015

- **LAB size (square metres):**

532

General information - summary table

GENERAL INFORMATION	Name of the LAB	**Machining Lab**	MAIN PURPOSE	
	VET/HVET centre	Bidasoa LHII	Education	X
	Floor space of the lab (sqm)	532(71 cell1, 461 cell2-cell9)	Training	X
	Main topic/learning content	Cyber Physical infrastructure (CPS), Cloud technologies, Virtual Reality (VR) and Augmented Reality (AR), Communication and Networking (Industrial Internet of Things IIoT), Machine-to-Machine Communication (M2M), RFID technologies, Sensors and actuators.	Research/Applied innovation	X
	I4.0 related technologies	Machining on: Conventional lathe and milling machining, CNC machining, EDM, Grinding, Welding		

PURPOSE	Learning content	Machine learning such as CNC machining, Additive Manufacturing, conventional lathe/milling		
	Secondary purpose	Production management, Safety, I4.0 related topics, machining services for external enterprises		
	LAB type	Specific	Mixed	Learning Factory

		Name of the programmes carried out on the Lab	EQF Level	Lab hours	Nº subjects on the lab	Hour/Week x nº of weeks	Nº students (3)
LEARNING CONTENTS	Learning programmes/study programmes/levels	Higher Technician in Production Scheduling in Mechanical Manufacturing	5	198 252	2	6x33 12x21	2x25 3x25
		Technician in machining	4	330 210 252	3	11x33 10x21 12x21	2x25 2x25
		Higher Technician in Manufacturing Design Mechanics	5	198	1	6x33	1x25
		_	_	_	_	_	_
		_	_	_	_	_	_
		_	_	_	_	_	_

SETTINGS	Nº of cell	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5	Cell 6	Cell 7	Cell 8	Cell 9
	Category of cell	CNC lathes	CNC mills	Lathes	Mills	EDM	Grinding	Welding	Tools warehouse	Material store
	Nº machines	3	4	13	7	3	5	2	_	3
	I4.0 Enabler technologies used and implementation level	Robotics	Additive Manufacturing	Cloud	CPS	Mobile/Tablet	AR/VR	Big data analytics	Ai	IoT/IIoT
		Sensors/Actuators	RFID	M2M	Cybersecurity	Digital twin				

OPERATIONAL MODEL

1.1	**Operator**	academic institution			non-academic institution					profit-oriented operator	
		university	college	BA	vocational school / high school	chamber	union	employers´ association	industrial network	consulting	producing company
1.2	**Trainer**	professor	researcher	student assistant		technical expert /int. Specialist			consultant	educationalist	
1.3	**Development**	own development			external assisted development				external development		
1.4	**Initial funding**	internal funds			public funds				company funds		
1.5	**Ongoing funding**	internal funds			public funds				company funds		
1.6	**Funding continuity**	short term funding (e.g., single events)			midterm funding (projects and programmes < 3 years)				long term funding (projects and programmes > 3 years)		
1.7	**Business model for trainings**	open models				closed models (training programme only for single company)					
		club model	course fees								

Note: in 1.7 Business models for training there are different modalities: For students in the initial training model, the programs are state funded. For tailored training for companies, it is course fee. We also use closed models

This laboratory is within a VET centre that imparts institutionalized, intentional, and planned learning processes and whose results are accredited.

Description of funding methods

Bidasoa LHII being a public VET centre belonging to the Basque Country Education ministry so that the activities of the centre are mainly funded by the VET department of education.

Bidasoa LHII plans and monitors its own budget, deciding independently how to use the resources.

- Bidasoa LHII is funded mainly by the government. However, it is allowed to earn and retain income (for example, by selling training services) to fund investments, research, or other activities.

- Bidasoa LHII being a public body has to some degree, the authority to enter independently into contracts with other organisations such as businesses, training providers and donors e.g., to buy or sell services or equipment. There is limitation in the maximum amount of the contracts and the nature of them.

- However, Bidasoa LHII has not the authority to take out loans, for example, to fund investment.

PURPOSE AND TARGETS

2.1	Main purpose	education	vocational training	research							
2.2	Secondary purpose	test environment / pilot environment	industrial production	innovation transfer	advertisement for production						
2.3	Target groups for education & training	pupils	students: bachelor	students: master	students: phd students	employees: apprentices	employees: skilled workers	employees: semi-skilled workers	employees: unskilled	employees: managers: lower mgmt	employees: managers: middle mgmt
		employees: managers: top mgmt	entrepreneurs	freelancer	unemployed	open public					
2.4	Group constellation	homogeneous	heterogeneous (knowledge level, hierarchy, students + employees, etc.)								
2.5	Targeted industries	mechanical & plant eng.	automotive	logistics	transportation	FMCG	aerospace				
		chemical industry	electronics	construction	insurance / banking	textile industry	...				
2.6	Subject-rel. learning contents	prod. Mgmt & org.	resource efficiency	lean mgmt	automation	CPPS	work system design	HMI	design	Intralogistics design & mgmt	...
2.7	Role of LAB for research	research object	research enabler								
2.8	Research topics	production management & organization	resource efficiency	lean mgmt	automation	CPPS	changeability	HMI	didactics	...	

The main purpose of the workshop is the teaching of various practical courses, all of them in the field of mechanical manufacturing. Learning and practicing how to use the machinery available in this workshop, students acquire the technical skills related to the different training programmes available in the school. However, this is not its only purpose, as courses are also given to both workers and unemployed industrial personnel (initial training and specialization programmes). Moreover, prototyping, research and manufacturing services are offered to companies within a programme called TKgune.

According to these objectives, the most habitual tasks performed in the workshop are the following:

- Prepare the procedures for the machining of parts, defining the resources, the necessary times, and the control systems.
- Execute and/or supervise the machining, assembly, and maintenance processes, controlling the times and the quality of the results.
- Execute and/or supervise the programming and tuning of numerical control machines for machining.

On the other hand, new tasks are being included and/or implemented in the workshop:

- Schedule production training, using computerized management techniques and tools.
- Determine the necessary provisioning of material and tools through an intelligent warehouse.
- Management and execution of the maintenance of resources and machines.

These tasks are completely related to the 4.0 industry implementation process that the school is doing. In the medium term, there are two main objectives:

- Create an advanced 4.0 manufacturing lab where all the management is done through an Enterprise Resource Planning (ERP) and all the information is placed on the cloud. This system should manage the purchase, entry and stock of raw material, consumables and spare parts, production process, tools' smart warehouse, machinery, preventive and corrective maintenance, and digital information for the functioning of the lab.
- Develop an Industry 4.0 based training methodology, where students acquire skills related to Industry 4.0 (see chapter 6).

In the short term, the main goal is the implementation and familiarisation of all the staff with the smart warehouse available in the workshop, and the implementation of the Enterprise Resource Planning (ERP) in the workshop's day-to-day operations. These aspects are described in detail in section 2.5.

Regarding the target groups of the workshop, it is mainly used by students from 3 different programs:

- Senior Technician in Production Scheduling in Mechanical Manufacturing (EQF level 5),
- Senior Technician in Manufacturing Design Mechanics (EQF level 5)
- Technician in machining (EQF level 4)

But, as mentioned before, besides the initial training programmes, the workshop is also used for:

- Specialization programs
- Training for employment
- Improvement and recycling programs
- Tkgune - Applied innovation and technical services to SMEs
- Tailor-made training for SMEs (not very common)

Description of the relation between each study program and the LAB

Each programme uses different cells and equipment depending on the period and the course. However, students in both EQF4 and EQF5 programmes follow a similar evolution in their study programmes regarding the use of the workshop. During the first course, students are focused on conventional machining, while in the second course, the focus main focus is on the CNC machining. Opposite to EQF5 programmes, EQF4 programmes include grinding, Electrical Discharge Machining (EDM) and welding training during the second course.

Nowadays, both EQF4 and EQF 5 programmes focus students' learning on the preparation and production of parts. The main difference between different programmes is the level of rigorousness and specialization acquired by students. EQF5 students are supposed to acquire not only machining technical competences, but also management and planning ones.

The aim of the implementation of the ERP and the intelligent warehouse, is to allow EQF5 students performing real management and planning tasks, to develop their competences on this field and to learn tasks the new tasks mentioned before:

- Schedule production training, using computerized management techniques and tools.
- Determine the necessary provisioning of material and tools through an intelligent warehouse.
- Management and execution of the maintenance of resources and machines.

PROCESS

<table>
<tr><td>3.1</td><td>Product life cycle</td><td>product planning</td><td>product development</td><td>product design</td><td>rapid prototyping</td><td>manufacturing</td><td colspan="2">assembly</td><td>logistics</td><td colspan="2">service</td><td>recycling</td></tr>
<tr><td>3.2</td><td>LAB life cycle</td><td>investment planning</td><td>factory concept</td><td>process planning</td><td>ramp-up</td><td>manufacturing</td><td colspan="2">assembly</td><td>logistics</td><td colspan="2">maintenance</td><td>recycling</td></tr>
<tr><td>3.3</td><td>Order life cycle</td><td>configuration & order</td><td>order sequencing</td><td colspan="2">production planning and scheduling</td><td>manufacturing</td><td colspan="2">assembly</td><td>logistics</td><td colspan="2">picking, packaging</td><td>shipping</td></tr>
<tr><td>3.4</td><td>Technology life cycle</td><td>planning</td><td>development</td><td colspan="2">virtual testing</td><td>manufacturing</td><td colspan="2">assembly</td><td>logistics</td><td colspan="2">maintenance</td><td>modernization</td></tr>
<tr><td>3.5</td><td>Indirect functions</td><td>SCM</td><td>sales</td><td colspan="2">purchasing</td><td>HR</td><td colspan="3">finance / controlling</td><td colspan="3">QM</td></tr>
<tr><td>3.6</td><td>Material flow</td><td colspan="4">continuous production</td><td colspan="7">discrete production</td></tr>
<tr><td>3.7</td><td>Process type</td><td colspan="2">mass production</td><td colspan="2">serial production</td><td colspan="5">small series production</td><td colspan="2">one-off production</td></tr>
<tr><td>3.8</td><td>Manufact. organization</td><td colspan="2">fixed-site manufacturing</td><td colspan="2">work bench manufacturing</td><td colspan="5">workshop manufacturing</td><td colspan="2">flow production</td></tr>
<tr><td>3.9</td><td>Degree of automation</td><td colspan="2">manual</td><td colspan="5">partly automated / hybrid automation</td><td colspan="4">fully automated</td></tr>
<tr><td>3.10</td><td>Manufact. Methods</td><td>cutting</td><td colspan="2">trad. primary shaping</td><td>additive manufact.</td><td colspan="2">forming</td><td>joining</td><td colspan="2">coating</td><td colspan="2">change material properties</td></tr>
<tr><td>3.11</td><td>Manufact. Technology</td><td colspan="3">physical</td><td colspan="4">chemical</td><td colspan="4">biological</td></tr>
</table>

The workshop is distributed in different cells where different work/production processes can be found, each of them optimized for the goals of the different courses which use these cells. Each cell has its specific workflow, arrangement, and technology. However, there are some processes common to most cells, as it is the ERP, the recycling process, the intelligent warehouse, etc.

As described in chapter 2, some of these common processes and tasks are related to a transition strategy towards a 4.0 modernized workshop concept which is being carried out in the school, and more specifically in this workshop. In the next chapter, the different technologies and equipment that enable this transition are described shortly.

Specific equipment used in the LAB, Addressing Industry 4.0

In recent years, the workshop has incorporated different technologies and/or work methodologies focused on the digitalisation of the workshop and industry 4.0 modernization. Some of them have been or are being implemented together with other VET centres in the area.

In the case of Bidasoa LHII, there are two main lines of work:

- Digitalisation of the workshop management and use. Centralisation in the cloud of the information used while working in the workshop, and access to it through a digital touch screen. The main areas in which this digitalisation process is being developed are digital management of workshop maintenance, access to the Odoo platform, access to information for teaching classes such as plans, processes, machine quadrants, etc.

- Implementation of an ERP, called Odoo, for:

  - The use of digital machining process sheets by means of tactile devices (tablets).
  - Data analysis: machine occupation, machining times.
  - Workshop management: machine reservation, machine use control and student working times, material and tool warehouse management, purchase management, maintenance management, etc.

In addition to these two main lines of work, work has been underway for some time on the implementation of an intelligent tool warehouse and the autonomous supply of EPIS by students.

Below, the main characteristics of the workshop are described in more detail in relation to the aforementioned areas of work.

- Information accessible in the cloud: The school has a digital management system based on google suite (school intranet). Work is underway to include all the information/digital tools used in the workshop within this system. The main elements included in this platform are:

  - Access to the Odoo platform (ERP system described below)
  - Information used by both the teaching staff and students in the workshop: work plans, machining process sheets, students-machines distribution tables, digital presentation and videos, documentation for the monitoring of the teaching activity (control documents for attendance or incident reports, for example), etc.
  - Access to tools used by teachers and/or students during lectures: access to Moodle platform, video conferencing tools, CAD-CAM tools, etc.

- Access to this management system and to all the mentioned elements and tools is made by means of a central touch device in which a fingerprint access device is included to ensure fast and safe access to the personnel working in the workshop.

Figure 1: school Intranet platform where all the management and information are centralized

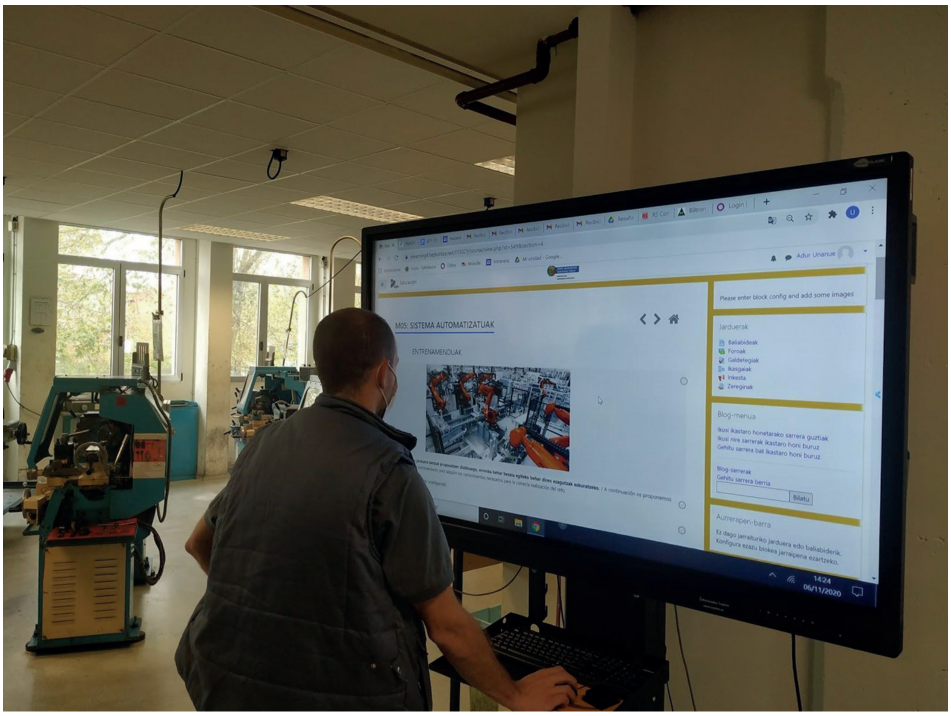


Figure 2: central touch screen of the workshop

- Odoo ERP: Odoo is an open-source resource planning system (ERP) which is being developed, customised, and implemented at the centre. Through this ERP, it is intended to cover the following aspects:

    - Management of computer maintenance.

    - Management of corrective/preventive maintenance in the workshop.

- Planning and management of the use of machines: reservations, occupation control, planning of student/machine use, assignment of specific work orders to specific students/machines, etc.

- Creation of digital process sheets on the platform. The aim is for the students to create the digital process sheet on the platform and then use it on the machine by means of a touch device that each machine has (tablets in this case). In this way, the use of paper is eliminated as each student can access all the information needed via the digital device (digital process sheet, work plan, technical information, etc.).

- Control of the evolution of students' work and control of the use of machines: teachers can monitor the state of the workshop and the students' work thanks to the system described in the previous paragraph. This monitoring can be done from any computer device. Furthermore, as mentioned in chapter 2, one of the objectives of the implementation of this ERP is that students of EQF5 level programmes can manage and schedule the work in the workshop, and the platform makes possible this monitoring by students too.

Figure 3: teacher using a digital process sheet made in the Odoo platform (ERP) in the digital touch device of a tuning machine.

- Big data analysis: The use of the ERP allows the acquisition of a large amount of data: level of use of machines, hours needed by each student in each operation/part, hours of use of elements/tools, etc. The medium-term objective is to be able to analyse all this information to obtain useful information for making decisions related to teaching/learning processes, workshop management, schedule management, maintenance, etc.

- Vending machine: From this course onwards, the workshop has a tool and PPE vending machine for students. In addition to the advantages in an organisational level, the machine offers the possibility to track data about PPE and tools. Thus, the aim is to analyse aspects such as the level of use and expenditure of the EPIS, total expenditure on tools and by type, and other opportunities that may arise with the aim of taking improvement actions accordingly.

- In addition to the mentioned digital devices, the workshop has a mobile box containing 14 laptops that students can use to work at the workshop next to machines. To make this possible, the workshop has been equipped with a wireless internet connection.

- Smart warehouse: The workshop has a smart warehouse that is being set up. By means of RFID UHF, the entrance of people is controlled together with the tools they take out. The tools are arranged in the warehouse and each element has an identifying RFID, so that when a person enters the warehouse to pick up or leave a tool and then leaves it again, this is recorded. This allows control of tool use, and in the future could allow automation of tool maintenance, replenishment, etc. The possibility of integrating the intelligent warehouse with the Odoo ERP is being analysed, which would also allow the automation of the purchase of spare parts, and therefore durability and tool usage analysis, etc.

SETTING

<table>
<tr><td>4.1</td><td>Learning environment</td><td>purely physical (planning + execution)</td><td colspan="2">physical supported by digital factory (see line “IT-Integration”)</td><td colspan="2">Physical, extended virtually</td><td>purely virtual (planning + execution)</td></tr>
<tr><td>4.2</td><td>Environment scale</td><td colspan="3">scaled down</td><td colspan="3">life-size</td></tr>
<tr><td>4.3</td><td>Work system levels</td><td>workplace</td><td colspan="2">work system</td><td colspan="2">factory</td><td>network</td></tr>
<tr><td>4.4</td><td>Enablers for changeability</td><td>mobility</td><td>modularity</td><td colspan="2">compatibility</td><td>scalability</td><td>universality</td></tr>
<tr><td>4.5</td><td>Changeability dimensions</td><td>layout & logistics</td><td>product features</td><td colspan="2">product design</td><td>technology</td><td>product quantities</td></tr>
<tr><td>4.6</td><td>IT-integration</td><td colspan="2">IT before SOP (CAD, CAM, simulation)</td><td colspan="2">IT after SOP (PPS, ERP, MES)</td><td colspan="2">IT after production (CRM, PLM…)</td></tr>
</table>

For what purpose are different IT-integrations used:

The workshop has different IT systems available, such as CAD and CAM software, simulators, or the ERP platform. As explained in chapter 3, the equipment supporting these systems (laptops, digital devices, wireless network, etc.) allows the integration of these IT systems on the workshop's day-to-day activity.

The purpose of these IT systems is to create a real and more efficient digital environment where students can learn and get on as they will have to do in their future jobs. This facilitates the acquisition of the digital competences students need like the use of different digital devices and environments, different communication protocols and other features concerning Industry 4.0.

General setting of the equipment:

The workshop has 532 m2. It is divided into two areas. The main area, of 462m2, is where most of the machines are located, on the one hand, all the conventional machining ones, and on the other hand, two CNC milling machines and two CNC machining centres. In this same workshop there are five grinding machines and a didactic milling machine.

It also has an assembly area, an automatic threading machine, three drills, 3 saws and two welding cabinets.

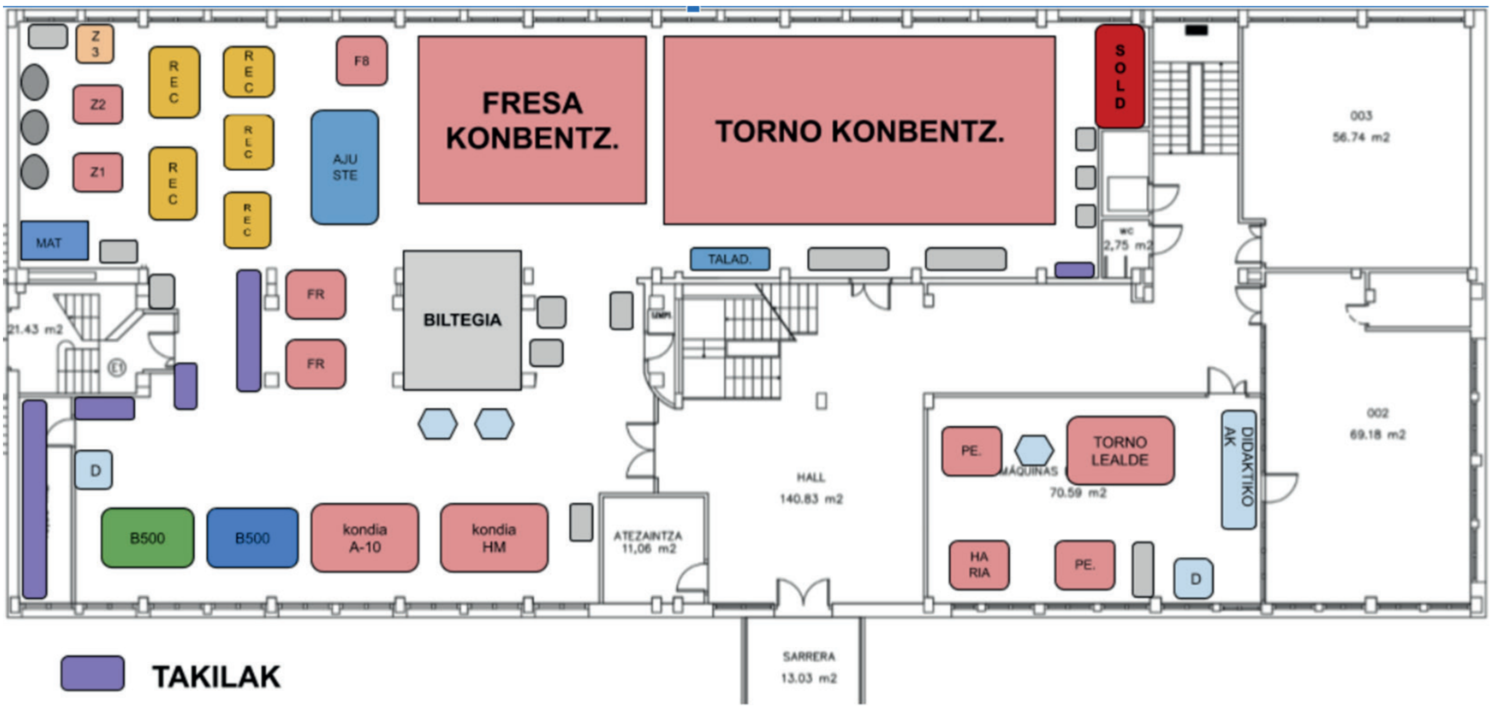


Figure 5: workshop overview

The second area has a CNC lathe, two die-sinking EDM machines and one wire EDM machine.

The CNC equipment available is as follows:

- 2 KONDIA B500 FAGOR CNC milling machines
- 1 KONDIA HM 1060 FAGOR CNC milling machine
- 1 KONDIA A10 HEIDENHAIN CNC milling machine
- 2 KONDIA Powermill CNC milling machines
- 1 CNC Didactic Milling Machine ALECOP 8010
- 1 LEALDE TCN10 CNC lathe
- 3 CNC Lathes ALECOP 8020

Figure 6: CNC LEALDE TCN10 Lathe

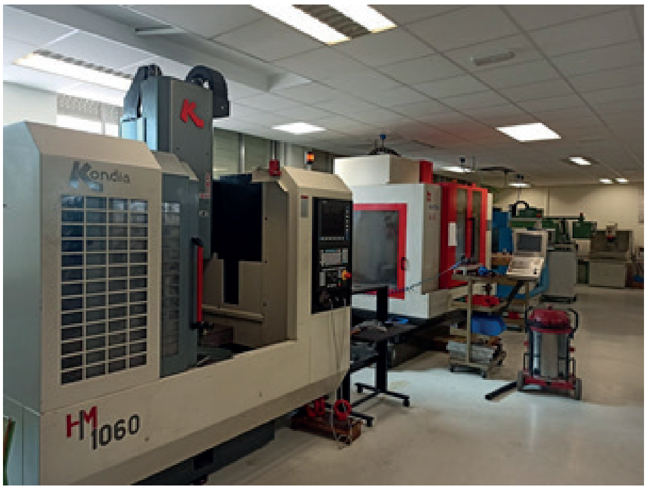


Figure 7: CNC milling cell

The following machines are available in the conventional workshop:

- 9 Pinacho lathes S-90/180
- 4 Pinacho 10 lathes SP/165
- 6 LAGUN FTV 4-SP milling machines
- 3 LETAG EE-3 emery
- 1 SAMUR S-400 saw
- STARRET ST3410 saw
- STARRET ST3602 saw
- 1 BELFLEX BF-20-TS drill
- 2 Holes QUANTUM B30 GT
- ERLO column drill TSA 25/30 series
- GAMOR GN 16 tapping machine
- OERLIKON Citotig 2200 welding equipment
- LINCOLN ELECTRIC Invertec V205-T welding equipment

The EDM area has the following machines:

- ONA PRIMA E250 Wire EDM
- ONA D-2030 penetration EDM
- ONA COMPACT2 penetration EDM

In addition to the machinery described, the workshop has two warehouses, one for raw materials and one for tools, and each of the areas has several tables and chairs.

Finally, both areas are supported by the additive manufacturing lab, which is not described in detail in this report, but has a close relation with the tasks performed and some of the skills acquired in the lab.

This lab has different additive manufacturing equipment such as:

- Ultimaker S2 3D printer
- Ultimaker S5 3D printer
- Creality CR-10 3D printer
- Stereolithography machine

PRODUCT

<table>
<tr><td>5.1</td><td>**Materiality**</td><td colspan="5">material (physical product)</td><td colspan="3">immaterial (service)</td></tr>
<tr><td>5.2</td><td>**Form of product**</td><td colspan="4">general cargo</td><td colspan="2">bulk goods</td><td colspan="2">flow products</td></tr>
<tr><td>5.3</td><td>**Product origin**</td><td colspan="3">own development</td><td colspan="3">development by participants</td><td colspan="2">external development</td></tr>
<tr><td>5.4</td><td>**Marketability of product**</td><td colspan="3">available on the market</td><td colspan="3">available on the market but didactically simplified</td><td colspan="2">not available on the market</td></tr>
<tr><td>5.5</td><td>**Functionality of product**</td><td colspan="3">functional product</td><td colspan="3">didactically adapted product with limited functionality</td><td colspan="2">without function / application, for demonstration only</td></tr>
<tr><td>5.6</td><td>**No. of different products**</td><td>1 product</td><td>2 products</td><td>3-4 products</td><td>> 4 products</td><td colspan="2">flexible, developed by participants</td><td colspan="2">acceptance of real orders</td></tr>
<tr><td>5.7</td><td>**No. of variants**</td><td>1 variant</td><td>2-4 variants</td><td>4-20 variants</td><td>…</td><td colspan="2">flexible, depending on participants</td><td colspan="2">determined by real orders</td></tr>
<tr><td>5.8</td><td>**No. of components**</td><td>1 comp.</td><td>2-5 comp.</td><td colspan="2">6-20 comp.</td><td>21-50 comp.</td><td colspan="2">51-100 comp.</td><td>> 100 comp.</td></tr>
<tr><td>5.9</td><td>**Further product use**</td><td colspan="2">re-use / re-cycling</td><td colspan="2">exhibition / display</td><td>give-away</td><td colspan="2">sale</td><td>disposal</td></tr>
</table>

Further description of the products manufactured in the LAB

This lab cannot be considered a Learning Factory since it is not focused on the production and/or assembly of a product or family of products. The products machined in the lab have usually a limited or no functionality, and their goal is to acquire certain specific skills while machining them.

These kinds of products are called training parts, but there are two main kinds of learning activities: the training parts, which aim to acquire the mentioned basic skills, and the “Challenge based collaborative learning”. The challenges are in most of the cases the design, manufacturing and assembly of products which solve a certain problem presented to students. The main goal while using this second methodology is to reproduce real life work situations in which students will have to get on in the future. In this case, the final result/product has a certain degree of functionality, but they are diverse, even between different groups of students.

Finally, since this laboratory provides technological innovation services and orders are accepted from companies, real prototypes, parts, or assemblies with real full or partial functionality are manufactured.

In conclusion, the information of the table must be filtered and interpreted in the singular context of this Lab.

6.1	**Competence classes**	technical and methodological competencies		social & communication competencies		personal competencies		activity and implementation-oriented competencies		
6.2	**Dimensions learn. targets**	cognitive		affective			psycho-motorial			
6.3	**Learn. scenario strategy**	instruction	demonstration			closed scenario		open scenario		
6.4	**Type of learn. environment**	greenfield (development of factory environment)				brownfield (improvement of existing factory environment)				
6.5	**Communication channel**	onsite learning (in the factory environment)				remote connection (to the factory environment)				
6.6	**Degree of autonomy**	instructed		self-guided / self-regulated			self-determined/ Self organized			
6.7	**Role of the trainer**	presenter	moderator		coach			instructor		
6.8	**Type of training**	tutorial	practical lab course		seminar		workshop		project work	
6.9	**Standardization of trainings**	standardized trainings				customized trainings				
6.10	**Theoretical foundation**	prerequisite	in advance (in bloc)		alternating with practical parts		based on demand		afterwards	
6.11	**Evaluation levels**	feedback of participants	learning of participants		transfer to the real factory		economic impact of trainings		return on trainings / ROI	
6.12	**Learning success evaluation**	knowledge test (written)	knowledge test (oral)		written report	oral presentation		practical exam		none

Specific competences addressed in the lab and Curriculum used:

This lab is used by the programs mentioned on section 2: Senior Technician in Production Scheduling in Mechanical Manufacturing (EQF level 5), Senior Technician in Manufacturing Design Mechanics (EQF level 5) and Technician in machining (EQF level 4).

The Machining Technician programme uses the lab for 3 different modules. Manufacturing by chip removal (363h) in the first year, and CNC (252h) and Manufacturing by abrasion, EDM, cutting and forming, additive manufacturing and by special processes (210h) in the 2nd year.

The programme of Higher Technician in Programming of production in mechanical manufacturing uses the lab for 3 different modules too. In the 1st year Mechanical Manufacturing Techniques (198h) and in the 2nd year CNC (240h) and CAM (40h).

Finally, the programme of Higher Technician in Design in Mechanical Manufacturing uses the lab for the module of Mechanical Manufacturing Techniques (198h) only, during the first year of the programme.

In addition to the technical knowledge and skills acquired in the different modules, students develop transversal competences and I4.0 related competences. According to companies' demands, these transversal competences are as important as the technical ones in day-to-day work. These are some of those I4.0 related competences, among others:

Doing simulations: CAM integrated into machines, use of computer and machine simulators, etc.

Knowledge on data acquisition systems: By means of the ERP, information is collected and processed for subsequent analysis (use of machines, machining times, tools life cycle, material stock, etc.) and decision making.

Familiarization with the integrated radio frequency identification systems.

Use of different digital tools/devices to access the ERP Management platform, the information available in the cloud: computers, tablets, touch Screen, machine interfaces, etc.

Organizing digital information, documentation, and files: The cloud, CAD-CAM files, ERP, etc.

Network systems and working methodology knowledge. Use of the cloud.

Correction in real time of deviations of the machined parts (dimensional, geometric, and surface tolerances), by using digital measuring tools and systems and managing obtained data.

The use of the ERP explained in previous chapters, brings with it important changes in comparison with the traditional working and teaching methodology used in the school: the creation of digital process sheets by students (students create these sheets in theoretical classrooms previous to manufacture the parts in the workshop, and can access them in situ via digital devices), easy tracking of the state of each student/machine during the lecture, analysis of machine occupation, analysis of tool life, calculation of working times, automation of material ordering, automation of tools ordering, etc. Therefore, the ERP does not aim to be a simple tool for the theoretical subject in which manufacturing process sheets are created. This tool can help the Higher-Level Cycle of Production Programming to make a leap in quality in the training of students, allowing them to consider all the aspects involved in the production process, being able to act on these and acquiring knowledge and real practice in production programming and not only in the mechanical manufacture of parts. In conclusion, it aims the students to become protagonists of their learning process, allowing them to observe their work process in its totality.

Learning Methodology

The central methodology on which the whole learning model is articulated, is called COLLABORATIVE LEARNING BASED ON CHALLENGES (http://y2u.be/JSh0RfOI7wM), a model developed by Tknika (http://y2u.be/JSh0RfOI7wM), the Basque applied research centre for vocational training.

The main idea of this methodology is to create challenges that are close to the reality students will have to face in their future business reality.

Therefore, traditional lectures and school structures are not used anymore as the main teaching methodology. Instead, students work in teams and confront problematic challenges they need to solve. For that purpose, they must identify the knowledge and skills needed, and obtain it with the help of teachers and by means of specific trainings but also themselves. Teachers take the role of guides, but the responsibility of solving the challenging situation falls on students. Working this way, students become responsible for their learning process, and develop transversal competences such as autonomous learning, teamwork, personal initiative, digital competences, etc.

Nowadays, the level of implementation of this new methodological model in each programme is different. Therefore, the traditional teaching-learning model still coexists with the new collaborative learning based on challenges method.

This method needs traditional subjects, timetables, and master classes to disappear. Therefore, a higher flexibility in spaces, labs and teachers' timetables is needed. The inclusion of the different I4.0 related tools and technologies mentioned before can facilitate this methodological change.

METRICS

7.1	**No. of participants per training**	1-5 participants	5-10 participants	10-15 participants	15-30 participants	30> participants	
7.2	**No. of standardized trainings**	1 training	2-4 trainings	5-10 trainings		> 10 trainings	
7.3	**Aver. duration of a single training**	≤ 1 day	> 1 day until ≤ 2 days	> 2 days until ≤ 5 days	> 5 days until ≤ 10 days	> 10 days until ≤ 20 days	> 20 days
7.4	**Participants per year**	< 50 participants	50-200 participants	201-500 participants	501-1000 participants	> 1000 participants	
7.5	**Capacity utilization**	< 10%	> 10 until ≤ 20%	> 20%until ≤ 50%	> 50%until ≤ 75%	> 75%	
7.6	**Size of LAB**	≤ 100 sqm	> 100 sqm bis ≤ 300 sqm	> 300sqm bis ≤ 500sqm	>500 sqm bis ≤ 1000 sqm	> 1000 sqm	
7.7	**FTE in LAB**	< 1	2-4	5-9	10-15	> 15	

This is a lab in which 3 different groups of students can work, each of them between 20 and 25 members.

8.1	Further information	photographs	video
8.2	Aspect to improve	technical	methodological

Aspects to improve

One of the key factors in the evolution of the lab is the human factor, both in the evolution of the methodological model and in the implementation of the different I4.0 lines of work described before. For this reason, training of the staff is considered very important to improve their general digital competences, principally the ones related to the strategic lines of work implemented in the lab.

The implementation of Industry 4.0 related technologies and features are an ongoing process. In a short and medium term many new implementation and investments are foreseen

- Full implementation of the smart warehouse.
- Full implementation of the ERP.
- Integrating the maintenance management system in the ERP.
- Integration of the tools and raw material storehouse in the ERP and automatizing the purchase system of both.
- Extending the use of digital process sheets to all the programmes and student groups.
- Develop the use of obtained big data and its treatment through the ERP.
- Metrology in line processes.
- Include all the CNC machinery in the network.

Strength and weaknesses of the LAB. Lessons learned

One of the main weaknesses concerning the I4.0 implementation stage, is the initial stage in which most of the lines of work are.

Secondly, the lack of space is a big problem in the lab. The new learning methodological model demands a high level of flexibility and creates complex organizational planning and scheduling needs. To solve this big issue, it is necessary to rethink the available space in the lab.

Thirdly, the engagement of teachers with the different processes and technologies which are being implemented in the lab is another important point to consider. We still need to convince part of the team about the advantages and the need to accomplish these changes.

Finally, the biggest strength is that the new processes and technologies implemented in the lab have a pedagogical base, which is the main goal of the lab. Therefore, it is something we must maintain in the development of the lab I4.0 transformation.

TKGUNE Machining Lab

General aim/purpose (short summary):

The TKGUNE machining workshop, with advanced machinery and resources, was created in 2016 to meet the following needs:

1.- Provide applied innovation services (TKGUNE) to small and medium-sized companies (SMEs).

2.- Teach specializations for Vocational Training students.

3.- Offer advanced machining courses in different CNC controls and machines for workers and unemployed in the Employment Training area.

4.- Offer customized courses for small and medium-sized companies (SMEs).

Year of inauguration:

2016

LAB size (square metres):

600

General information - summary table

GENERAL INFORMATION	Name of the LAB	**TKGUNE Machining Lab**						MAIN PURPOSE		
	VET/HVET centre	CIFP IMH LHII						Education		X
	Floor space of the lab (sqm)	600						Training		X
	Main topic/learning content	Machining on CNC multitasking and 5-axis machining centres, precision grinding, wire EDM and metrology						Research/Applied innovation		X
	I4.0 related technologies	Data acquisition and analysis, IIoT, Cybersecurity, Robotics								
PURPOSE	Learning content	CNC Machining: Multitasking, 5-axis machining centres, 3-axis machining centres, precision grinding, wire EDM and metrology. Mechatronics: Assembly and commissioning of advances machinery.								
	Secondary purpose	Production management, Smart maintenance and I4.0 related technologies.								
	LAB type	Specific			Mixed			Learning Factory		
LEARNING CONTENTS	Learning programmes/study programmes/levels	Name of the programmes carried out on the Lab				EQF Level	Lab hours	Nº subjects on the lab	Hour/Week x nº of weeks	Nº students (3)
		Production Management and Mechanical Manufacturing				5	168	_	8x21	10x1
		Industrial Mechatronics				5	198	_	6x33	10x1
		_				_	_	_	_	_
		_				_	_	_	_	_
		_				_	_	_	_	_
		_				_	_	_	_	_
SETTINGS	Nº of cell	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5	Cell 6	Cell 7	Cell 8	Cell 9
	Category of cell	CNC Controls & Simulation mock-ups	Multitasking machines, Machining centres, High precision grinding machine 6 Submerged wire EDM	Flexible and intelligent modular manufacturing system	_	_	_	_	_	_
	Nº machines	3	5	1	_	_	_	_	_	_
	I4.0 Enabler technologies used and implementation level	Robotics	Additive Manufacturing	Cloud	CPS	Mobile/Tablet	AR/VR	Big data analytics	Ai	IoT/IIoT
		Sensors/Actuators	RFID	M2M	Cybersecurity	Digital twin				

OPERATIONAL MODEL

1.1	**Operator**	academic institution			non-academic institution				profit-oriented operator	
		university	college	BA	vocational school / high school	chamber	union	employers´ association	industrial network	consulting	producing company
1.2	**Trainer**	professor	researcher	student assistant		technical expert /int. Specialist		consultant	educationalist	
1.3	**Development**	own development			external assisted development			external development		
1.4	**Initial funding**	internal funds			public funds			company funds		
1.5	**Ongoing funding**	internal funds			public funds			company funds		
1.6	**Funding continuity**	short term funding (e.g., single events)			midterm funding (projects and programmes < 3 years)			long term funding (projects and programmes > 3 years)		
1.7	**Business model for trainings**	open models			closed models (training programme only for single company)					
		club model	course fees							

Note: in 1.7 Business models for training there are different modalities: For students in the initial training model, the programs are state funded. For tailored training for companies, it is course fee. We also use closed models.

PURPOSE AND TARGETS

2.1	**Main purpose**	education	vocational training	research												
2.2	**Secondary purpose**	test environment / pilot environment	industrial production	innovation transfer	advertisement for production											
2.3	**Target groups for education & training**	pupils	students			employees								entrepreneurs	freelancer	unemployed	open public
			bachelor	master	phd students	apprentices	skilled workers	semi-skilled workers	unskilled	managers						
										lower mgmt	middle mgmt	top mgmt				
2.4	**Group constellation**	homogeneous	heterogeneous (knowledge level, hierarchy, students + employees, etc.)													
2.5	**Targeted industries**	mechanical & plant eng.	automotive	logistics	transportation	FMCG	aerospace									
		chemical industry	electronics	construction	insurance / banking	textile industry	...									
2.6	**Subject-rel. learning contents**	prod. Mgmt & org.	resource efficiency	lean mgmt	automation	CPPS	work system design	HMI	design	Intralogistics design & mgmt	...					
2.7	**Role of LAB for research**	research object	research enabler													
2.8	**Research topics**	production management & organization	resource efficiency	lean mgmt	automation	CPPS	changeability	HMI	didactics	...						

The TKGUNE machining workshop, with advanced machinery and resources, was created in 2016 to meet the following needs:

1.- Provide applied innovation services (TKGUNE) to small and medium-sized companies (SMEs) in complex machining processes in multitasking machines and in lathes and multi-axis machining centres.

2.- Teach specializations for Vocational Training students, who after studying and working for 2 years in the Dual model can take a third year also in dual mode, in which they acquire a high qualification to respond to the needs of companies and to be able to plan and execute complex production processes. Two specialization programs can be carried out at the IMH:

- Advanced Machining of Special Materials in High Speed and High Performance. It is carried out after studying the higher degree cycle of Production Programming in Mechanical Manufacturing.

- Implementation of Advanced Machine Tool Manufacturing Projects. It is done after studying the higher degree cycle of Industrial Mechatronics.

3.- Offer advanced machining courses in different CNC controls and machines for workers and unemployed in the Employment Training area.

4.- Offer customized courses for small and medium-sized companies (SMEs).

Subsequently, in 2018 the Directorate of the IMH identified as a strategic objective “Digitize the workshops of the IMH”. The objective is to achieve a workshop that allows intelligent and automated decision-making thanks to the data generated in its manufacturing processes and its subsequent analysis. This requires integrating cyber-physical systems in our facilities.

This objective of digitizing the workshops involves tasks such as:

- Create physical systems that generate data.

- Create an IIoT system that manages the collection of said data and its transmission and conservation.

- Generate mathematical algorithms that analyse data for intelligent and automated decision making.

- Integrate technologies associated with INDUSTRY 4.0; OT networks, cybersecurity, robotics, augmented / mixed / virtual reality, big data / smart data, etc.

- Schedule the production and maintenance of resources using computerized management techniques and tools (MES, ERP, SCADA, GPAO, etc.).

- Create a Showroom 4.0 for companies.

Description of the relation between each study program and the LAB

The use of this workshop is carried out by 2 professional specialization programs (EQF 5):

1.- Advanced machining of special materials at high speed and high performance. This professional specialization program is aimed at Senior Technicians in Production Programming in Mechanical Manufacturing (800h).

Students who use this laboratory do so to acquire the following general skills:

Obtain parts with complex geometries, in special materials and of great responsibility in the currently emerging sectors (Aeronautics, Space, Biomedicine, Wind ...) through a high-level technology based on high-speed and high-performance machining, planning and controlling processes machining operations and manufactured products, adapting the manufacturing drawings to the needs of the process, designing the tools, preparing and fine-tuning the machines, taking responsibility for the first-level maintenance of the equipment and their mechatronics, achieving the criteria quality, complying with the company's occupational and environmental risk prevention plans, and current applicable regulations.

2.- Development of advanced manufacturing machine tool projects. This professional specialization program is aimed at Higher Technicians in Industrial Mechatronics (650h).

Students who use this laboratory do so to acquire the following general skills:

Build advanced manufacturing machine tools and provide installation, maintenance and user advice services to the client, using high-level mechatronic techniques, assembling mechanical, electrical-electronic, pneumo-hydraulic, and computer components; installing and starting up the machine tool in its final location; verifying the geometry of the machine with advanced metrology equipment; and machining the machine receiving part; as well as advising the client in the machining processes, use of the machine and the management and performance of its maintenance, achieving quality criteria, complying with the company's occupational and environmental risk prevention plans, and current applicable regulations.

In addition to achieving the general skills required within mechanical manufacturing and Industrial Mechatronics, in the near future, they will be prepared to work in an environment related to Industry 4.0:

- Program simulation: by computer, machine, CAM integrated in machine, 3D simulation, virtual, etc.
- Integration of data acquisition systems. Artificial vision cameras.
- Integration of radio frequency identification systems.
- Correction in real time of the deviations of the machined parts (dimensional, geometric, and surface tolerances).
- Use of computer tools and software to access and manage the necessary and generated documentation (PC, tablet, smartphone, machine interface, integrated CAD / CAM / ERP systems, PLM, etc.).
- Registration of the program and the documentation generated in folder structure, CAD / CAM / ERP integrated systems, PLM, etc.
- Machining strategies: high performance, high feed, adaptive machining, ...).
- Programming of robots (industrial and collaborative) for manipulation and machining.
- Monitoring of computer security regulations and procedures (cybersecurity).
- Analysis of process data in real time (Big Data, Smart Data, ...).

PROCESS

3.1	**Product life cycle**	product planning	product development	product design	rapid prototyping	manufacturing	assembly		logistics	service		recycling
3.2	**LAB life cycle**	investment planning	factory concept	process planning	ramp-up	manufacturing	assembly		logistics	maintenance		recycling
3.3	**Order life cycle**	configuration & order	order sequencing	production planning and scheduling		manufacturing	assembly		logistics	picking, packaging		shipping
3.4	**Technology life cycle**	planning	development	virtual testing		manufacturing	assembly		logistics	maintenance		modernization
3.5	**Indirect functions**	SCM	sales	purchasing		HR	finance / controlling			QM		
3.6	**Material flow**	continuous production				discrete production						
3.7	**Process type**	mass production		serial production		small series production					one-off production	
3.8	**Manufact. organization**	fixed-site manufacturing		work bench manufacturing		workshop manufacturing					flow production	
3.9	**Degree of automation**	manual		partly automated / hybrid automation					fully automated			
3.10	**Manufact. Methods**	cutting	trad. primary shaping		additive manufact.	forming		joining	coating		change material properties	
3.11	**Manufact. Technology**	physical			chemical				biological			

This workshop occupies a space of 600m2 in which 24 students can work at the same time. The space is divided into 3 different cells which are made up of 9 different machines. The cells that we can find are CNC controls, Robotics and Simulation mock-ups (1), Multitasking machines, Machining centres, High precision grinding machine and Submerged wire EDM (2) and Flexible and intelligent modular manufacturing system (3).

Specific equipment used in the LAB, Addressing Industry 4.0:

The idea of the workshop is to be fully digitized at least to the same level that the industry is digitizing its production plants. This offers a fully digitized TVET training space designed to the same industry standards.

Among others, the workshop includes the following characteristics:

- OT network + Cybersecurity (TITANIUM) to avoid external intrusions.
- IIoT systems for monitoring manufacturing processes and data acquisition: SAVVY, INGETEAM, AINGURA, VIXION, ERIS, PTC (ThingWorx).
- Communication between all machines and IIoT systems via Wi-Fi.

4.1	**Learning environment**	purely physical (planning + execution)	physical supported by digital factory (see line "IT-Integration")		Physical, extended virtually		purely virtual (planning + execution)
4.2	**Environment scale**	scaled down			life-size		
4.3	**Work system levels**	workplace	work system		factory		network
4.4	**Enablers for changeability**	mobility	modularity	compatibility		scalability	universality
4.5	**Changeability dimensions**	layout & logistics	product features	product design		technology	product quantities
4.6	**IT-integration**	IT before SOP (CAD, CAM, simulation)		IT after SOP (PPS, ERP, MES)		IT after production (CRM, PLM…)	

For what purpose are different IT-integrations used:

The items integrated in the lab are related to the digitalization of the processes. Machine communication and data acquisition.

The purpose of those equipment and the associated IT resources is to get the student from all programs used to work on digitized environments. The data created during the learning process is analysed and used by the students as a learning activity to improve the overall process. Students become familiar with the use of data analytic tools and to make decisions based on real results.

General setting of the equipment:

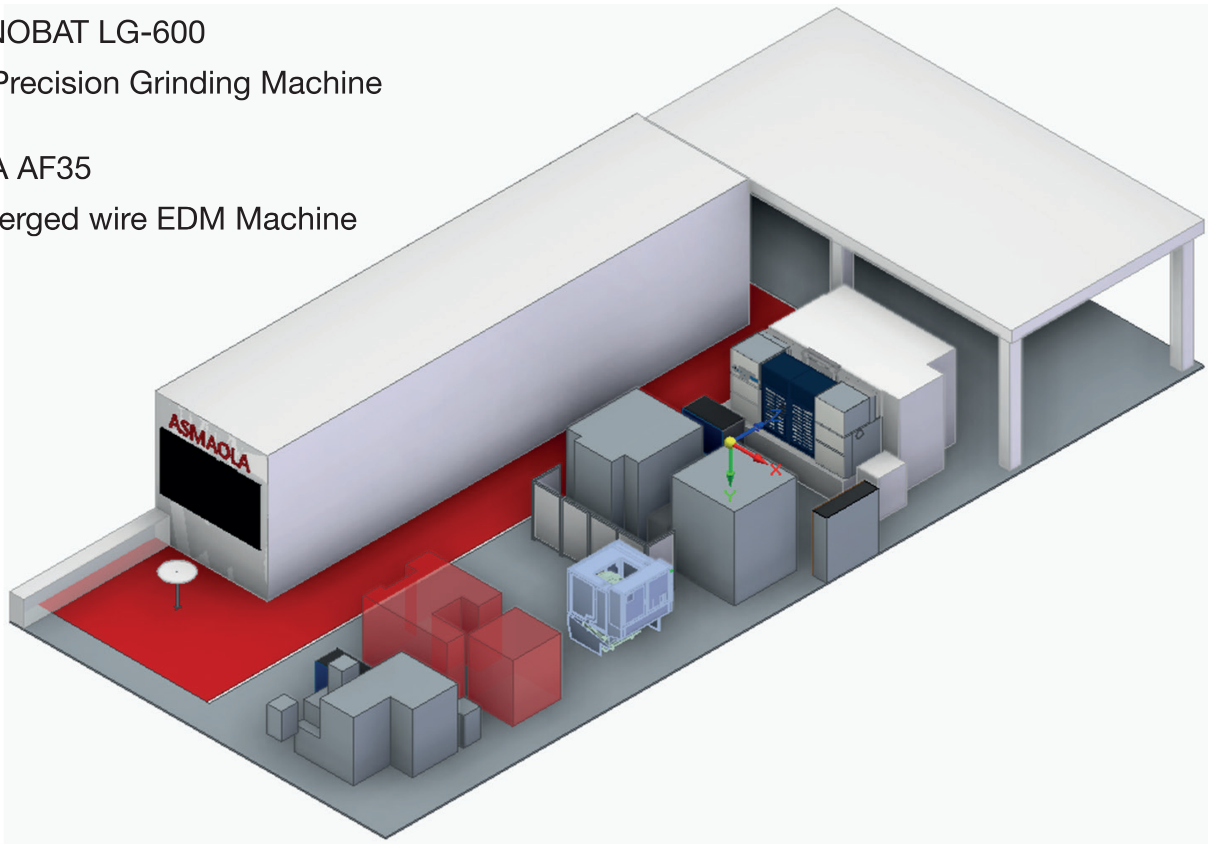
This workshop occupies a space of 600m2 in which 24 students can work at the same time. The space is divided into 3 different cells which are made up of 9 different machines. The cells that we can find are CNC controls, Robotics and Simulation mock-ups (1), Multitasking machines, Machining centres, High precision grinding machine and Submerged wire EDM (2) and Flexible and intelligent modular manufacturing system (3).

1.- The CNC controls, Robotics and Simulation mock-ups (1) area is completed with 7 components, which are:

- 1 Siemens SINUMERIK ONE CNC
- 1 Fagor 8065 CNC
- 2 Simulation mock-ups
- 1 Collaborative UR5e Robot
- Data acquisition and analysis system

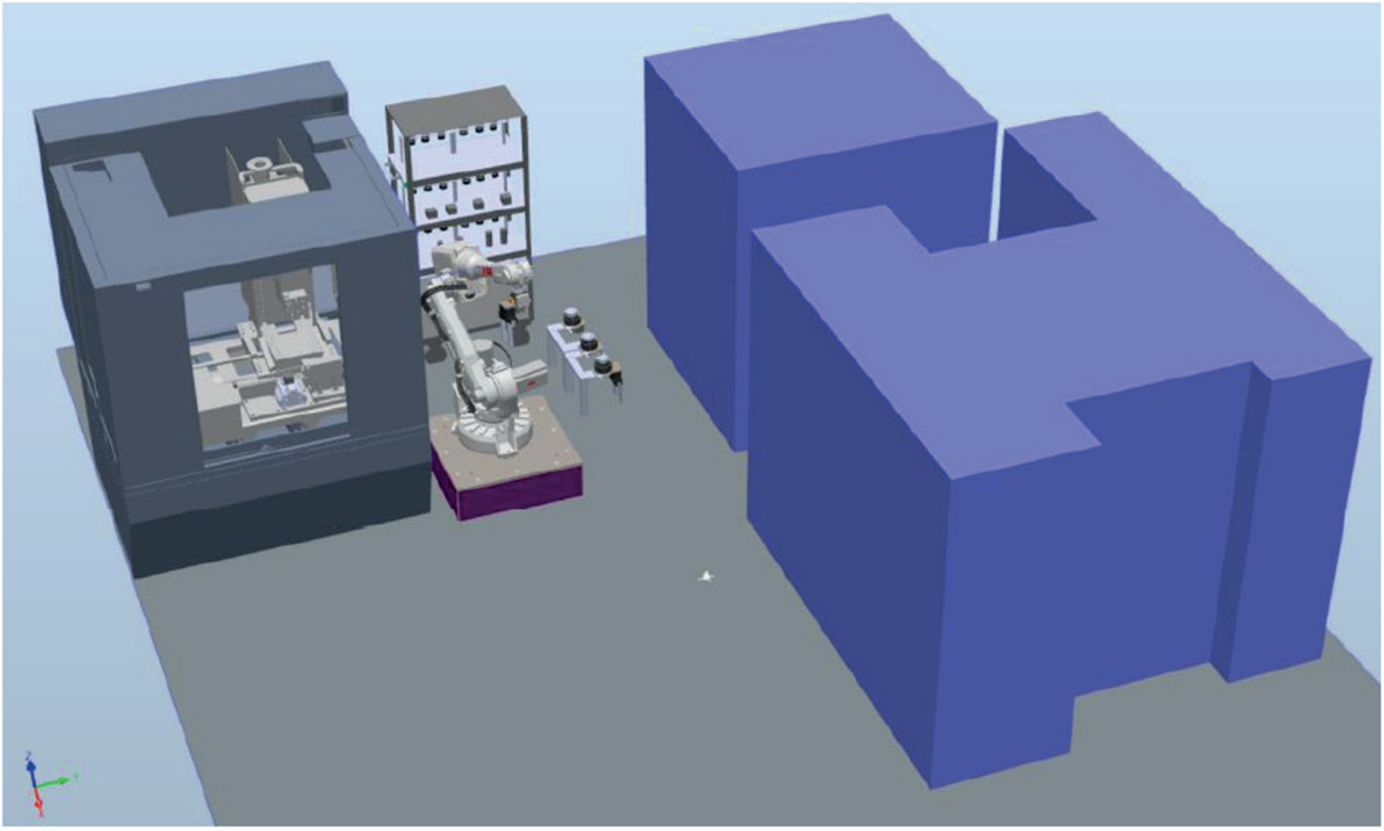
2.- The Multitasking machine, Machining centres, High precision grinding machine and Submerged wire EDM (2) area is completed with 5 machines, which are:

- 1 IBARMIA ZVH 38
  Multitasking Machine
- 1 KONDIA SEASKA
  5 axis Milling Machine
- 1 KONDIA P60v2
  3 axis Precision Milling Machine
- 1 DANOBAT LG-600
  High Precision Grinding Machine
- 1 ONA AF35
  Submerged wire EDM Machine



3.- The Flexible and intelligent modular manufacturing system (3) area is completed with 1 machine and 1 collaborative robot, which are:

- 1 BERKOA IKASMAK 5.1 Multitasking Machine
- 1 Collaborative UR5e Robot



<table>
<tr><td>5.1</td><td>Materiality</td><td colspan="5">material (physical product)</td><td colspan="3">immaterial (service)</td></tr>
<tr><td>5.2</td><td>Form of product</td><td colspan="4">general cargo</td><td colspan="2">bulk goods</td><td colspan="2">flow products</td></tr>
<tr><td>5.3</td><td>Product origin</td><td colspan="3">own development</td><td colspan="3">development by participants</td><td colspan="2">external development</td></tr>
<tr><td>5.4</td><td>Marketability of product</td><td colspan="3">available on the market</td><td colspan="3">available on the market but didactically simplified</td><td colspan="2">not available on the market</td></tr>
<tr><td>5.5</td><td>Functionality of product</td><td colspan="3">functional product</td><td colspan="3">didactically adapted product with limited functionality</td><td colspan="2">without function / application, for demonstration only</td></tr>
<tr><td>5.6</td><td>No. of different products</td><td>1 product</td><td>2 products</td><td>3-4 products</td><td>> 4 products</td><td colspan="2">flexible, developed by participants</td><td colspan="2">acceptance of real orders</td></tr>
<tr><td>5.7</td><td>No. of variants</td><td>1 variant</td><td>2-4 variants</td><td>4-20 variants</td><td>...</td><td colspan="2">flexible, depending on participants</td><td colspan="2">determined by real orders</td></tr>
<tr><td>5.8</td><td>No. of components</td><td>1 comp.</td><td>2-5 comp.</td><td colspan="2">6-20 comp.</td><td>21-50 comp.</td><td colspan="2">51-100 comp.</td><td>> 100 comp.</td></tr>
<tr><td>5.9</td><td>Further product use</td><td colspan="2">re-use / re-cycling</td><td colspan="2">exhibition / display</td><td>give-away</td><td colspan="2">sale</td><td>disposal</td></tr>
</table>

Further description of the products manufactured in the LAB

In this laboratory, on the one hand, sets designed by the students of the specialization themselves are manufactured. These kits have limited functionality because they are not approved products.

On the other hand, as this laboratory provides technological innovation services and orders are accepted from companies in which we must manufacture real parts or assemblies, they have full functionality.

6.1	**Competence classes**	technical and methodological competencies	social & communication competencies	personal competencies	activity and implementation-oriented competencies		
6.2	**Dimensions learn. targets**	cognitive	affective	psycho-motorial			
6.3	**Learn. scenario strategy**	instruction	demonstration	closed scenario	open scenario		
6.4	**Type of learn. environment**	greenfield (development of factory environment)	brownfield (improvement of existing factory environment)				
6.5	**Communication channel**	onsite learning (in the factory environment)	remote connection (to the factory environment)				
6.6	**Degree of autonomy**	instructed	self-guided / self-regulated	self-determined/ Self organized			
6.7	**Role of the trainer**	presenter	moderator	coach	instructor		
6.8	**Type of training**	tutorial	practical lab course	seminar	workshop	project work	
6.9	**Standardization of trainings**	standardized trainings	customized trainings				
6.10	**Theoretical foundation**	prerequisite	in advance (in bloc)	alternating with practical parts	based on demand	afterwards	
6.11	**Evaluation levels**	feedback of participants	learning of participants	transfer to the real factory	economic impact of trainings	return on trainings / ROI	
6.12	**Learning success evaluation**	knowledge test (written)	knowledge test (oral)	written report	oral presentation	practical exam	none

Specific competencies addressed in the lab and Curriculum used:

Of the training programs offered at the centre, the use of this workshop is carried out by 2 professional specialization programs (EQF 5):

1.- Advanced machining of special materials at high speed and high performance. This professional specialization program is aimed at Senior Technicians in Production Programming in Mechanical Manufacturing (800h).

Through the development of the following learning areas, the general competence indicated below is acquired. 168 hours take place in the centre and the rest (632 hours) in the company:

- Adaptation of planes and complex solids for high-speed, high-performance machining (90h).
- Special materials used in emerging sectors (70h).
- Planning the machining of complex figures in special materials at high speed and high performance (210h).
- Machining of complex figures in special materials at high speed and high performance (180h).
- Verification of parts machined at high speed and high performance (130h).
- High speed and high-performance machining project (120h).

GENERAL COMPETENCE:

Obtain parts with complex geometries, in special materials and of great responsibility in the currently emerging sectors (Aeronautics, Space, Biomedicine, Wind ...) through a high-level technology based on high-speed and high-performance machining, planning and controlling processes machining operations and manufactured products, adapting the manufacturing drawings to the needs of the process, designing the tools, preparing and fine-tuning the machines, taking responsibility for the first-level maintenance of the equipment and their mechatronics, achieving the criteria quality, complying with the company's occupational and environmental risk prevention plans, and current applicable regulations.

2.- Development of advanced manufacturing machine tool projects. This professional specialization program is aimed at Higher Technicians in Industrial Mechatronics (650h).

Through the development of the following learning areas, the general competence indicated below is acquired. 198h in the centre and the rest (452h) in the company:

- Assembly of the structure, components, and devices of the advanced manufacturing machine tool (240h).
- Functional optimization of machine tools (90h).
- In-process and post-process measurement of machining (90h).
- Adaptation of machine tools to production characteristics (200h).
- Transport and positioning of heavy components of advanced manufacturing machine tools (30h).

Build advanced manufacturing machine tools and provide installation, maintenance and user advice services to the client, using high-level mechatronic techniques, assembling mechanical, electrical-electronic, pneumo-hydraulic, and computer components; installing and starting up the machine tool in its final location; verifying the geometry of the machine with advanced metrology equipment; and machining the machine receiving part; as well as advising the client in the machining processes, use of the machine and the management and performance of its maintenance, achieving quality criteria, complying with the company's occupational and environmental risk prevention plans, and current applicable regulations.

All these modules, in addition to achieving the general skills required within mechanical manufacturing and Industrial Mechatronics, are prepared to work on different skills related to I4.0. They are between them:

- Program simulation: by computer, machine, CAM integrated in machine, 3D simulation, virtual, etc.
- Integration of data acquisition systems. Artificial vision cameras.
- Integration of radio frequency identification systems.
- Correction in real time of the deviations of the machined parts (dimensional, geometric, and surface tolerances).
- Use of computer tools and software to access and manage the necessary and generated documentation (PC, tablet, smartphone, machine interface, integrated CAD / CAM / ERP systems, PLM, etc.).
- Registration of the program and the documentation generated in folder structure, CAD / CAM / ERP integrated systems, PLM, etc.
- Machining strategies: high performance, high feed, adaptive machining, ...).
- Programming of robots (industrial and collaborative) for manipulation and machining.
- Monitoring of computer security regulations and procedures (cybersecurity).
- Analysis of process data in real time (Big Data, Smart Data, ...).

Learning Methodology

The central element on which the whole learning model is articulated is COLLABORATIVE LEARNING BASED ON CHALLENGES.

The presentation of a problematic situation, its transformation to a challenge, as well as the whole process until obtaining a result, is structured based on both the technical and specific competences of each program, as well as those transversal competences that currently are strategical, such as: autonomy in learning, teamwork, orientation towards extraordinary results, digital competences, etc …

Problematic situations, in all cases, are raised to a class configured in teams, where the work process has to enable the students to live the situation as a challenge and, from there, has to have the opportunity to generate the necessary knowledge that allow you to provide the best solutions.

The approach of the model through challenges needs a reinterpretation of the mechanics of learning. The interpretation that best fits the model, is to understand learning as a process of evolution, where the students are responsible for it. Challenge-based learning allows a scenario in which students individually and team levels are put into action and produce a result. This result is interpreted, it is analysed what has worked and what has not and is decided what is going to be done differently in the next challenge to approach higher objectives.

The main idea of this methodology is to create teams and for them to establish a contract in which they include the commitments acquired by the members of each of the teams. These contracts will evolve and transform as teams incorporate experiences. When working in the workshop, these teams will have to manage themselves by dividing up the work in order to overcome the challenge. Generally, the use of the machines is usually individually or in pairs.

This methodology allows us to work in an interdisciplinary way where students can work on transversal competences through challenges that are close to a business reality. The next step would be to create a Learning Factory, assimilating the operation of the workshop to a real workshop.

METRICS

7.1	**No. of participants per training**	1-5 participants	5-10 participants	10-15 participants	15-30 participants	30> participants	
7.2	**No. of standardized trainings**	1 training	2-4 trainings	5-10 trainings		> 10 trainings	
7.3	**Aver. duration of a single training**	≤ 1 day	> 1 day until ≤ 2 days	> 2 days until ≤ 5 days	> 5 days until ≤ 10 days	> 10 days until ≤ 20 days	> 20 days
7.4	**Participants per year**	< 50 participants	50-200 participants	201-500 participants	501-1000 participants	> 1000 participants	
7.5	**Capacity utilization**	< 10%	> 10 until ≤ 20%	> 20%until ≤ 50%	> 50%until ≤ 75%	> 75%	
7.6	**Size of LAB**	≤ 100 sqm	> 100 sqm bis ≤ 300 sqm	> 300sqm bis ≤ 500sqm	>500 sqm bis ≤ 1000 sqm	> 1000 sqm	
7.7	**FTE in LAB**	< 1	2-4	5-9	10-15	> 15	

In this lab 24 students/workers can work grouped in 3 cells.

FURTHER INFORMATION & ASPECTS TO IMPROVE

8.1	**Further information**	photographs	video
8.2	**Aspect to improve**	technical	methodological

We have planned to edit graphic documentation such as videos and photos to present the new facilities to other professional training centres, companies, and institutions, although we are yet to implement the last details of the workshop to be able to do so. We hope to be able to do it between January and February 2021.

Aspects to improve:

Strength and weaknesses of the LAB

The greatest strength we have, on the one hand, at this time is that the hardest and least visible work is done; OT network, cybersecurity, data capture and monitoring systems (IIoT), communication between machines and IIoT systems.

And on the other, we have projects with different suppliers interested in collaborating with us and companies willing to participate with us in innovation projects aligned with the 4.0 strategy.

And on the other, as a weakness, we have a long journey to implement intelligence in our production processes through data analysis for intelligent and automated decision making and the integration of all our systems with the ERP.

Smart Factory Lab

General aim/purpose (short summary):

The objective proposed for the medium term is that students will be able to learn in an environment that is oriented to Industry 4.0. For this, the educational workshop is being transformed into a digitalisation-based design.

Year of inauguration:

1976

LAB size (square metres):

1800

General information - summary table

GENERAL INFORMATION	Name of the LAB	**Smart Factory**	MAIN PURPOSE	
	VET/HVET centre	CIFP USURBIL LHII	Education	X
	Floor space of the lab (sqm)	1800	Training	X
	Main topic/learning content	Industry 4.0 - SMART MANUFACTURING	Research/Applied innovation	X
	I4.0 related technologies	Development of an advanced manufacturing process, monitored and controlled by a smart management system, ERP		
PURPOSE	Learning content	Pilot environment, didactics for students from vocational training and employees, Innovation transfer, applied research		
	Secondary purpose	Production management, Smart maintenance and I4.0 related technologies.		
	LAB type	Specific	Mixed	Learning Factory

		Name of the programmes carried out on the Lab	EQF Level	Lab hours	Nº subjects on the lab	Hour/Week x nº of weeks	Nº students (3)
LEARNING CONTENTS	Learning programmes/study programmes/levels	Production Management and Mechanical Manufacturing	5	198 126	2	6x33 6x21	3x20 3x20
		Machining Technician	4	198	3	11x33 5x33 10x21	_
		_	_	_	_	_	_
		_	_	_	_	_	_
		_	_	_	_	_	_
		_	_	_	_	_	_

SETTINGS	Nº of cell	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5	Cell 6	Cell 7	Cell 8	Cell 9
	Category of cell	I+D+i area	Raw material, Cutting machine, Collaborative robot	Palletized warehouse	Lathes	Mills	Grinding	CNC	END	Tool warehouse
	Nº machines	5	2+1	1	24	14	4	6	2	1
	I4.0 Enabler technologies used and implementation level	Robotics	Additive Manufacturing	Cloud	CPS	Mobile/Tablet	AR/VR	Big data analytics	Ai	IoT/IIoT
		Sensors/Actuators	RFID	M2M	Cybersecurity	Digital twin	Others			

OPERATIONAL MODEL

1.1	**Operator**	academic institution			non-academic institution				profit-oriented operator	
		university	college	BA	vocational school / high school	chamber	union	employers´ association	industrial network	consulting	producing company
1.2	**Trainer**	professor	researcher	student assistant	technical expert /int. Specialist	consultant	educationalist			
1.3	**Development**	own development	external assisted development	external development						
1.4	**Initial funding**	internal funds	public funds	company funds						
1.5	**Ongoing funding**	internal funds	public funds	company funds						
1.6	**Funding continuity**	short term funding (e.g., single events)	midterm funding (projects and programmes < 3 years)	long term funding (projects and programmes > 3 years)						
1.7	**Business model for trainings**	open models		closed models (training programme only for single company)						
		club model	course fees							

Note: in 1.7 Business models for training there are different modalities: For students in the initial training model, the programs are state funded. For tailored training for companies, they are fee courses. We also use closed models.

The main objective of the project is to create an intelligent mechanical workshop, where starting from research, we can acquire knowledge to be able to later develop it in the different fields and areas of our organization, and thus acquire the necessary data to apply the intelligence that our needs require.

From the mechanical department of Usurbil LHII, within the project "Taller 4.0" and after the experience of the Intelligent Tool Store, operative since September 2016, we are working in the creation of an integral 4.0 system of stock management to be executed within the framework of this joint project.

Functionality from the entry of raw materials to the finished product, as well as having control of all consumables and spare parts for mechanical manufacturing in an agile way and online management.

This system will also manage the warehouse of raw material stocks, spare parts, hardware, production process, traceability, equipment, manuals-documentation-history of machines. In short, the entire mechanical manufacturing stock.

This project will contribute to develop an Industry 4.0 based training methodology in the field of Smart Factory for different target groups:

1 - Initial training model:

Our centre is a public centre that depends on the Vice-Counsellorship of the Professional Training School Department of the Basque Government. The centre's staff is 100% dependent on the Basque Government. The number of teachers depend directly on the number of groups of students in initial training and the projects in which we participate. Our school usually has around 80 teachers for 25 groups and 470 students.

Initial training has public funds to cover some costs such as energy consumption, communications, purchase of raw material or purchase of equipment.

Of the training programs offered at the centre, the use of this lab is made by 2 programs: Technician in machining (EQF level 4), Senior Technician in Production Scheduling in Mechanical Manufacturing (EQF 5).

The Machining Technician program makes the use of the lab on 3 of its modules. In the 1st year Manufacturing by chip removal (363h) and in the 2nd year CNC (252h) and Manufacturing by abrasion, EDM, cutting and forming, additive manufacturing and by special processes (210h).

The program of Higher Technician in Programming of production in mechanical manufacturing makes use of the lab on 3 of its modules. In the 1st year Mechanical Manufacturing Techniques (198h) and in the 2nd year CNC (240h) and CAM (40h).

The project affects two floors of the same building where the cutting warehouse is located on the ground floor and the machining workshop is on the upper floor. The machining workshop will be supplied with the materials cut in the cutting warehouse by means of the vertical pallet warehouse.

- Program simulation: by computer, machine, CAM integrated in machine, 3D simulation, virtual, etc.

- Integration of data acquisition systems. Artificial vision cameras.

- Integration of radio frequency identification systems

- Use of computer tools and software to access and manage the necessary and generated documentation (PC, tablet, smartphone, machine interface, integrated CAD / CAM / ERP systems, PLM, etc.).

- Registration of the program and the documentation generated in folder structure, CAD / CAM / ERP integrated systems, PLM, etc.

- Programming of robots (industrial and collaborative) for manipulation and machining.

- Analysis of process data in real time (Big Data, Smart Data, ...).

2 - Training for companies:

We have courses, funded by the Basque Government's Department of Industry, for unemployed technicians and active technicians. The courses aimed at unemployed technicians are long courses, around 500 hours of training, with the aim of obtaining accreditation. The courses aimed at active technicians are shorter courses, around 50 hours, which help them to improve their knowledge.

For tailored training for companies are open courses that are funded by the company that demands the course.

For management of the centre's courses for companies, around 3000 hours/year, our centre has a foundation called Zubigune (www.zubigune.com).

The foundation was created by companies in the region with the aim of supporting vocational training centres and companies in the surrounding area. The foundation is made up of 7 people for the management of the projects and personnel hired temporarily for the development of the projects.

3 - Applied innovation

The TKGUNE applied innovation projects are collaborative projects with small and medium sized companies with the aim of supporting companies in their innovation and transferring the knowledge acquired in the project to the classroom with the students. These innovation projects are developed by the teaching staff and in collaboration with the companies.

4 - Research

Usurbil LHII's SMART FACTORY will also be used in some Research Projects to be developed in collaboration with different Universities, such as:

- Manufacturing process development.
- Data analysis.
- Psychology of student's behaviour.
- Entrepreneurship.
- Business administration.

PURPOSE AND TARGETS

2.1	Main purpose	education	vocational training	research							
2.2	Secondary purpose	test environment / pilot environment	industrial production	innovation transfer	advertisement for production						
2.3	Target groups for education & training	pupils	students	employees	entrepreneurs	freelancer	unemployed	open public			
			bachelor	master	phd students	apprentices	skilled workers	semi-skilled workers	unskilled	managers	
										lower mgmt	middle mgmt
										top mgmt	
2.4	Group constellation	homogeneous	heterogeneous (knowledge level, hierarchy, students + employees, etc.)								
2.5	Targeted industries	mechanical & plant eng.	automotive	logistics	transportation	FMCG	aerospace				
		chemical industry	electronics	construction	insurance / banking	textile industry	...				
2.6	Subject-rel. learning contents	prod. Mgmt & org.	resource efficiency	lean mgmt	automation	CPPS	work system design	HMI	design	Intralogistics design & mgmt	...
2.7	Role of LAB for research	research object	research enabler								
2.8	Research topics	production management & organization	resource efficiency	lean mgmt	automation	CPPS	changeability	HMI	didactics	...	

Main purpose. Workshops are designed mainly for initial training. The executional part of the challenges, an important phase for the student to get the right skill, are realized by students in the workshops. This is usually in the mornings.

In the afternoons, the workshops are designed to be used for continuous training courses, oriented to active or unemployed technicians. As described before, we also work with courses on demand, in which the courses are prepared specifically for one or two companies.

Secondary purposes. Within the programme called ZUBILAN, the students of the first and second year run a production for companies manufacturing a part with real market specifications. It is a small production serial and helps the student in his learning process.

The applied innovation is another of the work lines of Usurbil LHII. This project is called TKGUNE (www.tkgune.eus), it is the third line of work of the centre, and thanks to it we collaborate with small and medium sized companies in projects to develop their innovation system.

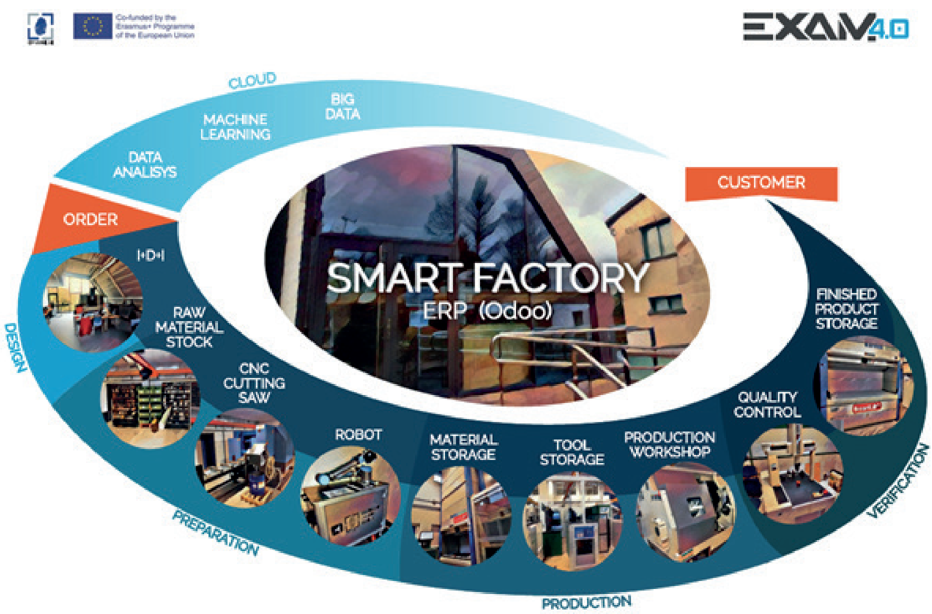
Also, and in collaboration with different Universities, we develop research projects with University students who are finishing their degree.

PROCESS

3.1	**Product life cycle**	product planning	product development	product design	rapid prototyping	manufacturing	assembly		logistics	service		recycling
3.2	**LAB life cycle**	investment planning	factory concept	process planning	ramp-up	manufacturing	assembly		logistics	maintenance		recycling
3.3	**Order life cycle**	configuration & order	order sequencing	production planning and scheduling		manufacturing	assembly		logistics	picking, packaging		shipping
3.4	**Technology life cycle**	planning	development	virtual testing		manufacturing	assembly		logistics	maintenance		modernization
3.5	**Indirect functions**	SCM	sales	purchasing		HR	finance / controlling			QM		
3.6	**Material flow**	continuous production				discrete production						
3.7	**Process type**	mass production		serial production		small series production					one-off production	
3.8	**Manufact. organization**	fixed-site manufacturing		work bench manufacturing		workshop manufacturing					flow production	
3.9	**Degree of automation**	manual		partly automated / hybrid automation					fully automated			
3.10	**Manufact. Methods**	cutting	trad. primary shaping		additive manufact.	forming		joining	coating		change material properties	
3.11	**Manufact. Technology**	physical			chemical				biological			

With a total operational surface of 2000 square metres, and depending on the objectives of the training courses, different process flows can be arranged in our workshop.

The workshop is distributed in cells where different configurations are available, as is described in the next image:



Description of the different parts of the Smart Factory process:

Research, development, and innovation office

In this office the customer's order will be received, and so the teachers will transform it into a challenge for the students. This order can be both a theoretical exercise generated by teachers, or a real order coming from a company.

Defining this challenge means:

- to design and generate the manufacturing process.
- to schedule this process on time, machine occupations, costs, energy to be consumed and other detailed information in the ERP Odoo.

Raw material stock

On this site, the needed raw materials are stored.

Depending on the production needs defined by Odoo, orders to the material suppliers will be placed automatically. We are analysing that the material bars will be identified with a RFID based chip, and so the ERP Odoo will be aware anytime of the quantity of material that the raw material storage has stored.

The aim is to create a cutting warehouse under the influence of the current Industry 4.0. The stock control system chosen will give permission to the people identified by RFID technology to use the machines, control the stocks of raw materials, execute, and archive the cutting orders, notifying when the minimum stock is reached and preparing the order according to needs.

During the cutting process, the aim is to have the information and control of people, materials, and machines in that warehouse. And automatic warning is given for each of the aspects considered critical from the operational and management point of view.

The cutting warehouse has been distributed in the plant, in the most convenient way to guarantee safety in the handling of loads. Giving great importance to the arrangement of the raw material, a place for everything and everything in its place "5S". For this purpose, three compact beehives have been built, according to easily machined steels, aluminium, and special steels, for rounds, squares, rims, tubes, and construction profiles. With these beehives we are able to sort out 227 sizes of these 3-metre-long laminates in a very small space.

CNC cutting saw

This CNC technology based cutting saw converts the raw material bars automatically into raw parts to be stored on the material storage system. This process will be calculated by Odoo, depending on the minimum stock needs of the material stockage system and planned production needs.

Although the cutting on size and quantities of raw parts is automatic, the feeding of the raw material bars to the machine must be done by teachers manually.

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EXAM 4.0

THE EXCELLENT ADVANCED MANUFACTURING 4.0