EXAM 4.0

THE EXCELLENT ADVANCED MANUFACTURING 4.0

Advanced Manufacturing Labs running

Piloting the Advanced Manufacturing workshop 4.0

03

THE EXCELLENT ADVANCED MANUFACTURING 4.0

Co-funded by the
Erasmus+ Programme
of the European Union

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EXAM 4.0 partners:

TKNIKA – Basque VET Applied Research Centre, CIFP Miguel Altuna, DHBW Heilbronn – Duale Hochschule Baden-Württemberg, Curt Nicolin High School, Da Vinci College, AFM – Spanish Association of Machine Tool Industries, 10XL, and EARLALL – European Association of Regional & Local Authorities for Lifelong Learning.

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0 ABSTRACT

Specific WP5.3 result:

A proposal of a VET centre 4.0 AM Workshop /LAB Model:

- Conceptual design: Elements and relationships among them.
- The supporting structure of the service: Coordination, timing, funding, indicators, expected results.
- Advantages of the approach.
- Objectives of the initiative end expected results.

LTR5: AM workshop 4.0 (= Exam4.0 Collaborative Learning Factory) as a successful scenario for skilful and committed teachers to transfer technical and transversal skills to the AM sector.

The characteristics of the AM Workshop 4.0 Framework are being implemented in VET centres where teachers, besides their involvement in the learning process, are also providing services to AM industries.

1 Introduction

EXAM4.0, the platform for Excellence centres for Advanced Manufacturing, has defined an approach to set up Advanced Manufacturing Labs at HVET/VET centres.

Defining a Europe-wide model for an advanced manufacturing workshop is a complex task, given the diversity of VET systems in the European Community. Moreover, the area of study, advanced manufacturing and Industry 4.0, is an evolving, highly technological sector with a high degree of uncertainty.

When defining and subsequently piloting an advanced manufacturing lab model, we have based ourselves on previous studies carried out in EXAM4.0. Specifically, EXAM4.0 Learning Dialogues on technological trends in industry and pedagogical trends in education, always within the field of AM.

Our approach has been to deal with I4.0 technologies from a holistic approach, giving importance to the interrelation of the technological elements implemented in our labs. This aspect has arisen the need to integrate multiple I4.0 technologies in the same scenario.

We have also sought to make room for collaboration, both intra-organisationally and externally, at different levels: between teachers and also between students.

Based on those descriptions, the so called **EXAM 4.0 Collaborative Learning Factory** has been defined to pilot the model of AM Lab. During the piloting process, we have generated several reports to document the work we have carried out. The structure of the piloting process is as shown in figure 1, where each section of the flow chart refers to a specific report:

Labs for Advanced Manufacturing-CLF

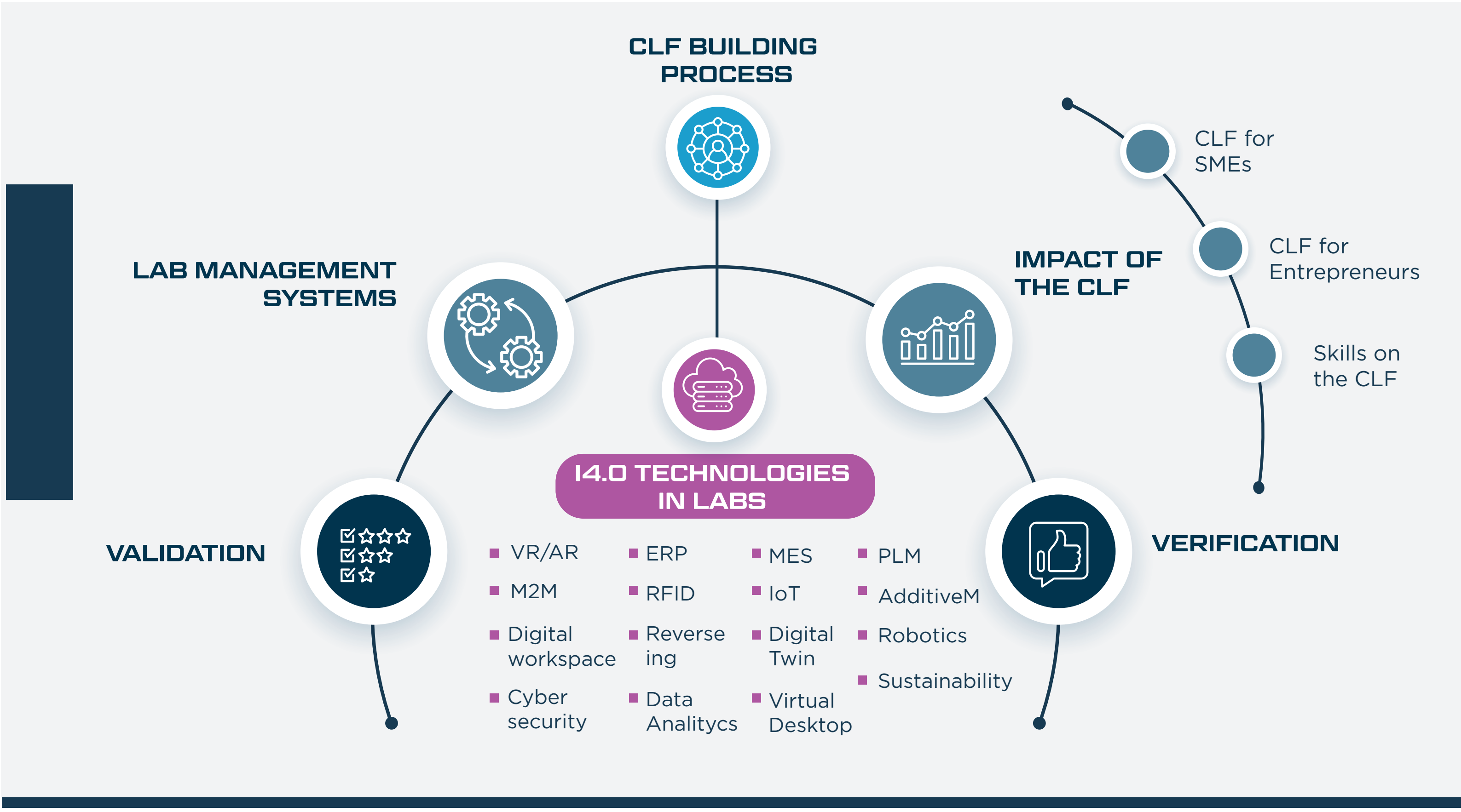

Figure 1: Piloting process of Advanced Manufacturing Labs. Source: EXAM4.0

The document you are handling "Advanced Manufacturing Labs running" gathers information about industry 4.0 technologies piloted in different labs represented in the EXAM4.0 consortium.

Sections 2 and 3 describe the conceptual design of the CLF.

Section4 includes details about the piloting process of 16 industry 4.0 technologies implemented in our labs and the relations among them. After an approach to technologies, we have described their influence on the CLF, the benefits and the opportunities for collaboration they provide.

2 The Collaborative Learning Factory as union element

One of the objectives of the EXAM4.0 as Platform of CoVEs in Advanced Manufacturing, is the definition of the main characteristics of the AM labs in VET institutions to respond to the emerging needs in terms of qualifications/skills that have arisen due to the digital transformation and Industry 4.0.

The EXAM4.0 consortium has formulated a LF model to converge solutions to gain skills 4.0 and coworking opportunities offered by a CoVE's network. The model defined and piloted in EXAM4.0 is called Collaborative Learning Factory (hereafter CLF). **It is a LF of LFs composed of 4 organisations from 4 European countries whose aim is:**

- to co-create in LF environments among the members of the platform
- to enrich the regional LF proposals
- to accelerate the implementation of I4.0 enabling technologies at the participating centres
- to formulate a collaboration model where more VET schools can join in.
- To improve skill provision systems for AM.

The EXAM 4.0 partners combined the labs from each center to create a collaborative LF, which is to be used for three main purposes.

1. to provide an industry 4.0 learning environment usable by future partners of the platform.
2. to pilot the implementation of advanced manufacturing key enabling technologies.
3. to show the concept of the CLF by producing the EXAM 4.0 robot.

Each center implemented a certain number of technologies in their lab, ensuring that all relevant technologies were covered. All centers also contributed to the production of the EXAM 4.0 robot that was created within the CLF. The partners had a collaborative approach, combining the labs from the different centers into one CLF. With assistance from the implemented technologies, each partner contributed to the CLF and production of the robot with their core business, but also supported the other activities in the production chain. The CLF approach ensures quality, exchange of data and information between partners, making it a high end education environment.

Detailed information about the CLF building process can be found in the document:

4 Evidences on performance: Recorded data

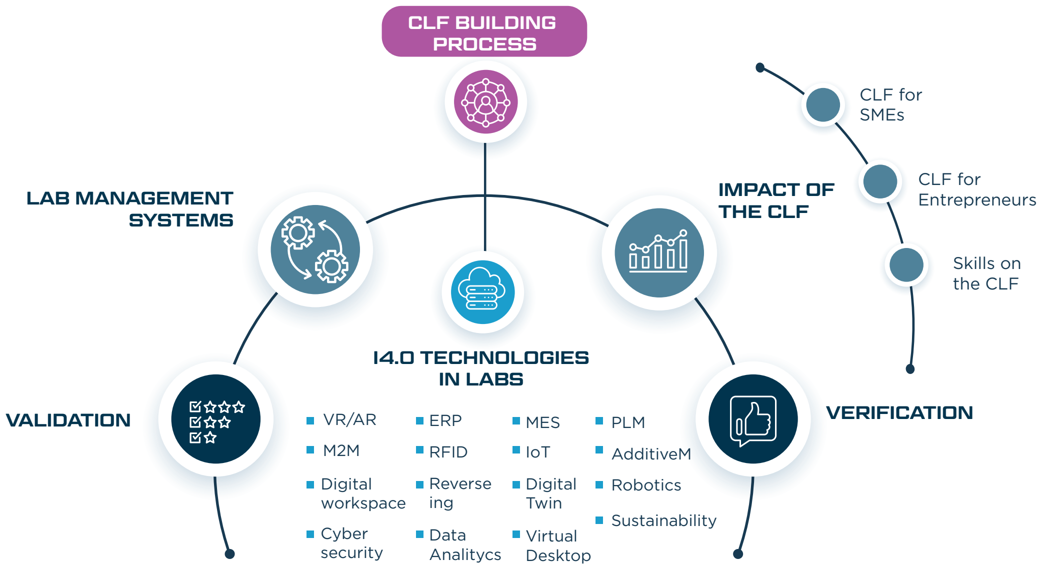

Figure 2: "4 Evidences on performance: Recorded data" report on the overall structure of the EXAM4.0 labs piloting process. Source: EXAM 4.0

3 Description of the piloting process

The consortium has designed and produced a smart product in collaboration, using EXAM4.0 Labs to manufacture and assemble the components of the product in the so called CLF

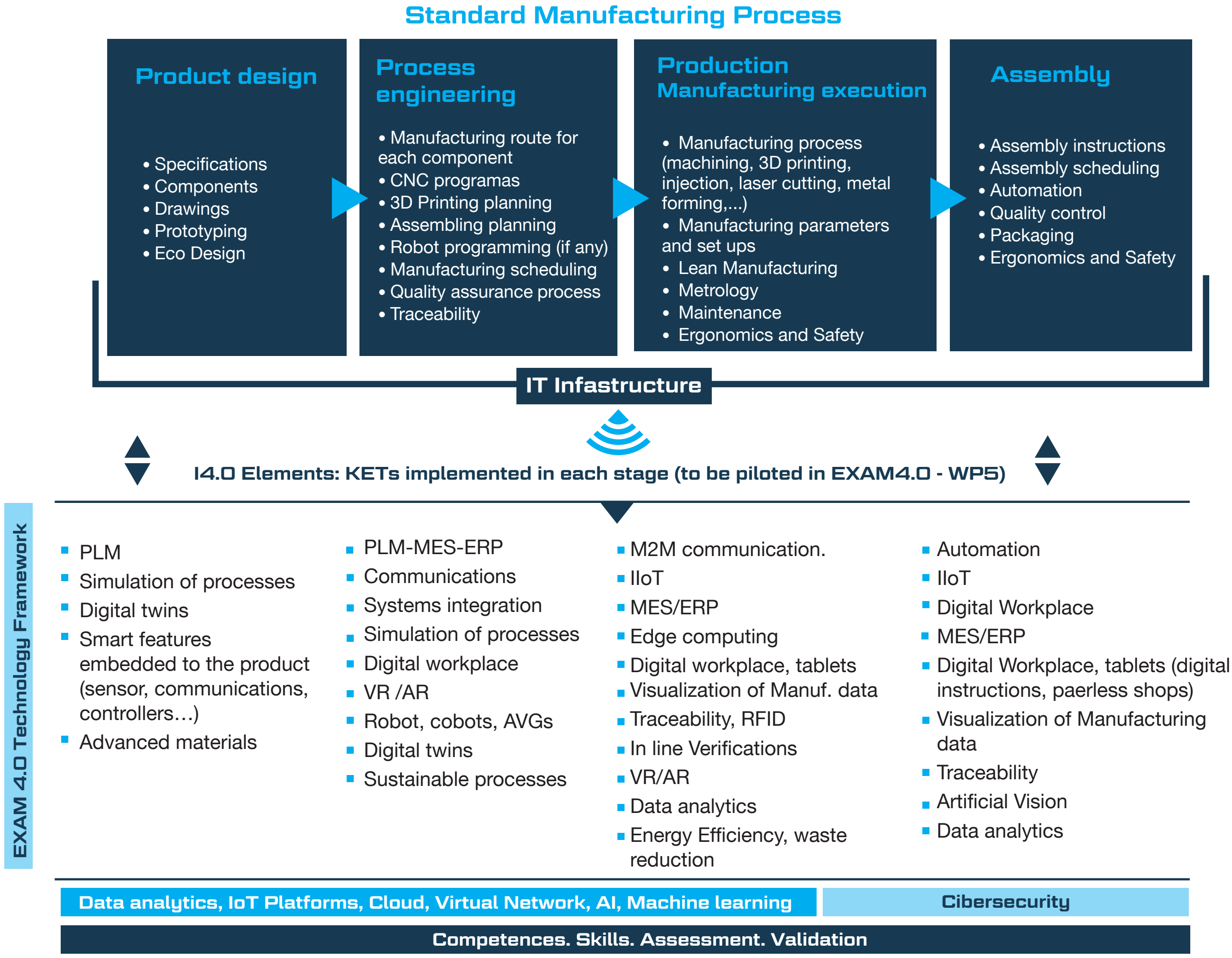

Figure 3: EXAM 4.0 Collaborative Learning Factory (CLF) process and technologies. Source: Authors' creation

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

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

1) Competences in the implementation of I4.0 elements

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

3) Improvement of transversal skills

The tested I4.0 enabling technologies for each stage of the CLF are listed in the following table:

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

Figure 4: Interrelation of the technologies in CLFs process. Source: Authors' creation

Following the piloting process of Advanced Manufacturing Labs for H/VET through the CLF, the EXAM4.0 partners have piloted 16 technologies embedded in Industry 4.0

The following image shows the overall structure of the piloting process.

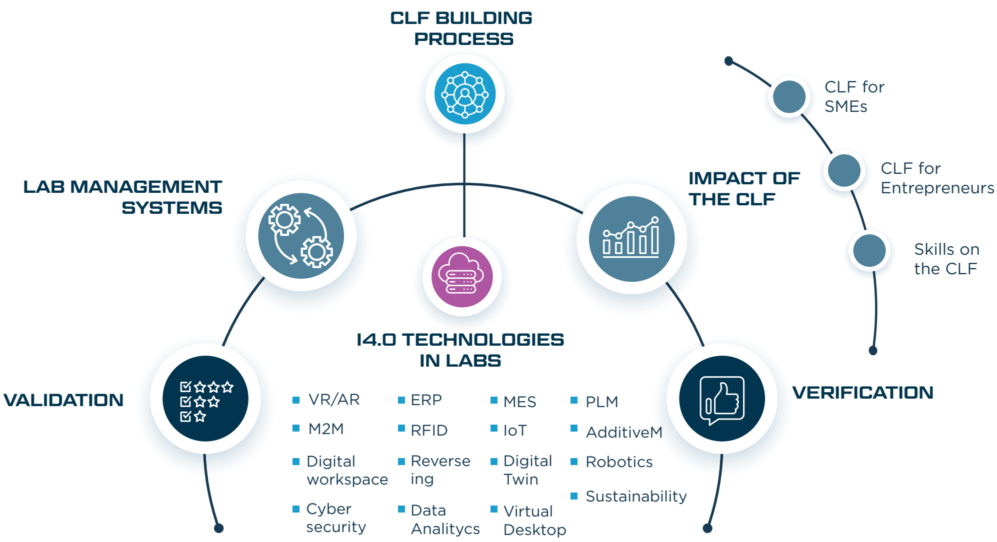

Figure 5: Overall structure of the EXAM4.0 labs piloting process. Source: EXAM4.0 15 elements

The different industry 4.0 technologies (I4.0 techs) have been inserted and piloted in the different partners' labs. In the table below you can find which partners have implemented and described each.

i4.0 tech #1:	IIoT	by Tknika
i4.0 tech #2:	Data analytics	by DVC
i4.0 tech #3:	VR/AR	by CNG, Tknika
i4.0 tech #4:	Reverse engineering	by Tknika
i4.0 tech #5:	Cybersecurity	by Tknika
i4.0 tech #6:	Digital twins	by Tknika
i4.0 tech #7:	M2M communication	by Miguel Altuna
i4.0 tech #8:	RFID	by Miguel Altuna
i4.0 tech #9:	Robotics	by DHBW, Miguel Altuna
i4.0 tech #10:	Additive Manufacturing	by CNG, DVC
i4.0 tech #11:	Virtual Desktops	by Miguel Altuna
i4.0 tech #12:	Digital workplace	by Miguel Altuna
i4.0 tech #13:	PLM	by Miguel Altuna
i4.0 tech #14:	ERP	by Bidasoa, Usurbil
i4.0 tech #15:	MES	by IMH
i4.0 tech #16:	Sustainability. Green processes, energy efficiency, waste reduction	by DVC

4 Piloted Industry 4.0 technologies

During the piloting process, for each of the 16 Industry 4.0 Technologies we have covered the following information:

Piloted Industry 4.0 technologies (i4.0 tech)

1. Definition and application of the I4.0 tech **in industry**
2. I4.0 tech **in HVET/VET labs**
   - Integration of the I4.0 tech **in VET labs**
   - Role of the I4.0 tech **in the EXAM4.0 CLF**
   - **Benefits** of the I4.0 tech for the EXAM 4.0 CLF
   - **Competences** addressed with the I4.0 tech
3. **Collaboration oportunities** opened by the I4.0 tech

Figure 6: Structure followed for each of the 16 the industry 4.o technologies piloted

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AM 4.0 labs running I4.0 technologies

Technology 1: IIoT

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0 Introduction

Following the piloting process of Advanced Manufacturing Labs for H/VET through the Collaborative Learning Factory (hereafter CLF), the EXAM4.0 partners we have piloted 16 technologies embedded in Industry 4.0

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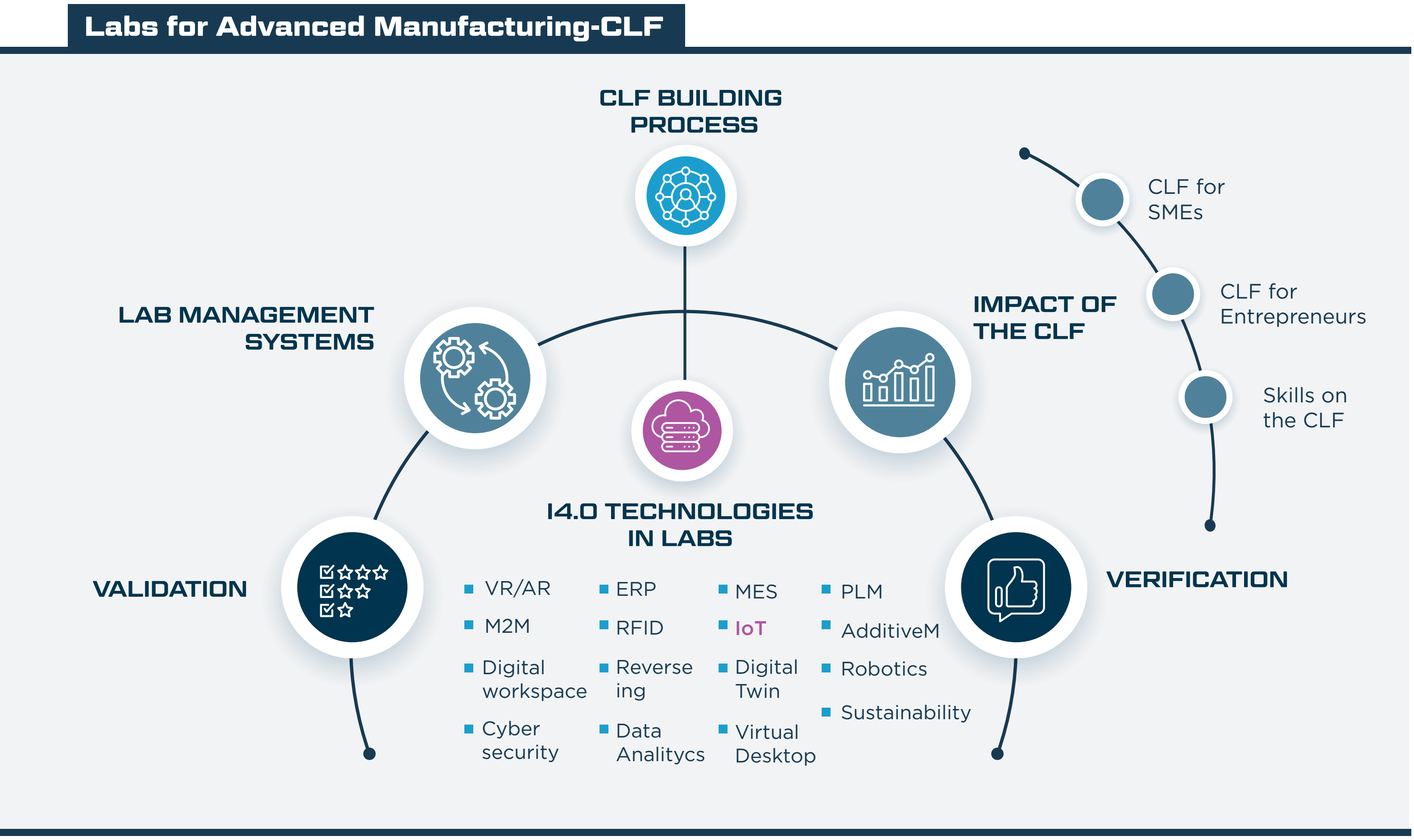

Figure 1: Overall structure of the EXAM4.0 labs piloting process. Source: EXAM4.0

The present report is the one out of 16 I4.0 technology described within the "Industry 4.0 technologies in labs" section, specifically #1 Industrial Internet of Things (IIoT).

1 Industrial Internet of Things (IIoT)

1.1. Definition and application of IIoT in industry

The Industrial Internet of Things (IIoT) is the set of autonomous sensors, instruments and devices connected via the Internet to industrial applications. This network makes it possible to collect data, perform analysis and optimize production, increasing efficiency and reducing the costs of the manufacturing and service provision process. Industrial applications are complete technological ecosystems that connect devices and devices with the people who manage the processes in assembly lines, logistics or large-scale distribution (Iberdrola, 2021).

Today's IIoT applications are mostly concentrated in manufacturing, transportation, and energy. In the immediate future, the adoption of the IIoT is expected to translate into the implementation of more industrial robots, such as cobots, warehouse and freight control systems, and predictive maintenance systems.

Figure 2: Idea of IIoT conexion in the industry. Source: https://www.iberdrola.com/innovacion/que-es-iiot

The difference between the Internet of Things (IoT) and its industrial version (IIoT) is that while IoT focuses on services for consumers, IIoT focuses on increasing security and efficiency in production centers.

Not all systems can be classified as IIoT. In general, it requires that they be networked systems that generate data for analysis and produce specific actions. The operation of IIoT systems is based on a layered structure:

- **Devices.** The visible part of the system are the devices: sensors, GPS locators, machines, among others.
- **Network.** Above it is the connectivity layer, that is, the network that is established between these devices and the servers through cloud computing or edge computing.
- **Services.** They are the computer applications that analyse and process the collected data to offer a specific service.
- **Content.** It is the interface with the human operator, which can be a computer, a tablet or even devices such as virtual reality glasses or augmented reality.

Among the applications that we can find in the IIoT are:

- **Autonomous vehicles:** The transport of components to the plant or to the warehouse, can be carried out by autonomous vehicles that are capable of moving from one side of the factory to the other detecting obstacles.
- **Machine performance optimization:** An idle machine represents a loss of revenue. Thanks to sensors and data processing, it is possible to optimize machine uptime within a manufacturing plant. They can also detect times of use or errors for predictive and preventive maintenance.
- **Reduction of human errors:** Human operators will continue to be essential in many tasks, but the tools they use will be connected to the system, to save time and avoid errors.
- **Improved logistics and distribution:** The stored products incorporate sensors that provide real-time data on their location and even on their temperature or environmental conditions.
- **Decrease in the number of accidents:** Wearables, such as glasses, bracelets or gloves, allow data collection from the operator who wears them - from their location or proximity to the machines to their pulse, temperature or tension - and thus reduce the possibility of accidents.

2 IIoT in HVET/VET labs

2.1. Integration of IIoT in Tknika´s LAB

In this section, we address how IoT technology can be incorporated into the laboratories of VET / HVET centres with the aim of acquiring data from CLF processes. With this goal, we have been working in Tknika's I4.0 Factory Lab using SMC´s SIF-400 Learning Factory described in WP4, section D4.2, as a test bed to develop fully interoperable equipment for data acquisition and analysis.

Figure 3: Tknika's I4.0 Factory Lab using SMC´s SIF-400 Learning Factory. Source: Tknika

SIFMES-400 allows the user to control and manage the SIF-400 system by storing and monitoring all process data. In the connected company, customers, manufacturers and suppliers are communicated and connected thanks to some of the functionalities of this software (SMCtraining, 2021).

It is structured in four blocks:

- **Management:** production orders, planner, launcher, inventory, logistics, customers, maintenance, database and data analysis...
- **Movements:** physical layout, logical layout, system reset and traceability of movements...
- **Visualisation:** system status and alarms: maintenance, energy, analysis and statistical process control...
- **Administration:** Database, role and disturbance management (Instructor)...

This software represents a major step forward in digitalization and smart manufacturing due to the fundamental role played by this technology in the new industrial reality.

On the other hand, we have chosen to use technologies and apps that allow collaborative work, opting for those that have a strong developer community.

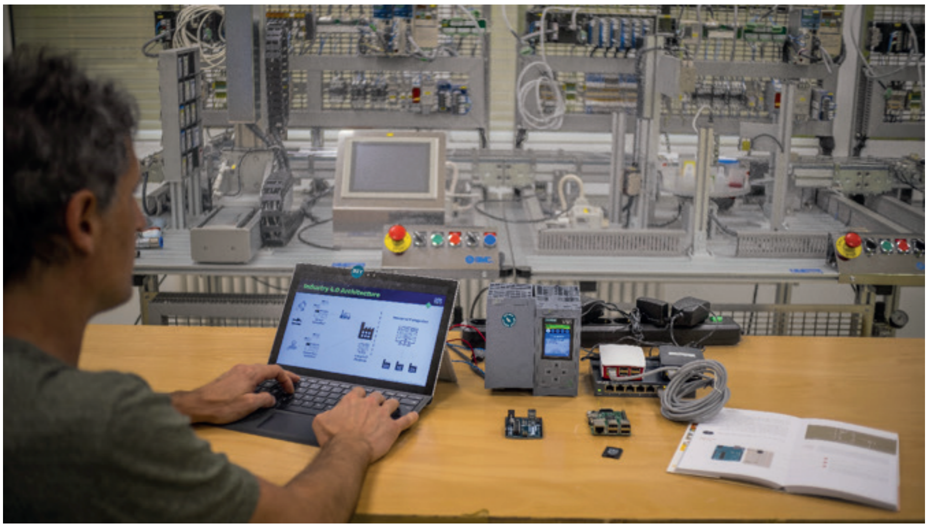

Figure 4: Teacher working on IIoT on Tknika's lab. Source: Tknika

With these techonologies an IIoT gateway (Hardware & Software) has been developed allowing us to communicate with any industrial controller that speaks OPC UA, Modbus or S7 protocol. The gateway, called IoM2040, has been developed based on a Raspberry Pi 4, and a software package, called IoMBian (Raspbian Lite, Node RED, Mosquitto, MQTT client, Monit, Samba, etc). Everything has been designed to be easy to implement.

More information about these projects can be found in the following links:

- **IoMBian:** https://github.com/Tknika/iombian
- **IoM2040:** https://github.com/Tknika/iom2040

Figure 5: IIoT technologies in Tknikas's lab. Source: Tknika

In the data analysis part, an IoT platform has been deployed in the cloud to provide service to the different CLFs. For that purpose **Thingsboard has been chosen (Thingsboard, 2021). ThingsBoard is an open-source IoT platform for data collection, processing, visualization, and device management**. It enables device connectivity via industry standard IoT protocols - MQTT, CoAP and HTTP and supports both cloud and on-premises deployments.

In this way the architecture of the IIoT system would look like this:

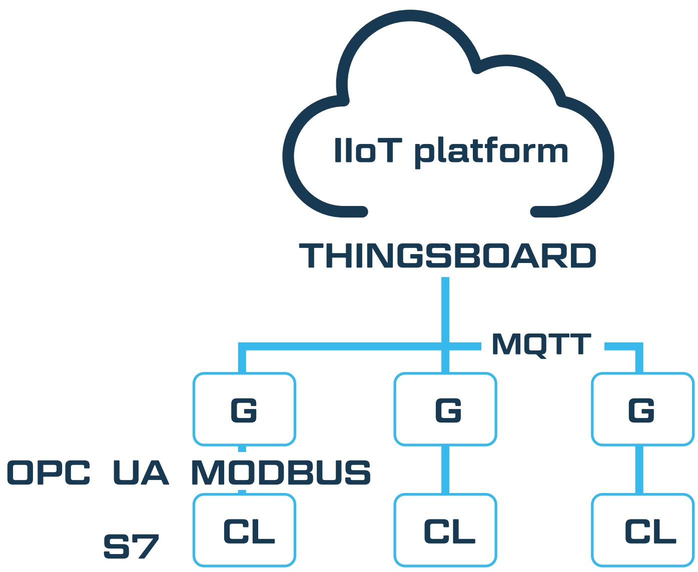

Figure 6: IIoT system architecture. Source: Tknika

2.2. Role of the IIoT in the EXAM4.0 CLF

The CLF that is going to be launched has divided its production process into 4 stages (product design, process engineering, production and assembly) as can be seen in the following image. Within these stages, robotics is going to help in the process engineering, production and assembly stages.

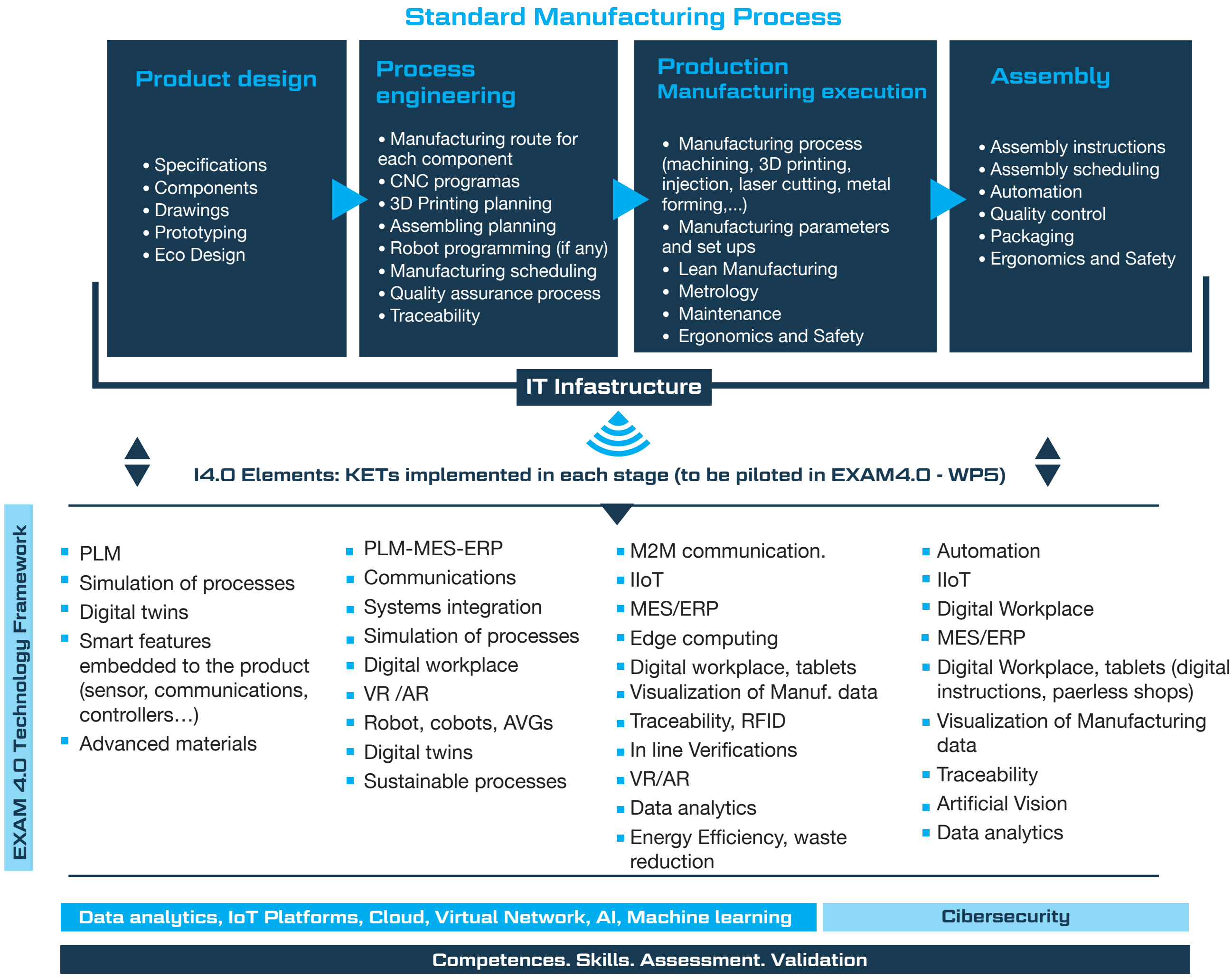

Figure 7: EXAM4.0 Collaborative Learning Factory (CLF) Value Chain Source: Author's creation

The projects and services mentioned above will be used to connect machines in labs and collect data that will allow us to introduce process improvement iterations and share information between partners. This requires forming a new profile that is capable of managing both the installation and the development of the data collection and analysis ecosystem.

Based on our experience in this field, we will design a teacher training course focused on VET teachers with the aim of equipping them with technology to implement in the labs, but also allowing them to introduce this new knowledge as soon as possible in the classroom. In the pilot course, all the tools mentioned above will be taught to analyze the path traveled by the data from the production process (OT) to the cloud (IT).

2.3 Benefits of using IIoT in EXAM4.0's CLF

There are huge benefits of adopting a fully connected IIoT manufacturing operation in the Labs. Some of these advantages are:

- Increase efficiency
- Reduce errors
- Improve security
- Reduce costs
- Share information

The greatest benefit of IIoT is that it provides the ability to automate and therefore optimize the operational efficiency of CLFs. Robotics and automated machinery can work more efficiently and precisely, increasing productivity.

Additionally, physical machinery can be connected to software through sensors that constantly monitor performance. This allows teachers and students to have a better understanding of the operational performance of the process.

Other advantages are:

- Data-driven decision making for all manufacturing functions.
- Performance monitoring from anywhere.

2.4. Competences addressed with IIoT

Among the competences that students will obtain working with IIoT platforms are:

- Obtain information to perform associated operations with the installation and commissioning of IoT systems.
- Configure the elements of the IoT system.
- Verify the operation of the IoT infrastructure, conducting functional tests on connected devices and systems, on site or remotely.
- Adapt to new work situations caused by technological and organizational changes in production processes.
- Identify the range of options for the way things can communicate.
- Select the most appropriate standards for building successful communications.
- Build addressing architectures that can scale to the required sizes.
- Analyse and record the interactions.
- Visualise the results of interactions.
- Deliver the security that modern services demand.
- Build new service networks that can support the future IIoT.

3 Collaboration opportunities opened by IIoT

The IIoT platform will allow the creation of a community of connected CLF-s. For that purpose we have decided to use ThingsBoard and we have purchased the professional edition license. ThingsBoard is an open-source IoT platform that enables rapid development, management, and scaling of IoT projects.

With ThingsBoard, we will be able to provide this service to more CLF-s in the future being a service that can be offered to new partners from the EXAM4.0 platform.
In the platform we will be able to:

- Provide devices, assets and customers, and define relations between them.
- Collect and visualize data from devices and assets.
- Analyze incoming telemetry and trigger alarms with complex event processing.
- Control devices using remote procedure calls (RPC).
- Build work-flows based on a device life-cycle event, REST API event, RPC request, etc.
- Design dynamic and responsive dashboards and present device or asset telemetry and insights to the customers.
- Enable use-case specific features using customizable rule chains.
- Push device data to other systems.

Figure 8: IIoT platform community with Thingsboard. Source: Tknika

4 References

Iberdrola. (26 October 2021). Retrieved from https://www.iberdrola.com/innovacion/que-es-iiot

SMCtraining. (26 October 2021). Retrieved from https://www.smctraining.com/en/newpage/newsdetail/2060

Thingsboard. (26 October 2021). Retrieved from https://thingsboard.io/docs/getting-started-guides/what-is-thingsboard/

EXAM 4.0

THE EXCELLENT ADVANCED MANUFACTURING 4.0

AM 4.0 labs running I4.0 technologies

Technology 2: Data Analytics

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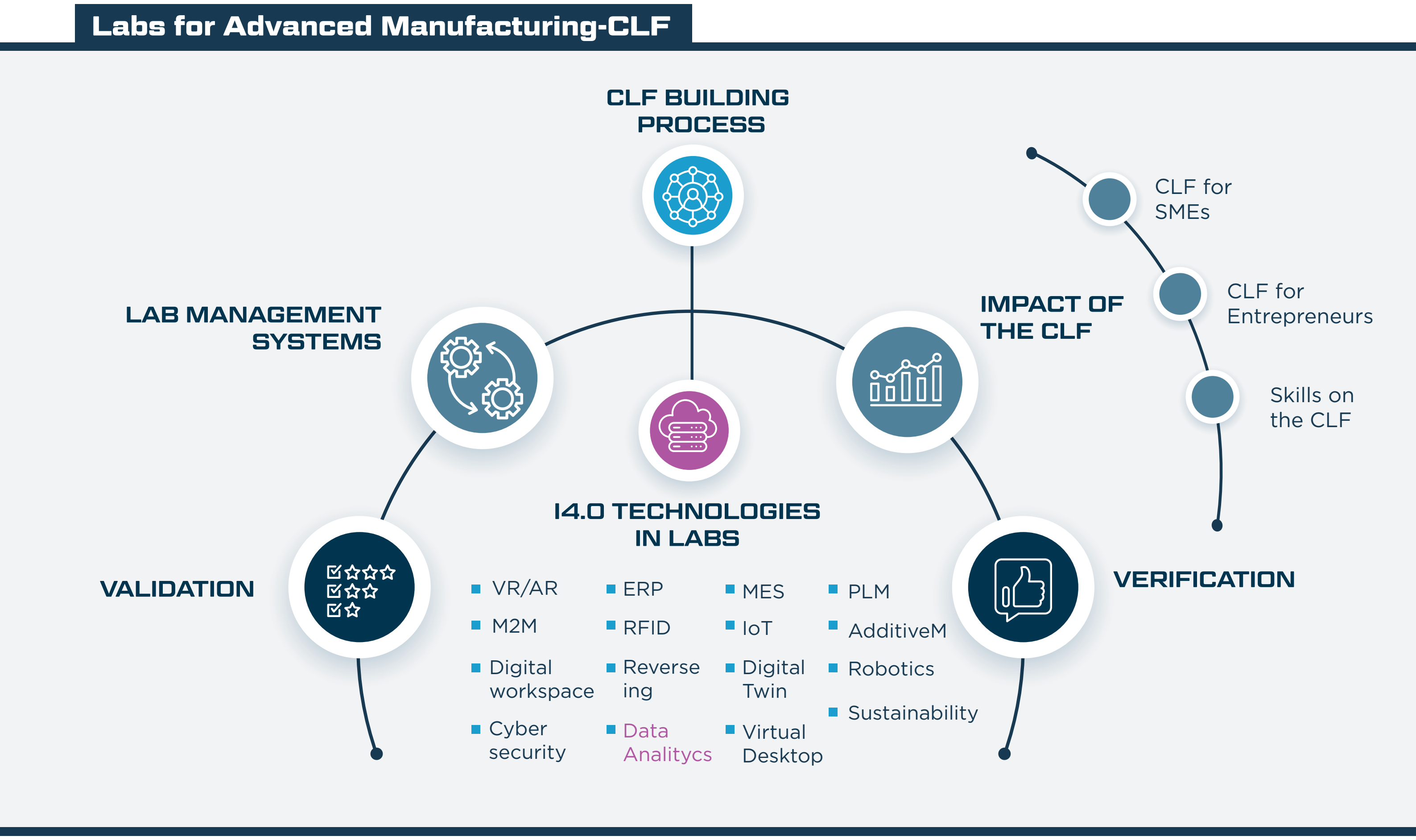

Figure 1: Overall structure of the EXAM4.0 labs piloting process.
Source: EXAM4.0

The present report is the one out of 16 I4.0 technology described within the "Industry 4.0 technologies in labs" section, specifically on #1 Data Analytics.

1

Definition and application of data analytics in industry

Data analytics is meant to be the process and the technique with which raw data is analysed in order to draw conclusions. In earlier years, data analytics was done manually, but this domain of expertise has been developed and currently most of the processes are automated into mechanical processes and algorithms.

Data analytics is a broad term. With a range of data analytic techniques, different kinds of information can be analysed to get insight in the processes to be improved. Data analytic techniques can be used to reveal metrics and trends, which easily could be lost in the mass of information. This information can then be used to optimize processes to increase the overall efficiency of a business or a system.

Figure 2: Data Analytics. Source: edX

Coupled with the rapid development of artificial intelligence, advanced analytics, robotics, emerging IoT-powered sensors and devices, Industry 4.0 offers manufacturers the ability to gather, store, process as well as utilize data in daily operations. Furthermore, business intelligence and business analytics help to draw insights about potential improvements. (Vyas, 2021) The results are tangible: from increased efficiency and higher quality to cost savings and minimized emissions. (Birand, 2021)

In industry for example companies can record the runtime, downtime, and work queue for various machines and then analyse the data to better plan the workloads. Furthermore, predictive data analytics is used for predictive maintenance (forecasting when the equipment fails to perform a task). And there are many more applications in which data analytics can be used for improvement of processes. On the other side, we need also to remember the fact that one of the biggest problems for an organization is the lack of talent to understand data and how to analyze it and apply that learning to specific business cases. (Dib, 2021)

2 Data Analytics workplace in HVET/VET labs

2.1. Data Analytics in an educational Lab

In this section we describe how Data Analytics can be incorporated in VET/HVET school's labs. Different options and applications are described.

There are different learning possibilities when it comes to Data Analytics in schools. A wide range of devices, systems and processes can be used as a source of data. These can be based on fictitious situations as well as real situations. The data source that will be used depends on the learning goals; is your focus on collecting data, analysing data, interpretation of data or the whole process.

Furthermore, the lab will give the opportunity to analyse data from existing systems as well as new systems. The latter will give learners the possibility to go through the whole Data Analysis process from defining the data analysis goal till the interpretation of results and even the application of adjustments.

Coming to educational institutions, another relevant application field for data analytics is its use to improve the learning processes of the students, in a similar way as the Learning Analytics discipline proposes. Learning analytics is the measurement, collection, analysis and reporting of data about learners and their contexts, for purposes of understanding and optimizing learning and the environments in which it occurs (SoLAR Society for Learning Analytics Research, 2011).The term Learning Analytic is widely used to evaluate teaching and learning in online environments. However, in Learning Factory environments, we can also have a lot of data related to the learner's performance that could be used to improve their particular process. Data coming from machines, equipment, and other systems as MES-ERP-PLM can be linked to the students. This data can later be processed, tracked and monitored.

2.2. Integration of data analytics in Da Vinci's / Sustainability Factory LAB

Within the Sustainability Factory (Duurzaamheidsfabriek) it is possible to gain the Data Analytics knowledge and skills by using data sets of real machines and processes. For example with the Xcaliber flow loop in the Flowcenter of Excellence FCoE.

Figure 3: Xcaliber flow loop in the Sustainability Factory . Source: Author's creation

This flow loop is located on the ground floor of the Sustainability Factory and offers a platform to support and facilitate industry and education. This regards metrology as such, i.e. the measurement of liquid flows in all aspects, including calibration. Furthermore, this involves testing/training and/or education w.r.t. (new) products and technologies, where a dynamic flow forms the context, like the process industry and maritime industry. Several datasets are created on the XCaliber flow loop. They provide readings from a wide array of instruments and actuators available on the XCaliber flow Loop. They contain various intervals (approximately after 3 minutes) where air is introduced into the system. They are time-series recorded from the Schneider SCADA system of XCaliber using APM-Studio.

Another FCoE installation used for Data Analytics research, training and education is the Dynamic Maritime Test Facility (DMTF). This loop offers its users a dynamic environment to test and/or research developments in maritime propulsion technology in a streaming water (i.e. flow) situation. With the TT-Sense ® implemented in the drive line, both thrust and torque at the shaft can be measured. In combination with shaft speed (rpm), flow speed and engine power, the performance of the propulsion line as a whole can be analysed and optimized.

Figure 4: The Dynamic Maritime Test Facility in the Sustainability Factory. Source: Author's creation

The partners in the industry as well as the students that make use of the Sustainability Factory can use the datasets for development of prognostic algorithms and exploratory analysis.

2.3. Integration of data analytics in Miguel Altuna VET centre's Lab. Use cases

The system implemented in the machining lab at Miguel Altuna allows the data acquisition of machines, tools and equipment use. The systems link learners and their learning process to the usage of lab's equipment. Thanks to the data analytics systems, three aspects are covered: i) improvement of the efficiency of the equipment ii) use of data by students to improve their projects and performances iii) tracking of students' learning processes. For further information refer to EXAM4.0, 3 I4.0 technology #7:-M2M (EXAM4.0, 2021)

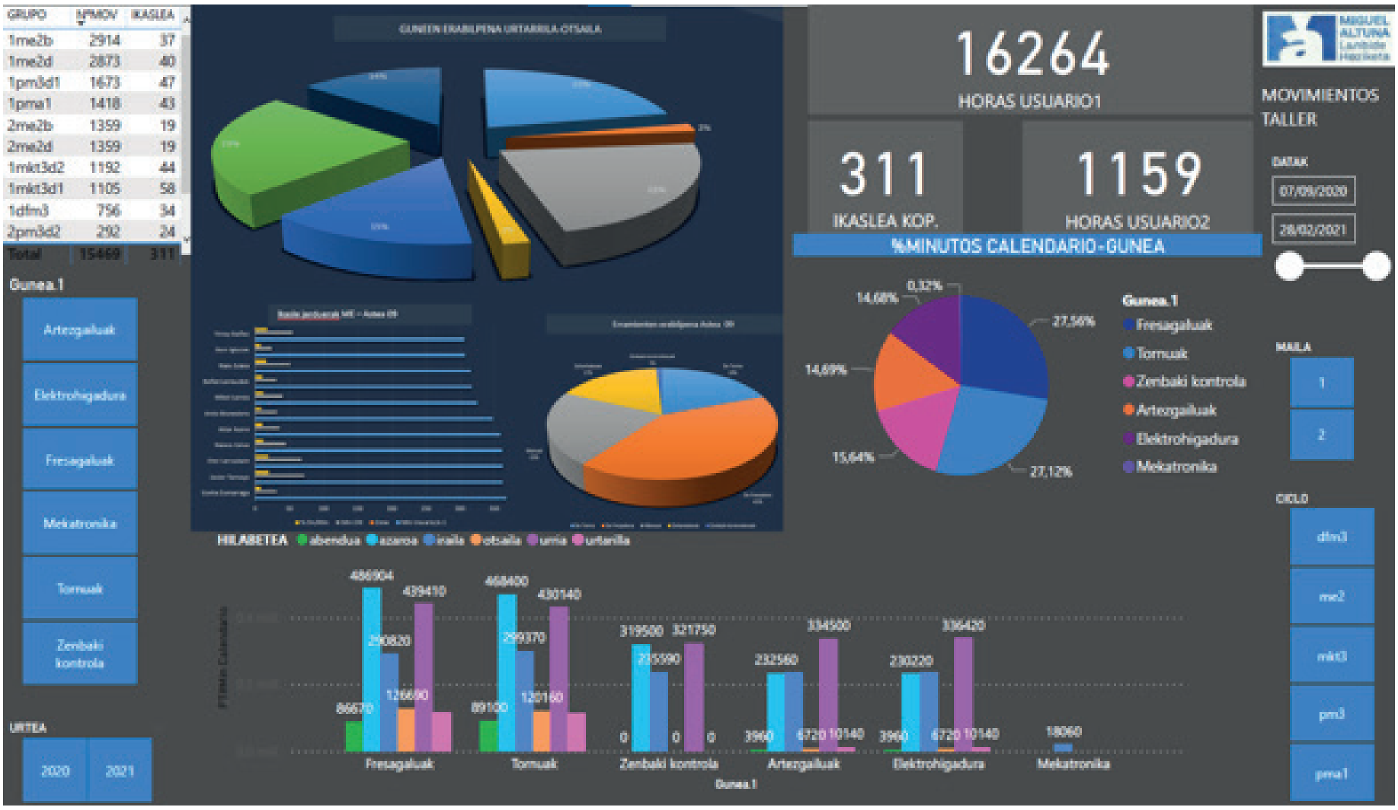

Figure 5: Graphics from Miguel Altun's labs machine usage Source: Miguel Altuna

2.4. Integration of data analytics in IMH VET centre's Lab. Use cases

As described in the EXAM4.0 AM lab piloting documents, the affiliate VET centre IMH from the Basque Country, uses data analytics systems to exploit the information coming from the MES system implemented in their machining lab. For further information, refer to EXAM4.0, 2_The ERP Enterprise Resource Planning, adapted to the project needs (EXAM4.0, 2021)

3 Role of the data analytics in the EXAM40 CLF

The CLF that is going to be launched has divided its production process into 4 stages (product design, process engineering, production and assembly) as can be seen in the following image. Within these stages, data analytics is going to be incorporated in the production stage.

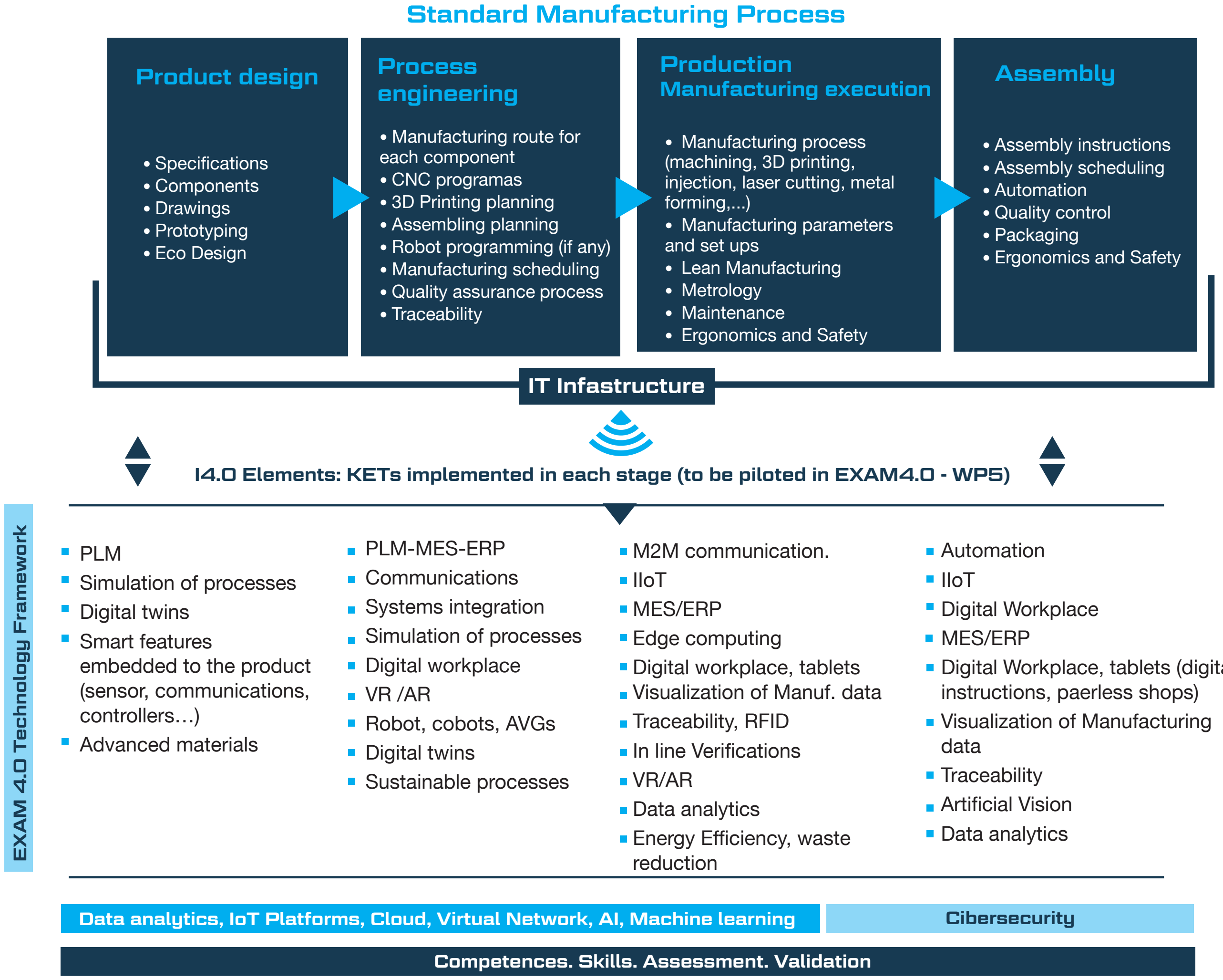

Figure 6: EXAM4.0 Collaborative Learning Factory's (CLF) Value Chain Source: Author's creation

Data Analytics plays a key role in the EXAM 4.0 CLF to optimize (production) processes. Within continuous improvement, the methods and techniques of data analytics are important for identifying opportunities for streamlining work and reducing waste.

On the one hand, material and tool purchase predictions can be made through predictive analysis. On the other hand, the continuous analysis of the data of the production process will help to improve them.

Finally, the analysis of the data on the use of the machines will facilitate preventive and predictive maintenance avoiding uncontrolled stoppages.

3.1. Benefits of using data analytics in EXAM's CLF

Technology has made it possible for data analysis to be automated through mechanical processes and algorithms to generate effective and fast conclusions, allowing us to obtain information that can be used to improve processes and increase the efficiency of the organization or system (Netec, 2021).

These data analysis techniques allow us to identify metrics and trends that were previously lost in the volume of data, any type of information can have a data analysis to improve processes and detect errors in organizations.

Among the many benefits that we can find when integrating data analytics are:

- Data insight. It allows you to quickly view data in a big picture, with breakdowns and live data.
- Identify patterns by creating a panoramic image with the information, being trends more easily to be identified.
- Simple communication and understanding of ideas.
- Identify risks and opportunities before they affect the process.
- Create models for data analysis, reusable and live.
- Obtaining information to provide intelligent actions, improving customer participation and reducing costs in the organization.

3.2. Competences addressed with data analytics

The competencies acquired with data analytics can be classified into two groups: Technical and soft competences.

The technical competences are the ones that are most closely related to the technical content to be acquired in the learning process of the students.
Among other technical competences the main ones are:

- Develop relevant programming abilities.
- Demonstrate proficiency with statistical analysis of data.
- Develop the ability to build and assess data-based models.

- Execute statistical analyses with professional statistical software.
- Demonstrate skill in data management.
- Apply data science concepts and methods to solve problems in real-world contexts and will communicate these solutions effectively.

As for the soft competences developed with data analytics are:

- **Teamwork**: being a collaborative tool, team members can plan their tasks and all have access to the production sheets, the control sheets....
- **Digital awareness**: they get used to virtual working environments, understanding the data obtained, managing it and drawing conclusions.
- **Personal**: autonomy, initiative, critical spirit, to be aware of the importance of good planning and to see how the decisions taken in the process affect them.
- **Communication**: between different students, the one who plans the production with the one who executes it, being aware of the importance of the different explanations (verbal and written) that are given within the production process and that can help achieve a better result.

4 Collaboration opportunities opened by data analytics

Smart technologies, like machine learning, help manufacturers turn the data they're already collecting into useful insights, to then take action on them. The results are tangible—from increased efficiency and higher quality to cost savings and minimized emissions. (Birand, 2021)

Indeed, data sharing is one of the key factors that allows collaboration among institutions. Furthermore, without an optimal data sharing infrastructure, the CLF model would hardly work.

On the one hand, when it comes to digitizing workstations, a lot of data is obtained about production, assembly and distribution processes. The accessibility to this data makes it easier for HVET that do not have such an infrastructure to work with real data. In this way, we bring the teaching-learning processes of other centres with less infrastructure closer to reality.

On the other hand, the availability of data created by one partner’s Labs for another partner, opens the door to set up working groups with students from different locations. Data analytics together with virtualization solutions, will lead CLF users to create joint projects among international student groups.

5 References

Akçapınar, G. (2017). Integrating Learning Analytics into Teaching and Learning Processes. In Various Aspects of ICT Integration in Education (pp.313-330). Publisher: Gazi Kitabevi Tic. Ltd. Şti.Editors: Yasemin Koçak Usluel.

Birand, B. (2021). Manufacturing Tomorrow. (F. a. Labs, Editor) Retrieved from https://www.manufacturingtomorrow.com/story/2021/03/what-does-industry-40-mean-for-data-analytics/16711/

Dib, J. E. (2021). The role of data analysis in Industry 4.0. (C. o. X., Editor) Retrieved from https://worldakkam.com/the-role-of-data-analysis-in-industry-4-0/74965/

EXAM4.0. (2021). EXAM4.0 Piloting AM labs. Industry4.0 technologies#7 Machine to Machine communication. Retrieved from https://examhub.eu/

EXAM4.0. (2021). EXAM4.0, Piloting AM labs, 2_The ERP_Enterprise Resource Planning,_adapted to the project needs . Retrieved from https://examhub.eu/

Netec. (2021, October 25). Retrieved from https://www.netec.com/post/beneficios-para-su-organizacion-con-data-analytics

SoLAR Society for Learning Analytics Research. (2011). What is Learning analytics? Retrieved from https://www.solaresearch.org/about/what-is-learning-analytics/

Vyas, B. (2021). softwebsolutions. Retrieved from Why the manufacturing industry should embrace data analytics: https://www.softwebsolutions.com/resources/data-analytics-in-manufacturing.html

THE EXCELLENT ADVANCED MANUFACTURING 4.0

AM 4.0 labs running I4.0 technologies

Technology 3: Virtual Reality/Augmented Reality

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Piloting the Advanced Manufacturing workshop 4.0

03

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Table of figures

0 Introduction

Following the piloting process of Advanced Manufacturing Labs for H/VET through the Collaborative Learning Factory (hereafter CLF), the EXAM4.0 partners we have piloted 16 technologies embedded in Industry 4.0

The following image shows the overall structure of the piloting process.

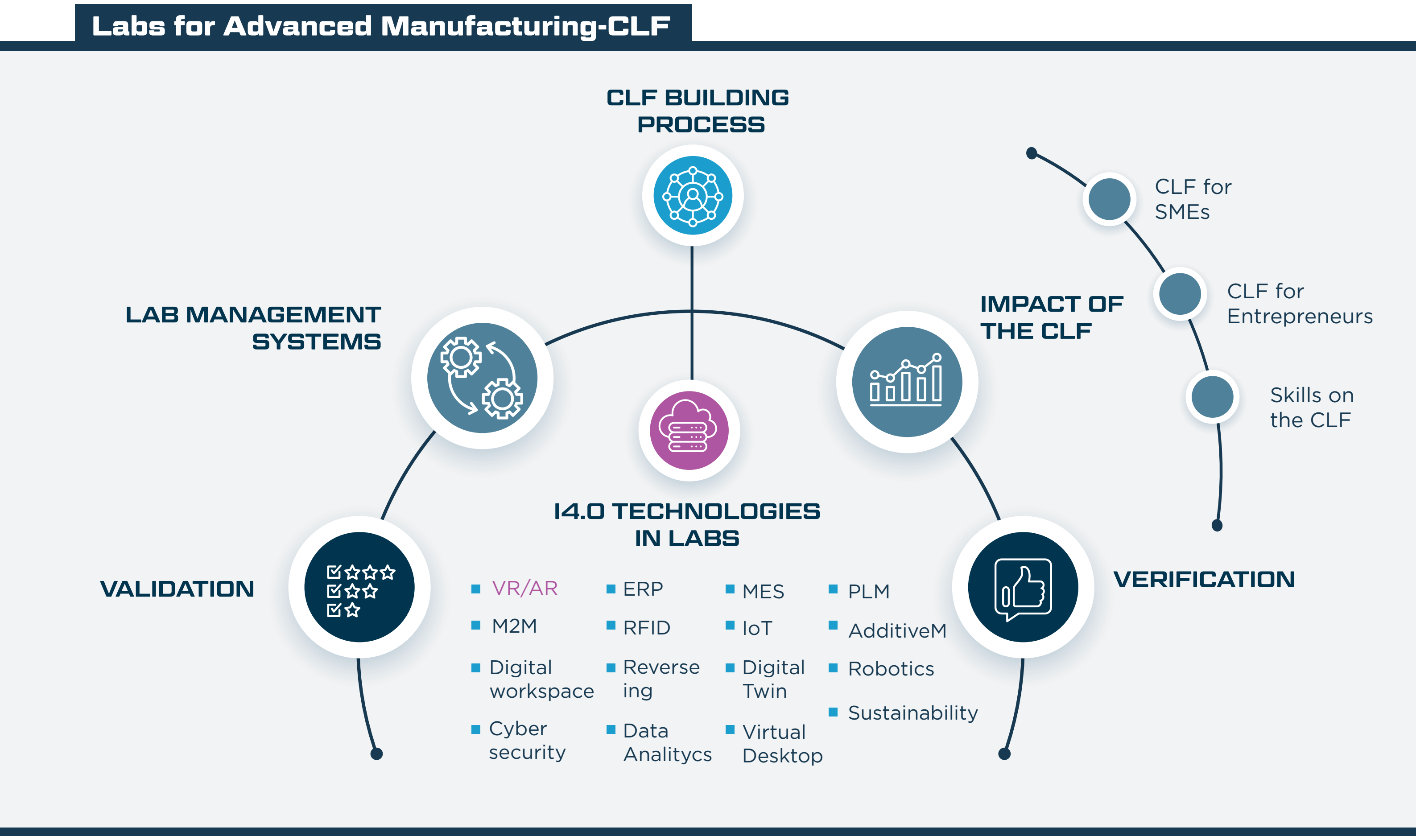

Figure 1: Overall structure of the EXAM4.0 labs piloting process.
Source: EXAM4.0

The present report is the one out of 16 I4.0 technology described within the "Industry 4.0 technologies in labs" section, specifically on #3 Virtual Reality (VR) and Augmented reality (AR)

1 Definition and application of VR/AR in industry

Virtual Reality, VR, is a technology used for simulation, creating a different vision and perception. In VR, the user experiences a virtual world by wearing a head mounted display, HMD. The virtual world, a 3D artificial environment, replaces the real world and creates a new reality for the user. VR is beneficial for education in many aspects, it is for example possible to access environments that effectively can transfer knowledge or accelerate the learning process. The following picture is an example that displays the view, the artificial reality, in a VR-HMD. This application is created at Curt Nicolin Gymnasiet and it is a virtual version of a lab at the school.

*Figure 2: A VR-application created at Curt Nicolin Gymnasiet.
Source: Curt Nicolin Gymnasiet*

AR, Augmented Reality, does not create a new reality in the way that VR does. AR is a set of addons to human senses that provides an extra layer of information, thus expanding the user's reality by, for example, adding artificial objects or information to the user's environment. AR can, just like VR, be utilized through a HMD, but it is also commonly used with other equipment such as smartphones or tablets. The following picture is an example of the view in a pair of Augmented Reality glasses, an artificial arrow extends the reality and gives the user information regarding which tool should be used.

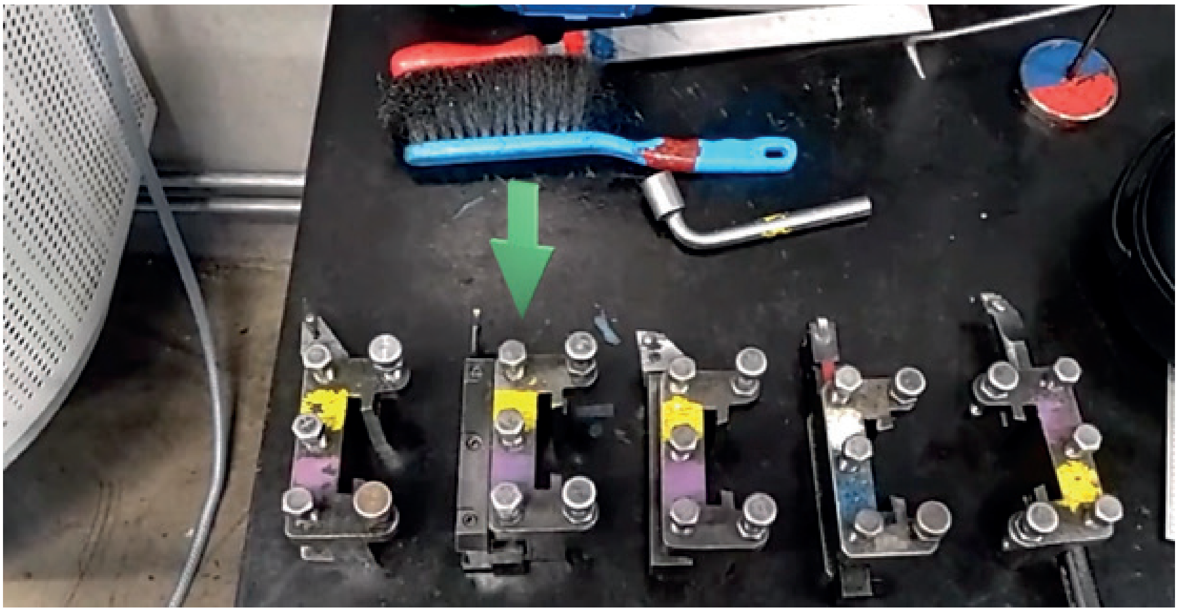

Figure 3: View of an AR user in Curt Nicolin Gymnasiet's lab.
Source: Court Nicolin Gymnasiet

For industries, the use of those technologies provides several advantages; it automatizes new workers' first steps with virtual reality (VR) tutorials for instance. It can help in everyday support for newcomers using augmented reality (AR) tele assistance and it is the easiest way to implement digital twin technologies in the higher levels with mixed reality interfaces (AR/ XR). There are some new tools and applications available within AR that are beneficial for both industries and institutions. Following are some examples of beneficial Augmented Reality features.

- Looking at 3D-objects digitally
- To get assistance virtually (which reduces traveling, thus expenses)
- Using simulations to show products
- Have digital meetings with colleagues or customers

Regarding industry, four main applications can be described:

- **Training**: So far, the new worker starter pack was composed of a mobile and a laptop but more and more industries have developed training programs using VR headsets. For instance, Accenture has acquired 60.000 new HMD for training and they will become part of the welcome pack. The purpose is double, on the one hand it will be used for training, on the other hand, it will be used for going deeper in the metaverse industry.

• **Remote collaboration:** Using virtual meetings but in VR worlds. Many enterprises are developing a user-friendly and easy solution for meeting and collaboration. Recently Facebook has invested more than 10.000.000$ just for creators of the new Facebook platform called Horizon. With this kind of platform the meetings will gain more human interactions and we will be able to see all kinds of kinesthetic reactions.

Figure 4: Workroom meeting in VR. Source: https://www.cnet.com/tech/computing/virtual-mark-zuckerberg-showed-me-facebooks-new-vr-workplace-solution/

• **Assembly industry and real time tutorials.** AR/XR HMDs are perfectly able to recognize the environment and its objects. Even more, they can project over that object extra information that could make the installation of difficult parts easier. This is the case of the T2AR program in NASA where astronauts follow the instructions over different and complex maintenance of the ISS installations.

Figure 5: Astronaut performing routine maintenance. Source :NASA

• **Warehouse logistics:** whenever we talk about AR we immediately think about HMD but the most extended hardware with AR (and XR) capabilities are not HMD but mobile phones and tablets. If those devices are ARCore and ARkit compatible, they can show AR scenarios. Warehouse logistics have developed, using these simple tablets, several apps where even the non-expert user can simulate how any piece of furniture would look in a certain spot at home. If we go further, using VR simulations we can virtually enter any place, any house, any facility without even having it developed or constructed. Underneath we can see an example from AR furniture.

Figure 6: Amazon room showing how a chair would look like in that room. Source Marketing4commerce.net

2 VR/AR in HVET/VET labs

VR/AR and XR provide the ability to enter in a virtual scenario that can be shared among different actors for collaborative learning.

Most of the time in VET and HVET facilities there is a teacher that has certain knowledge about a topic that could benefit the VET and HVET students in different cities. Sharing those skills would require different approaches that vary from using just a simple slide show presentation (which is not very effective) to using any of the video meeting tools.

First of all, the breakthrough of VR is the ability to have meetings around a 3D animated object in real time, with people from different cities. This provides the perfect environment for bringing third party actors to educational environments. We can easily ask any facility technician to share his or her skills with different teachers and students in real time, without moving from the workplace and using ad hoc modelled 3D objects.

Secondly, the AR tele assistance is being used for showing real life equipment from real life workplaces without moving the students or putting them in dangerous environments or situations.

Finally, the mixed reality ability to interact with AR objects in real life provides the perfect learning environments for teaching and showing real time effects over real life objects. Again, the tele assistance provided by most of the XR and AR head mounted display (HMD) leads to a better collaboration from people of different locations.

We have defined three levels of Virtual Reality education within VET/HVET labs.

- **THE FIRST LEVEL:** It is to learn how to handle the equipment and operate the interface. Examples of this could be how to install the physical VR equipment in a LAB, run updates and troubleshoot problems etc. This ensures that the students could work independently with this technology in the future. These are basic skills to move on to the next level.
- T**HE SECOND LEVEL:** It is to use applications within VR as a learning methodology instead of other more traditional methods, such as reading books. An example of a beneficial feature is simulation. These simulations can, for example, represent production processes and instructions or information. There are also a lot of games that are relevant to different educational objectives available on the market. An example of valuable games is where the participants can work in a team to solve problems and hence improve their collaboration skills. These applications and simulations contribute to the acceleration of learning. Students that use these applications get a lot of valuable education such as hands-on learning, with machines, before actually working with

real equipment. This reduces the risks that arise when working with real machines and equipment.

- **THE THIRD LEVEL:** It comprises learning on how to create games and applications for VR. This is currently done in education at Curt Nicolin Gymnasiet. The software used for this purpose, at CNG, is called Unreal Engine. This software has been used in order to create multiple VR-applications, including the one displayed in the first picture of the report.

We have defined two levels of Augmented Reality education within VET/HVET labs.

- **THE FIRST LEVEL:** It is to learn how to handle the equipment and manoeuvre the interface. This level is almost indistinguishable from the first level of VR education. The first levels comprise the knowledge on how to use the interface of the AR-equipment, install updates, troubleshoot for problems etc. It also includes the skill to be able to find and install applications that are relevant for different purposes. This technical expertise is vital in order to move on to the next level.

- T**HE SECOND LEVEL:** It is to, more comprehensively, integrate AR as a part of the education. **The following are some examples of ways to do this:**
  - o Get expert assistance digitally from another place.
  - o Get digital artificial instructions.
  - o Visualize 3D-objects and use digital drawings.

Headsets, such as the HoloLens 2, are sufficient tools to use during learning processes. There are various applications customized for this technology, some of them worth adapting into education.

Digitalisation is emerging and it is now more important than ever, because of the current Covid-19 pandemic, to use digital tools in an advantageous manner. It is possible to get distance -assistance by using AR. The person that wears the headset can call an expert, teacher or instructor. The expert will, on their screen, see the same thing as the user, by an integrated camera on the front of the headset. The expert can then add artificial objects, such as arrows or marks, which will appear in the field of view in real time for the user, augmenting reality and simplifying learning. This tool will also be beneficial for the CLF. Partners of the CLF are located at different geographic locations, but working together within the same learning factory. This digital AR-tool can minimize the distance between the partners in the sense of transforming knowledge.

AR has the possibility to provide the user with artificial guides. This is greatly beneficial to understand production chains, assembling of components, how to operate machines etc. The user will wear a headset or use the application through a smartphone. Artificial objects, information and various forms of support are added in the user's field of view. It could for example be simulations that display how to move, remove, rotate etc. an object or artificial text with information that appears just in time when it is needed.

Augmented Reality could also be used to look at 3D-objects or display virtual drawings, which contribute to a paperless production.

2.1. Integration of VR/AR in Curt Nicolin Gymnasiet lab

There are three VR labs implemented at Curt Nicolin Gymnasiet. These labs are equipped with various Virtual Reality headsets from different brands. Augmented Reality is implemented in education as well. AR equipment is more movable, thus not fixed into a specific lab. AR technologies are used in different labs, e.g in the workshop, at the school as a tool for educational improvement. Each of the “levels”, described in the previous section, are used in education at Curt Nicolin Gymnasiet, with regard to both Virtual Reality and Augmented Reality technologies.

Technologies and software used within the labs:

- Oculus quest 2
- Hololens 1 & 2
- HTC Vive
- Vavle index
- Unreal Engine
- Blender.

2.2. Integration of VR/AR in Tknika’s lab

The technology is used in the format of simulators, equipment that reproduces a production process and trains the student in it and then finishes their training in a real environment, achieving an acceleration of learning.

Figure 7: Virtual Reality Painting environment. Source: TKNIKA

The second level of integration is when the learning classroom is integrated with the virtual environment, in this way there is no break between the spaces and we can be in the real or virtual space at any time.

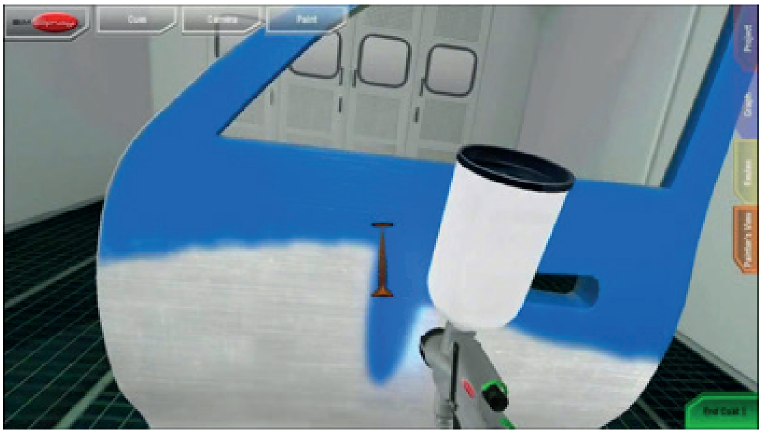

Figure 8: Virtual Reality Painting environment as seen by the user. Source:TKNIKA

Among the integrated software and hardware we use the following tools and devices:

- **Soldamatic**: for welding simulations
- **SimSpray**: for painting simulations
- **Innvison and InnXr**: for VR meetings in different cities
- **Some HMD**: Oculus quest2, HTC vive, Oculus Rift and others
- **Some AR and XR headsets**: Microsoft hololens 1 and 2
- **Unity**: as development IDE
- **Blender:** as modeling, sculpting and animation software
- **Motion captor:** for body tracking and movement capture

2.3. Role of the VR/AR in the EXAM4.0 CLF

The CLF that is going to be launched has divided its production process into 4 stages (product design, process engineering, production and assembly) as can be seen in the following image. Within these stages, VR/AR is going to be incorporated in the process engineering, production and assembly stage.

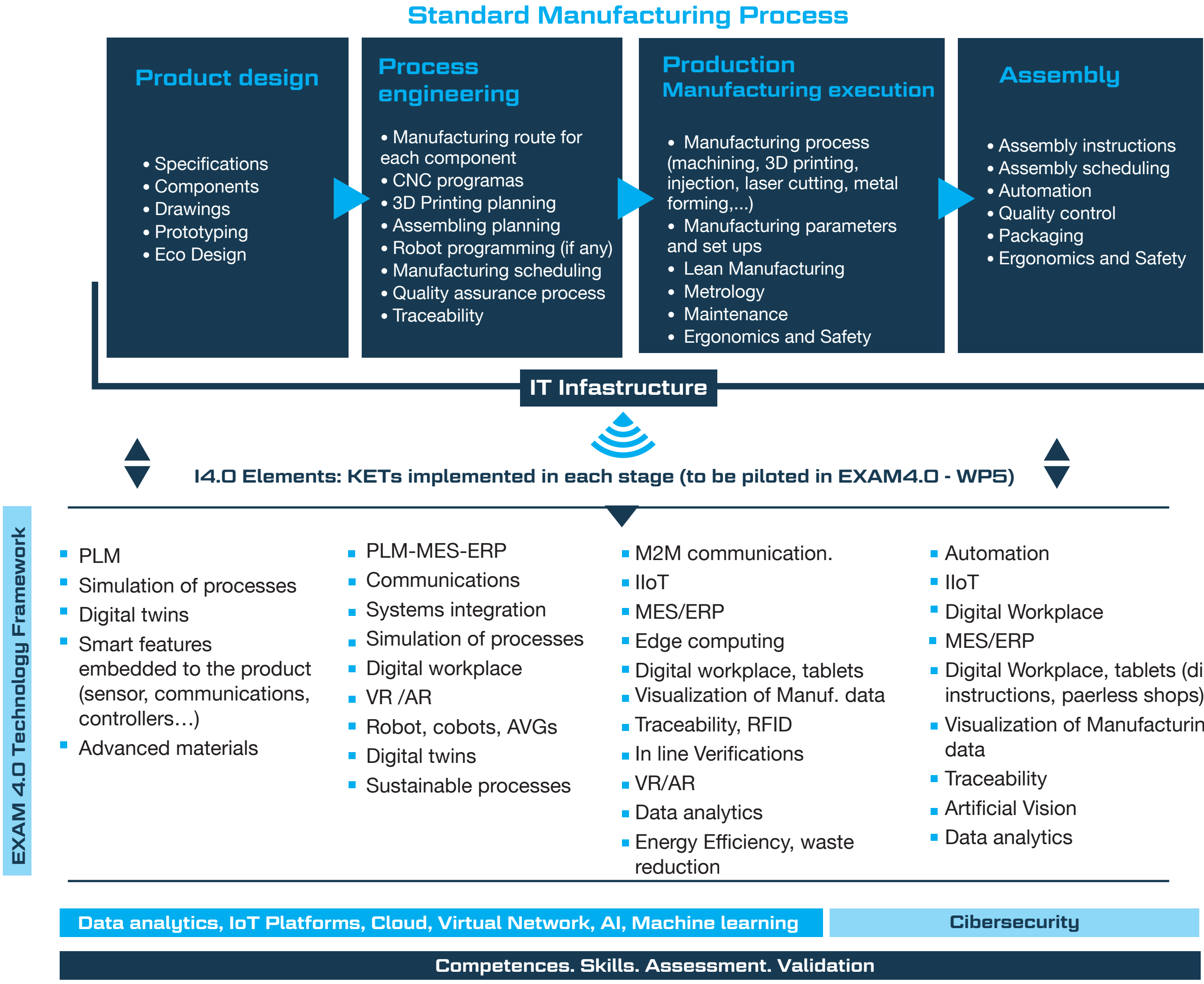

Figure 9: EXAM4.0 Collaborative Learning Factory's (CLF) Value Chain Source: Author's creation

The role of VR/AR in the CLF is to ensure good communication and collaboration between the partners of the learning factory in order to be able to fully exchange data and information. VR/AR applications are used in order to have meetings and discuss the products of the CLF

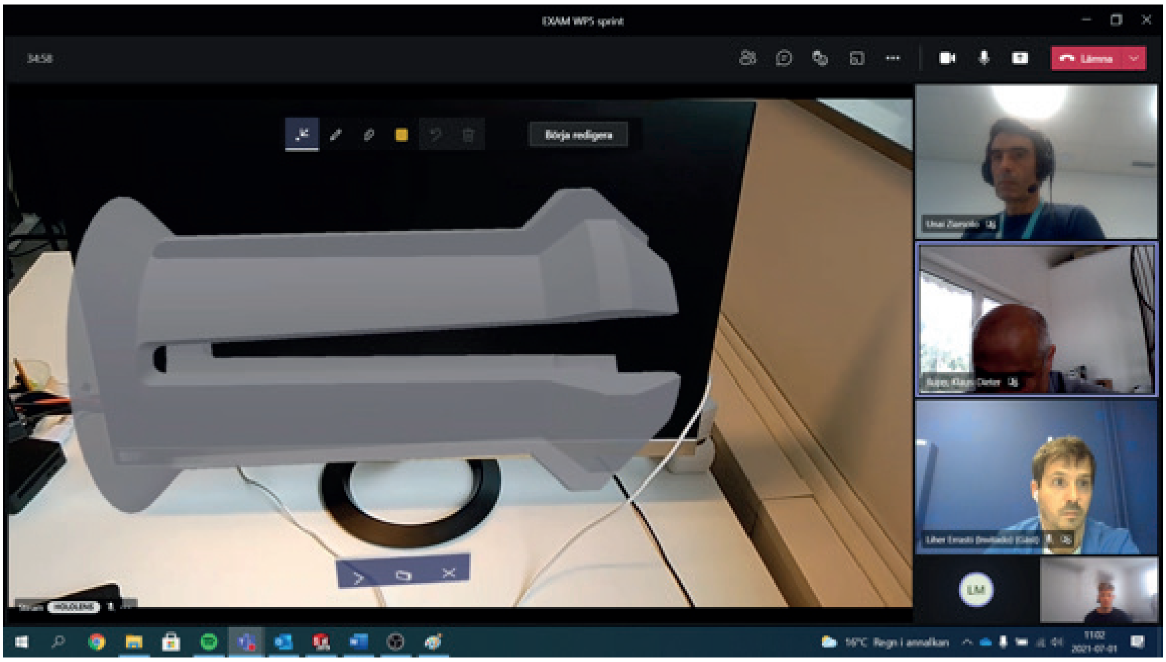

Figure 10: Meeting of Exam4.0 consortium during process engineering. Source: Author's creation

For example, the picture above shows a meeting with the consortium when Augmented Reality was used in order to show the features of the re-designed Clipper for the group. The Clipper is a flexible component that is a part of the EXAM robot produced in the CLF.

Moreover, it will also have an important role in the production and assembly part, since through VR / AR we can implement machine manuals, maintenance manuals, assembly manuals ...

2.4. Benefits of using VR/AR in EXAM4.0's CLF

When it comes to inserting VR / AR into the CLF we can talk about four main benefits:

- **Acceleration of the learning process**, with better monitoring and greater control over it. It is not only running the simulation, it also includes powerful feedback from several parametrized items so the students can perform better and know where the mistakes are made.
- **Reduction of consumable material** with consequent cost reduction. Using any of the virtual technologies the consumption of material is zero. We can simulate the use of the most expensive materials without truly using them at all. This is an eco-friendlier way of working and it prepares our students for the real world environment.

- **Increase in the physical security** of students as well as of the facilities involved in the processes. Using these technologies, we can simulate even catastrophic events such as heavy industry machinery fails or fire simulations. The safe environment leads the students to perform better in case of those stressful situations.

- **To ensure excellent communication**, exchange of data and information. The CLF is a collaboration using different partners' labs in order to create a Learning Factory. Communication and exchange of data is therefore an essential part of this collaboration, it is required for the functionality of the CLF. VR/AR is a useful tool in order to achieve this. Aforementioned methods, workroom meetings in VR, tele assistance etc., are useful in order to achieve this.

2.5. Competences addressed with digital workplace

VR/AR education is very beneficial for competence training because of the variety of simulations and applications that it can provide. The competencies addressed in VR/AR therefore vary depending on the educational objective focused on.

However, here are some examples of competencies addressed within the scope of VR/AR in the EXAM 4.0 CLF:

- **Communication, cooperation and teamwork:** Visualisation applications have been used during the pilot of the CLF to set high quality information exchange and communication amongst the partners. These applications will later be used as a part of the CLF to ensure that the different partners can exchange data, information and knowledge in an adequate way.

- **Technical expertise and IT knowledge:** Users will get both technical expertise and IT knowledge by working with the visualisation equipment and its appurtenant applications.

- **Problem solving:** The partners of the CLF have used AR in order to look at the robot's components. This part of the project required problem solving, because there were many features in the robot that were difficult to produce.

3 Collaboration opportunities opened by VR-AR

VR / AR is a great tool to work collaboratively. On the one hand, work meetings between different schools could be created through VR. That way, students from different countries could work together and get to know each other better. This practice could be very good as a previous knowledge exercise for a later exchange.

On the other hand, as seen in figure 9, the AR is a very helpful support when it comes to designing meetings. By means of AR all the members of the meeting can observe the piece while giving different opinions about it.

Finally, due to the digital twin, where the entire manufacturing process can be digitized, and the data analytic with the IioT, where data is collected in real time, students from centres that do not have enough resources to have the production machines, could work in a VR environment as if they were working on a real machine.

4 References

GE. (25 October 2021) Retrieved from
https://www.ge.com/additive/what-additive-manufacturing

Wikipedia. (29 September 2021) Retrieved from
https://en.wikipedia.org/wiki/Critical_thinking

EXAM 4.0

THE EXCELLENT ADVANCED MANUFACTURING 4.0

AM 4.0 labs running I4.0 technologies

Technology 4: Reverse engineering

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Piloting the Advanced Manufacturing workshop 4.0

03

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Table of figures

0 Introduction

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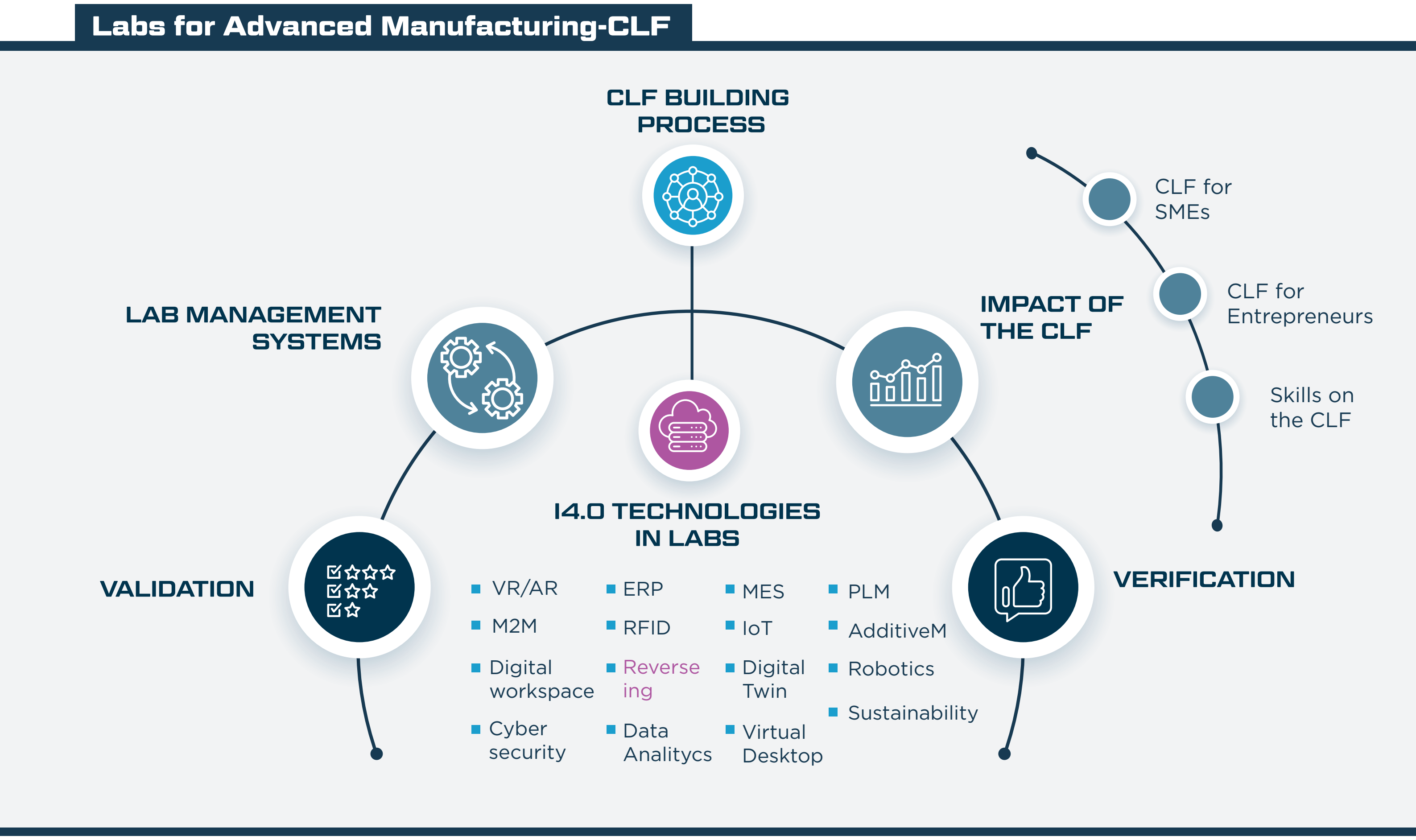

Figure 1: Overall structure of the EXAM4.0 labs piloting process.
Source: EXAM4.0

The present report is the one out of 16 I4.0 technology described within the "Industry 4.0 technologies in labs" section, specifically #4 Reverse Engineering.

1 Definition and application of reverse engineering in industry

Reverse engineering plays a vital role in the branch of mechanical design and manufacturing based industry.

This technique has been widely recognized as an important technique in the product design cycle. It is often essential to reproduce a CAD model of an existing part using any digitalization technique, when original drawings or documentation are not available. It is also useful for analysis and when modifications are required to construct an improved product design.

The product re-design with reverse engineering, will largely reduce the production period and costs in product manufacturing industries.

Figure 2: Inverse engineering scanner. Source: Artec EVA

Reverse engineering is the process of obtaining a geometric CAD model from measurements acquired by contact or non-contact scanning technique of an existing physical model. The typical procedure of replicating a part by reverse engineering can be the following one:

- Existing object
- Data acquisition (Contact or not contact)
- Pre-processing (Noise filtering and merging)
- Point cloud / STL data
- Feature extraction
- Segmentation and surface fitting
- CAD model
- Manufacturing process
- Finished product

A 3D scanning system is not just a 3D scanner. It is the sum of a 3D scanner, the software and, in many cases, the necessary training to know how to use it.

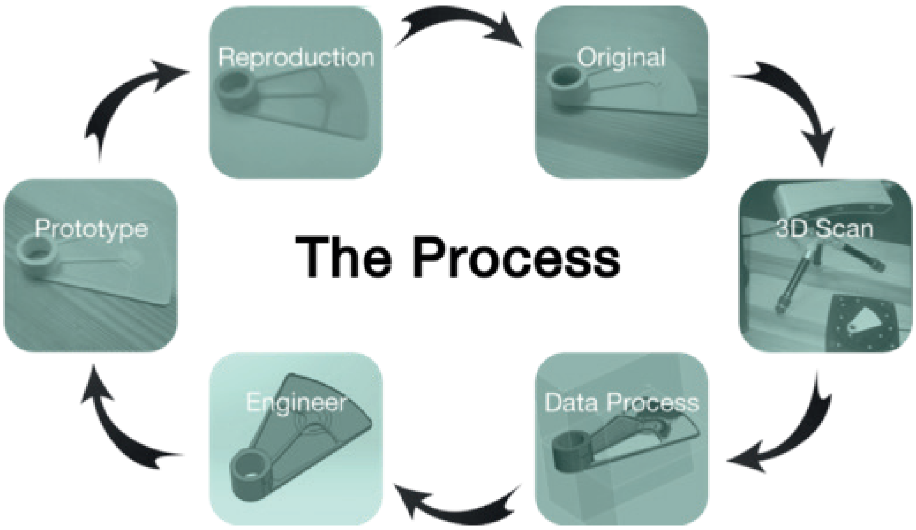

Figure 3: Inverse engineering process. Source: Siemens

Reverse engineering has a very wide range area of applications, such as:

- **Mechanical engineering:** product design, customization, 3D documentation
- **Industrial design and manufacturing:** quality control, rapid prototyping for automation and aerospace
- **Health:** orthopedic, prosthetics, plastic surgery, technical aids, pharmaceutical products
- **Science and education:** research, entertainment/animation, forensic science, online museums
- **Art and design:** preservation of historical heritage, architecture, fashion
- **Electronics**
- …

2 Reverse engineering in HVET/VET labs

2.1.Integration of reverse engineering in Tknika's Lab

Reverse engineering has been introduced in Tknika´s IKASLAB together with Additive Manufacturing technologies, as both technologies share common advantages and combine perfectly in certain applications.

Digitalization and replication of pieces work on complex surfaces, fast prototyping: these processes and features need the combination of both technologies to go ahead with projects properly.

Figure 4: Tknika's reverse engineering lab's overview. Source: Tknika

In the figure above Tknika's scanning corner can be seen. It is part of the Ikaslab Project's laboratory. Scanners from left to right: Creaform Go!Scan Spark, Creaform Handyscan 700 and Solutionix Rexcan CS+. All those scanners can be used by students of Basque VET System.

Figure 5: Creaform Academia 50 scanner equipment. Source: Tknika

Some of the scanners are fixed, it is the product to be scanned that moves, while in others, the product is still, the user moves the scanner across the surface to scan it.

Figure 6: Scanning with Creaform Academia. Source: Tknika

Among the projects carried out with the reverse engineering scanners, one of the most important is one in which a woman's puffed hand was scanned and custom-made prostheses were designed for her.

Figure 7: Scanning Maria's arm with Creaform Handyscan 700 scanner. Source: Tknika

The processing of the scanning was made with VX Elements software and final parts with SolidWorks CAD software.

We should not forget software applications. Although they are not as visible as scanners, they are at least as important to obtain a good final digital object.

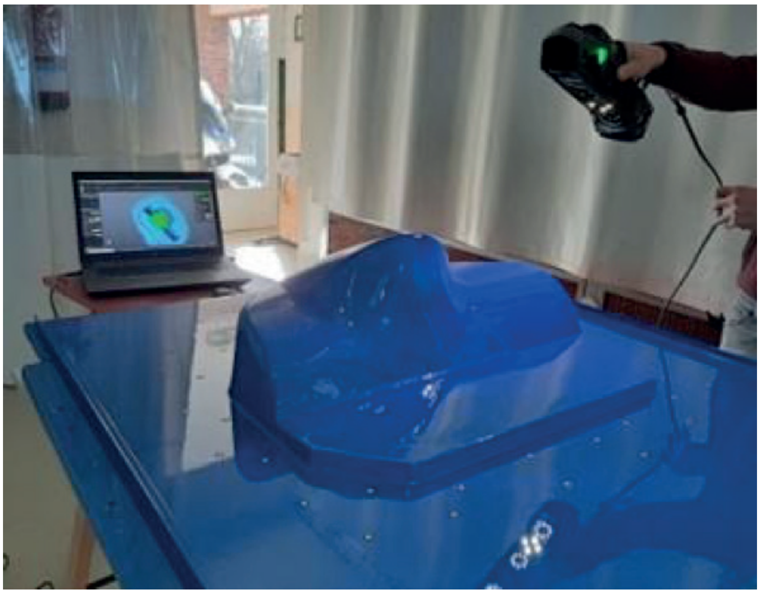

Figure 8: Scanning mould for carbon fiber part with Creaform Go!Scan Spark scanner. Source: Tknika

The software's used in Tknika are:

- **EZSCAN**: scanning and processing of cloud of points for Solutionix Rexcan CS+ scanner.
- **VX Elements**: scanning and processing of cloud of points for all Creaform scanners. It Comes together with VX Model to develop reverse engineering process and VX Inspect, which allows contrasting a reference model part.
- **POLYWORKS**: advanced industrial inspection software that combined with a handheld scanner can help in part inspection after or during a manufacturing process.
- **Geomagic Design X**: complete reconstruction of geometries beginning from a scanned part.

2.2. Role of the reverse engineering in the EXAM4.0 CLF

The CLF that is going to be launched has divided its production process into 4 stages (product design, process engineering, production and assembly) as can be seen in the following image. Within these stages, reverse engineering is going to be incorporated in the design and production stage.

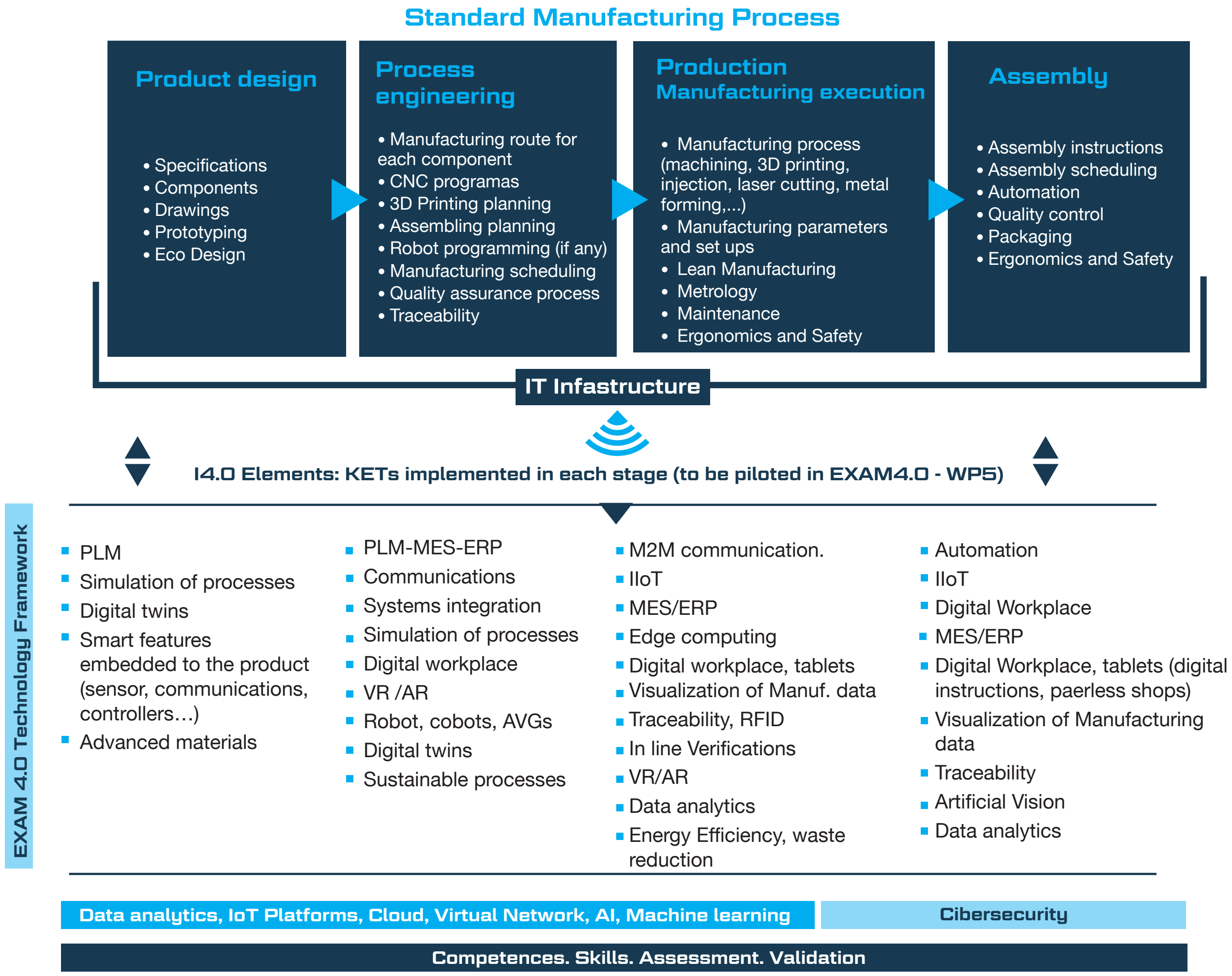

Figure 9: EXAM4.0 Collaborative Learning Factory's (CLF) Value Chain Source:Author's creation

The CLF we are addressing requires precise systems that convert physical pieces into mathematical models. Because of this, it is essential to have digitizing systems to be able to create digital models of the pieces. In this way, the verification of correct parts could be achieved by means of comparison to a digital pattern. The scanner could be used to digitize the parts.

The fact of digitizing the parts that are made in the manufacture of the CLF with the scanner, makes it possible to analyse design or manufacturing errors that arise. In this way, the relevant changes can be made in the designs of the parts based on the real digital model.

Finally, customizations could be made in the robots that are created in the CLF, since we could create claws, fasteners ... adapted to the individual products that the user requests by scanning the products.

2.3. Benefits of using reverse engineering in EXAM4.0's CLF

The major benefit of using Reverse Engineering processes is to facilitate and accelerate digitalisation processes. The knowledge and practice with the technology will allow easier detection of its applicability.

These benefits will increase even more when upcoming generative design or topology optimization processes are progressively introduced in industry.

Next generation of automatic or intelligent production systems can also introduce this technology as part of the process, integrating the scanner to a collaborative robot, for example.

These benefits can be obtained when introducing Reverse Engineering in an industrial process, which is being reproduced in each project developed in the lab:

- Increase efficiency
- Reduce errors
- Improve security
- Reduce costs
- Share information

2.4.Competences addressed with reverse engineering

The applicability of Reverse Engineering can be very wide and can touch different industrial areas. **The competences that students can achieve are:**

- Analyse different types of scanners/technologies and discover the applications of it.
- Perform the reverse engineering process: cloud of dots, mesh, solid.
- Experiment with different applications: reconstruction considering scanned part's forms, transformation and redesign of new functionalities. Comparison of measurements.
- Experiment with different software's, depending on the application to develop.

3 Collaboration opportunities opened by reverse engineering

As another tool which is part of 4.0 industry technologies, every sharing action of the learning process and its integration in education will help to improve this process itself and make it more efficient.

This is one of the outcomes of the 3D maker. Community evolution and education systems should learn from them; how they boost the development and share knowledge:

- Selection and use of scanners and software.
- Selecting technology for each need or application.
- Share of case studies.

4 References

Wikipedia. (25 October 2021). Retrieved from
https://en.wikipedia.org/wiki/Computer_security

THE EXCELLENT ADVANCED MANUFACTURING 4.0

AM 4.0 labs running I4.0 technologies

Technology 5: Cybersecurity

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Piloting the Advanced Manufacturing workshop 4.0

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Table of figures

0 Introduction

Following the piloting process of Advanced Manufacturing Labs for H/VET through the Collaborative Learning Factory (hereafter CLF), the EXAM4.0 partners we have piloted 16 technologies embedded in Industry 4.0

The following image shows the overall structure of the piloting process.

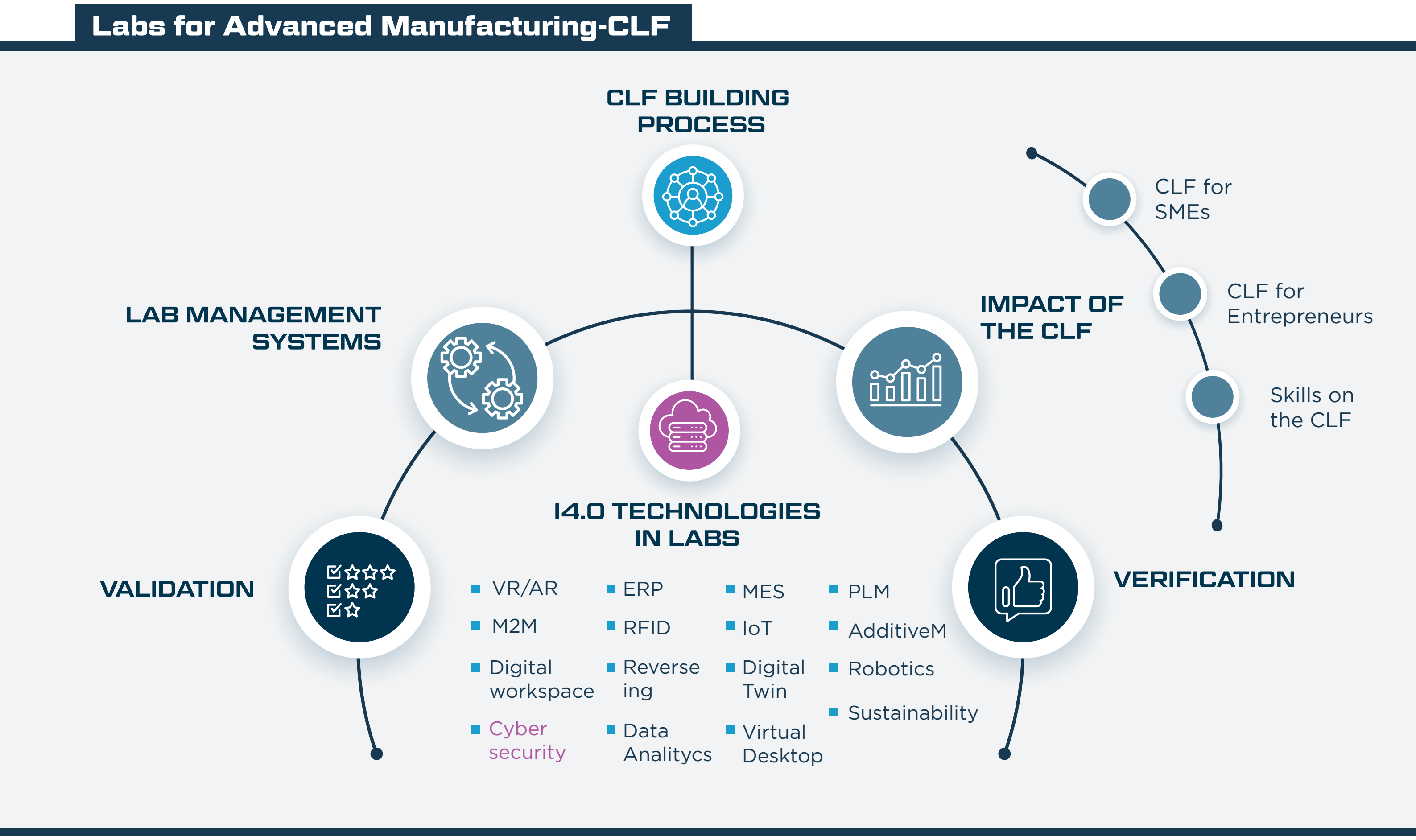

Figure 1: Overall structure of the EXAM4.0 labs piloting process. Source: EXAM4.0

The present report is the one out of 16 I4.0 technology described within the "Industry 4.0 technologies in labs" section, specifically #5 Cybersecurity.

1 Definition and application of cybersecurity in industry

Cybersecurity is the protection of computer systems and networks from information disclosure, theft of or damage to their hardware, software, or electronic data, as well as from the disruption or misdirection of the services they provide. For a long time, this concept applied mostly to traditional IT devices, but with the spreading of the new 4.0 Industry, these practices had to be applied to any connected device. Cybersecurity is a trend in our more and more digitized and interconnected world. In order to respond to this need we simulate an industrial factory with IT and OT elements in our lab to provide different network casuistry, and create different scenarios where we can test protection and attack methods against our isolated networks, minimizing risks (Wikipedia, 2021).

2 Cybersecurity in HVET/VET labs

2.1. Cybersecurity in Tknika's Lab

In this section we address how Cybersecurity practices should be incorporated into the laboratories of VET / HVET centers with the aim at a safe performance of CLF processes. With this goal, we have been working in TKNIKA's Cybersecurity Factory Lab using different scenarios.

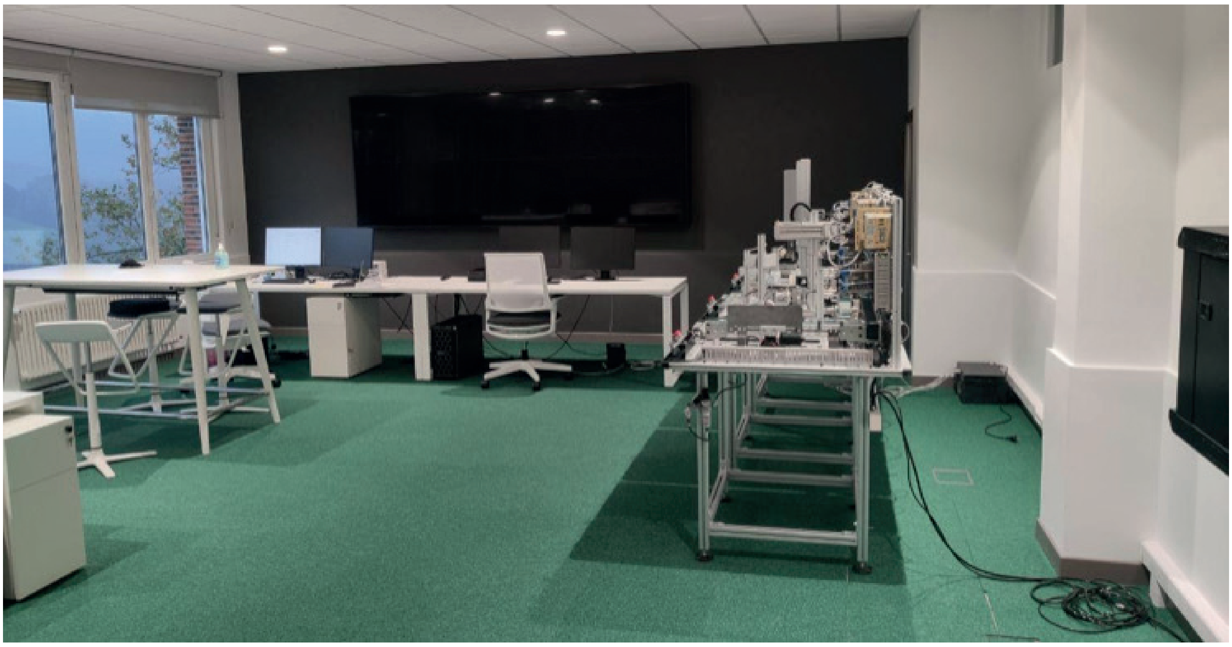

Figure 2: Tknika's cybersecurity lab's overview. Source: Tknika

Cybersecurity can be applied directly into two types of HVET/VET branches:

- On the one hand, we have IT related scenarios, which consist of an IT zone and a honeypot, as described in the WP4, section D4.2. In the IT zone, we have a rack with firewalls, switches and 3 PCs used to research the vulnerability of IT systems, in order to train in the creation and development of secure IT systems.

  In the honeypot zone we research what types of attacks an exposed device can get, where they come from, and how to mitigate them.

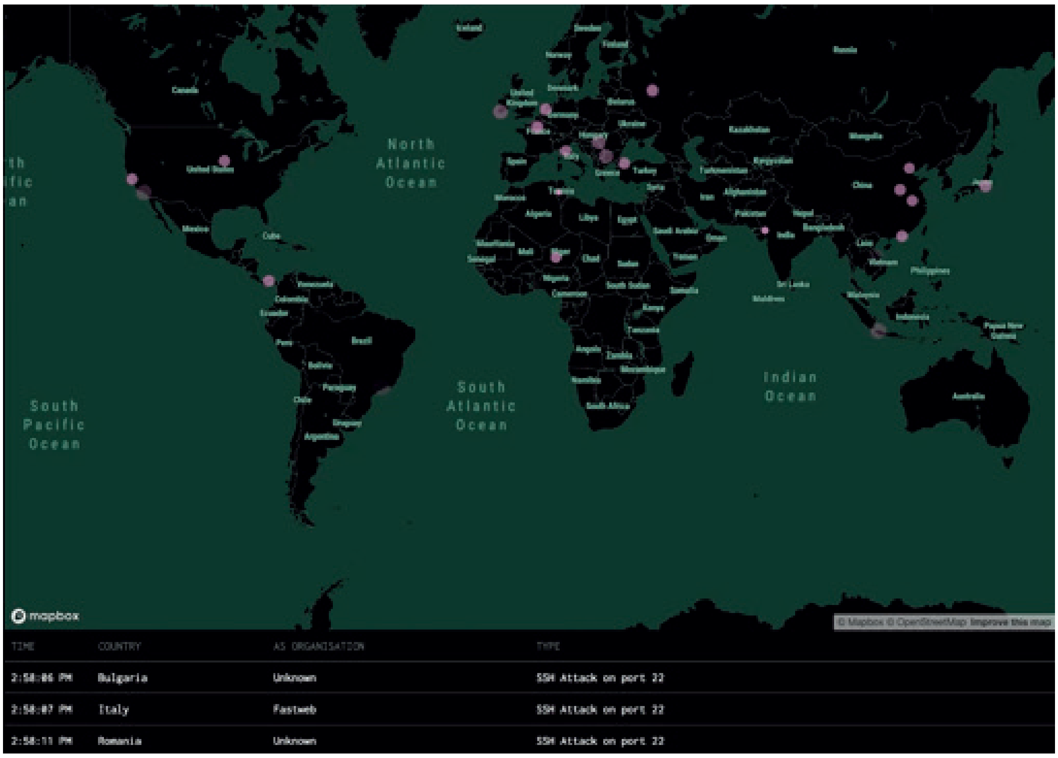

Figure 3: Realtime honeypot attacks example. Source: Tknika

The industry partners, as well as the students that make use of the Sustainability Factory, can use the datasets for development of prognostic algorithms and exploratory analysis.

Besides those specific branches, the basics and good usage of the Internet can be taught in any HVET/VET cycle to avoid information loss, ransomware, virus, malware…

In order to achieve all of this, different software is used, such as:

- Proxmox Virtual environment
- VMWare
- VirtualBox
- Modern Honey Network
- Visual Studio 2019
- PaloAlto Academy
- Wireshark
- Kali

Additionally, we have the industry and automation related escenarios, also described in the WP4, section D4.2., the Omrom PLC area and the Siemens PLCs area.

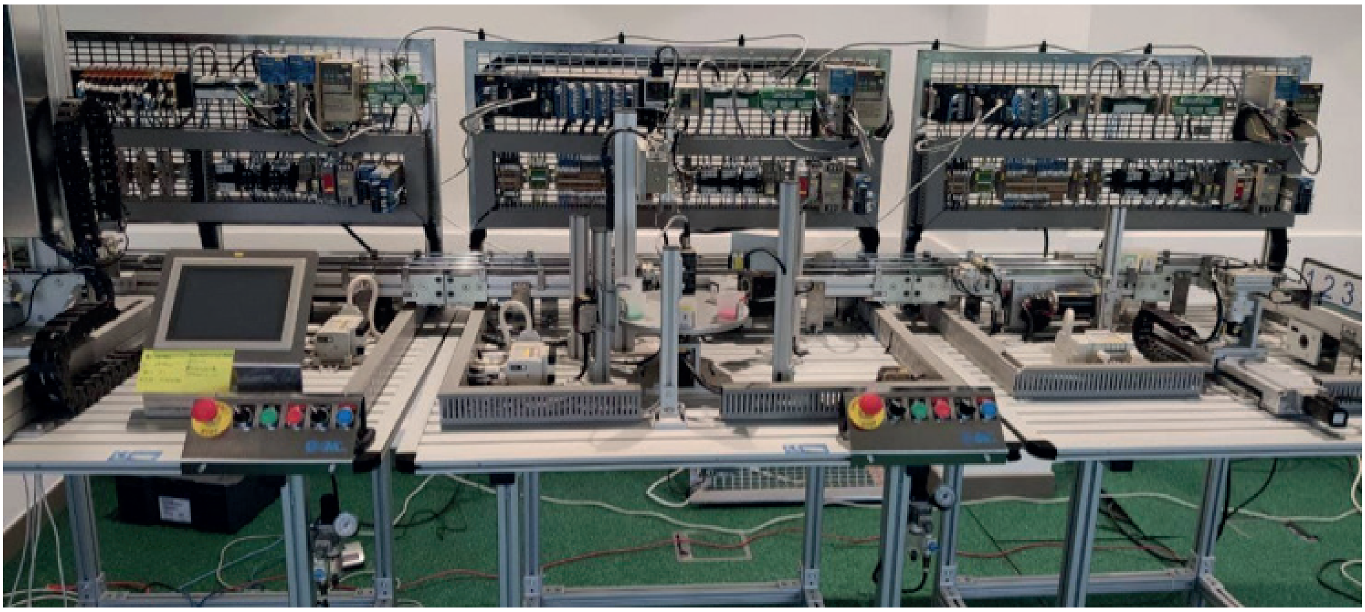

Figure 4: Omrom PLC area. Source: Tknika

Usually automation elements were isolated, but Industry 4.0 and remote assistance, among other factors, has forced these systems to be connected to the network. Due to lack of updating the automated systems, industry and automation related students should/must be aware of the danger and take action to protect them.

Overall, all IT systems must be protected. Not only the ones that are located in offices or server rooms but also in industrial machine HMI or Scadas.

In order to achieve all this, different software is used, such as:

- TIA Portal
- Cx One

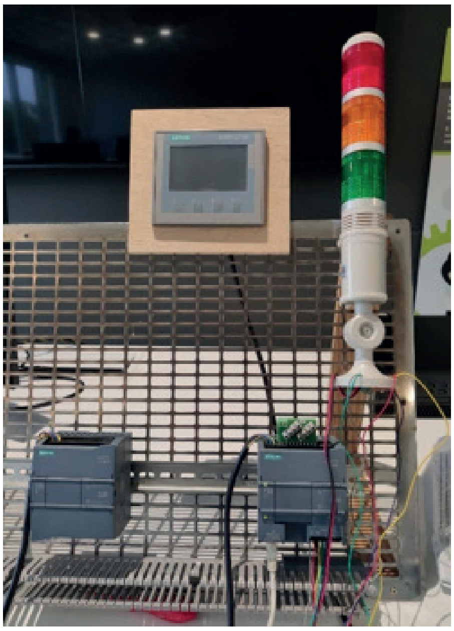

Figure 5: Siemens PLC cell. Source: Tknika

2.2. Role of the cibersecurity in the EXAM4.0 CLF

The CLF that is going to be launched has divided its production process into 4 stages (product design, process engineering, production and assembly) as can be seen in the following image. Within these stages, cybersecurity is going to be incorporated in the production stage.

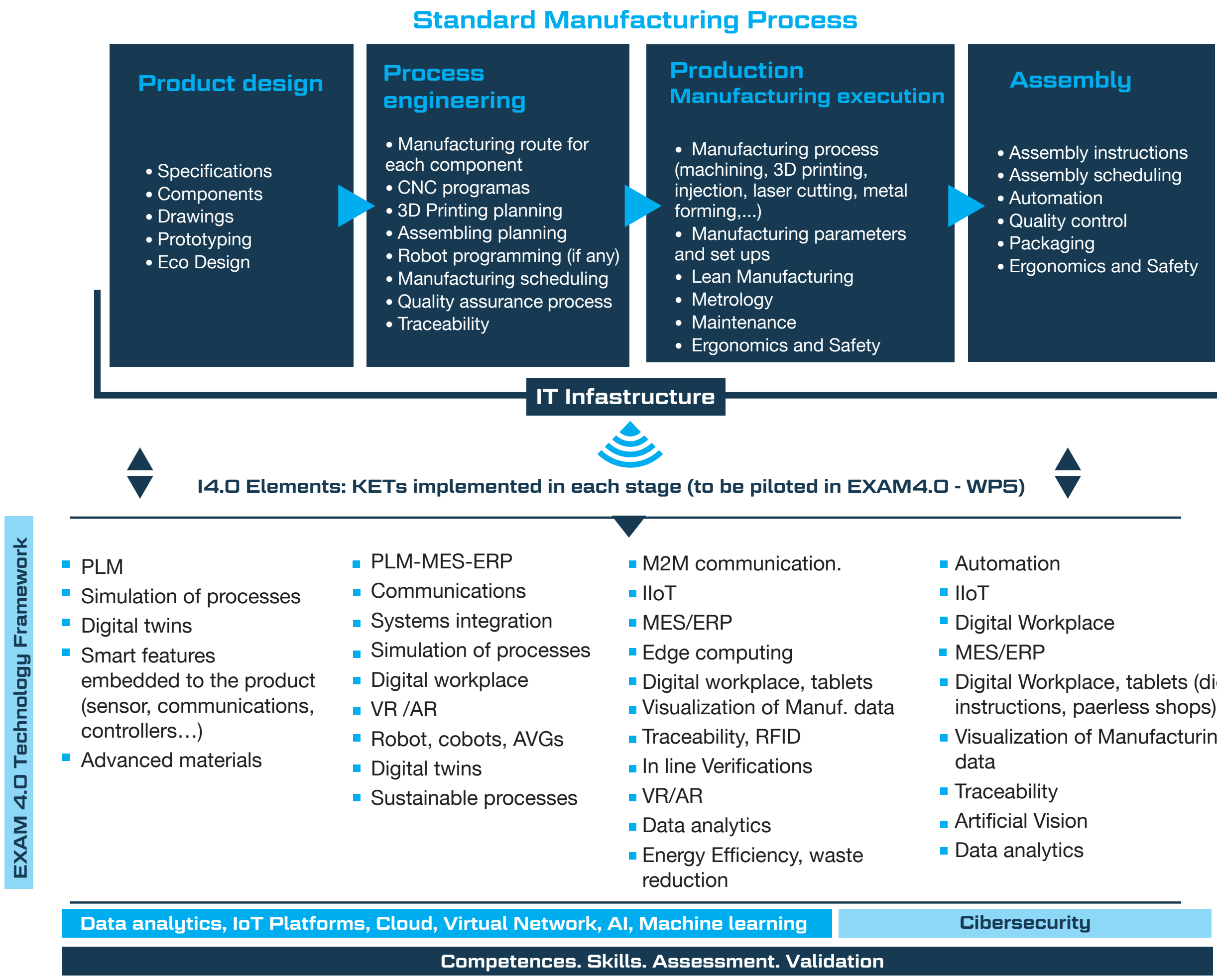

Figure 6: EXAM4.0 Collaborative Learning Factory's (CLF) Value Chain Source:Author's creation

The previously mentioned Cybersecurity scenarios will be useful in all the stages of the CLF.

In early stages while the student makes the analysis and design is done, all the components such as firewalls, servers… and subnet design among other things must have a place.

In mid-late stages cybersecurity will provide a more quiet environment, with less risk, never being 0 risk. Due to this, cybersecurity protocols and systems should be checked and improved constantly.

This focus on cybersecurity will ensure that the students enrich their profile with these capabilities. In order to achieve this, we will design several teacher training programs focused on VET teachers, allowing them to add this knowledge in their previous subjects.

2.3.Benefits of using cybersecurity in EXAM4.0's CLF

There are huge benefits to adopting and integrating Cybersecurity in the EXAM CLF.
These are some of them:

- Risk awareness
- Improve security
- Gain risk detection and management capabilities
- Simulate attacks in a controlled environment
- Improve reaction time against real attacks
- Test of different network compositions to make sure that is secure
- Development and Research of new attacks to industrial components and different systems such as RFID, NFC...

The greatest benefit of Cybersecurity is that it provides the skills to identify the risks in both IT and OT scenarios, and therefore help to create secure CLFs. And of course, all these benefits are directly transferred to the students.

2.4. Competences addressed with cybersecurity

The competencies acquired with data analytics can be classified into two groups: Technical and soft competences.

The technical competences are the ones that are most closely related to the technical content to be acquired in the learning process of the students.
Among other technical competences the main ones are:

- Knowledge about Cybersecurity technology
- Cybersecurity risk assessment
- Cybersecurity Monitoring and Reporting
- Vulnerability and Penetration Testing
- Creative thinking
- Secure software development
- Fundamental skills about how to use IT tools securely
- Secure configuration of IT and OT infrastructure

As for the soft competences developed with cybersecurity are:

- **Teamwork:** being a collaborative tool, team members can plan their tasks and all have access to the production sheets, the control sheets....
- **Digital awareness:** they get used to virtual working environments, understanding the data obtained, managing it and drawing conclusions.
- **Personal:** autonomy, initiative, critical spirit, to be aware of the importance of good p**lanning and to see how the decisions taken in the process affect them.**
- **Communication:** between different students, the one who plans the production with the one who executes it, being aware of the importance of the different explanations (verbal and written) that are given within the production process and that can help achieve a better result

3 Collaboration opportunities opened by cyber-security

The knowledge acquired with the different Cybersecurity scenarios empowers the HVET users not only to create secure remote collaboration opportunities from other laboratories interested in the same field, but also to promote them to test theoretical knowledge into real scenarios.

In a similar way, collaboration with non-academic institutions is very important. External partners and enterprises can provide with real life scenarios that need to be addressed and tested on the CLF, as nowadays cybersecurity is not optional but a requirement.

4 References

Wikipedia. (25 October 2021). Retrieved from https://en.wikipedia.org/wiki/Computer_security

AM 4.0 labs running I4.0 technologies

Technology 6: Digital twin

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Piloting the Advanced Manufacturing workshop 4.0

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Table of figures

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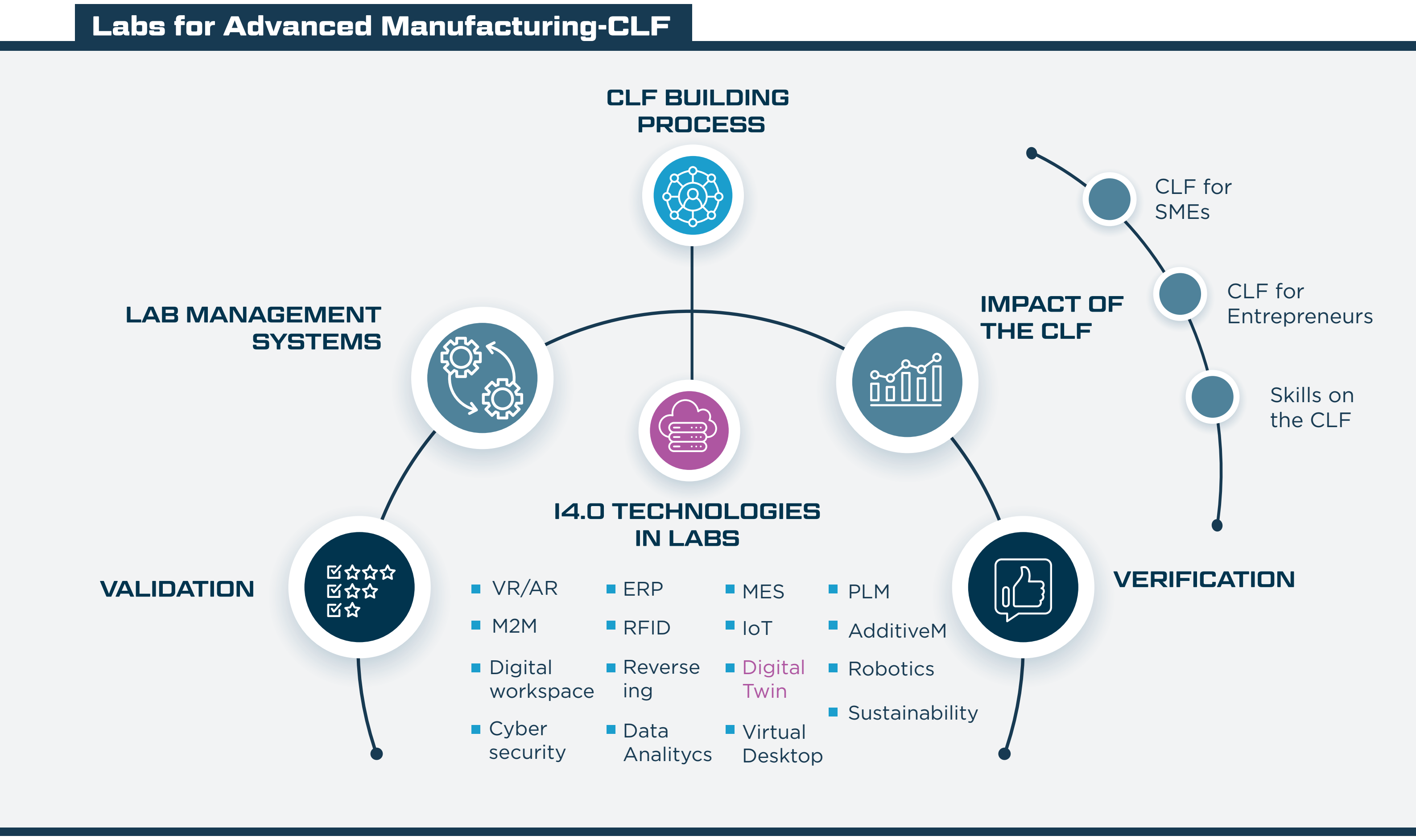

Figure 1: Overall structure of the EXAM4.0 labs piloting process.
Source: EXAM4.0

The present report is the one out of 16 I4.0 technology described within the "Industry 4.0 technologies in labs" section, specifically #6 Digital Twins.

1 Definition and application of digital twin in industry

A digital twin is a digital representation of a real-world entity or system. The implementation of a digital twin is an encapsulated software object or model that mirrors a unique physical object, process, organization, person or other abstraction. Data from multiple digital twins can be aggregated for a composite view across a number of real-world entities, such as a power plant or a city, and their related processes.

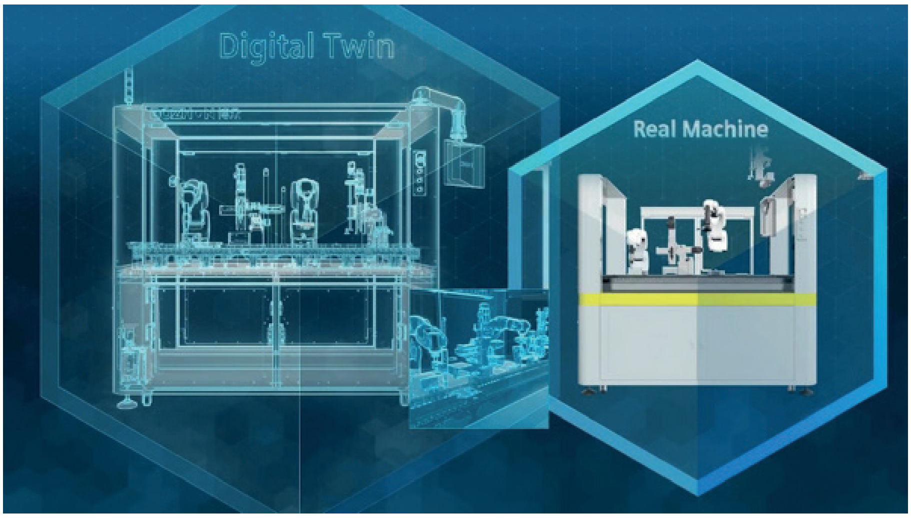

Figure 2: Digital twin in production.
Source: https://www.plm.automation.siemens.com/global/es/webinar/digital-twin-in-manufacturing/68561

The digital twin concept consists of three distinct parts: the physical product, the digital/virtual product, and connections between the two products. The connection between the physical product and the digital/virtual product is data that flows from the physical product to the digital/virtual product and information that is available from the digital/virtual product to the physical environment.

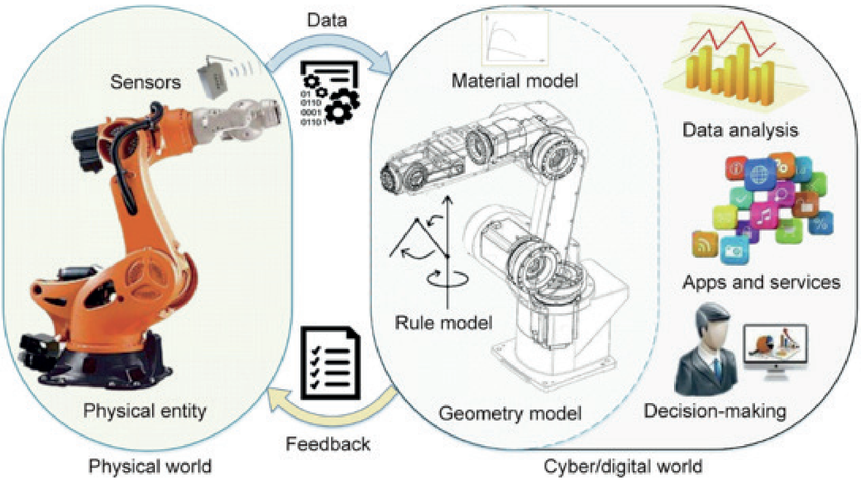

Figure 3: Digital twin architecture.
Source: https://www.engineering.org.cn/en/10.1016/j.eng.2019.01.014

To create a digital twin, you have to collect a lot of data, both about the object and what is around it. With this information, computational models that represent the behaviours or states of the physical object can be created (Xataka, 2021).

This data can be related to the life cycle of a product, its design specifications, its production processes, engineering and production information (including materials, parts, methods and quality control) ...

A digital twin can be as complex or as simple as needed. The amount of data you collect will also determine how accurately the digital model simulates the physical version.

Once all the data has been collected, it is used to create analytical models with which to predict the effects and behaviours of that object in the event of possible changes.

These simulations are generated taking into account issues such as engineering, physics, chemistry, statistics, machine learning, artificial intelligence, business logic or objectives. These models can be displayed through 3D renderings and augmented reality modelling.

The development and creation of a digital twin is used mainly for three main issues:

- **Digital Twin Prototype (DTP):** before creating a final physical product, a digital one is made to see what it would really look like and how it would behave.
- **Digital Twin Instance (DTI):** once a product has already been manufactured, the digital twin is used to test different scenarios of use with the virtual and not with the real one.
- **Digital Twin Aggregate (DTA):** Collects information from the above case to determine a product's capabilities, run forecasts, and test operational parameters.

Through these three typical use cases, companies can predict different outcomes based on variable data, which helps determine where things need to go or how they work before they are physically implemented.

Some of the advantages of digital twins in the industry that we can highlight are:

- To have a realistic model to carry out all kinds of experiments without putting the replicated production system at risk.
- To design new scenarios and observe their behaviour when the variables that concern you are modified.
- To know when system failures will occur, allowing us to develop maintenance plans in advance.
- To evolve the production system in an agile and constant way, incorporating changes that improve productivity in a real way.
- To predict the expected result with reliable data.

2 Digital twin in HVET/VET labs

2.1. Integration of digital twin in Tknika's Lab

As a professional in technical education, you are challenged daily to deliver the most engaging and relevant course you can. The need to keep up to date with the latest technology innovations, whilst managing the resources you have, can be difficult.

This, coupled with a growing demand for online learning and remote access from your students, can create accessibility challenges (Simumatik, 2021).

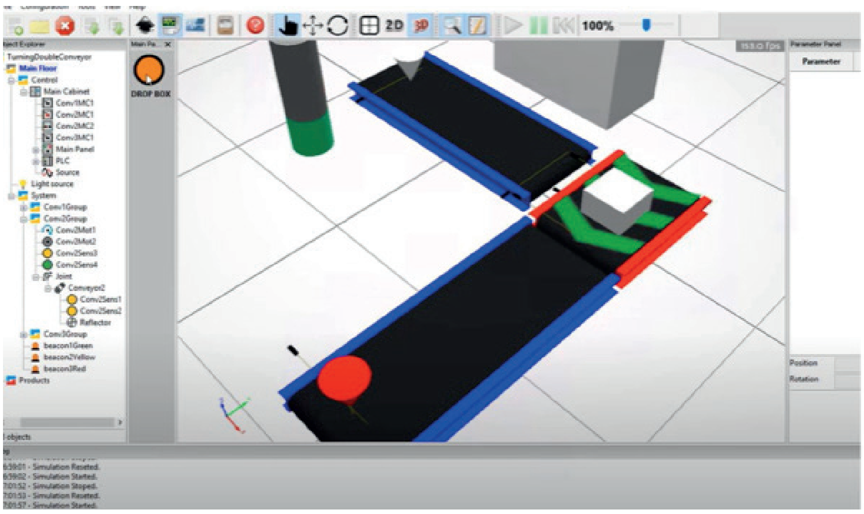

Figure 4: Working in Simumatik. Source: Tknika

Digital twins in education are particularly helpful. As mentioned earlier, they consist of virtual models of a process, product, or service, paired with its real-world counterpart. This pairing of the virtual and physical realms allows students to learn data analysis and system monitoring to avoid problems, as well as how to prevent downtime, develop new opportunities, and plan using simulations.

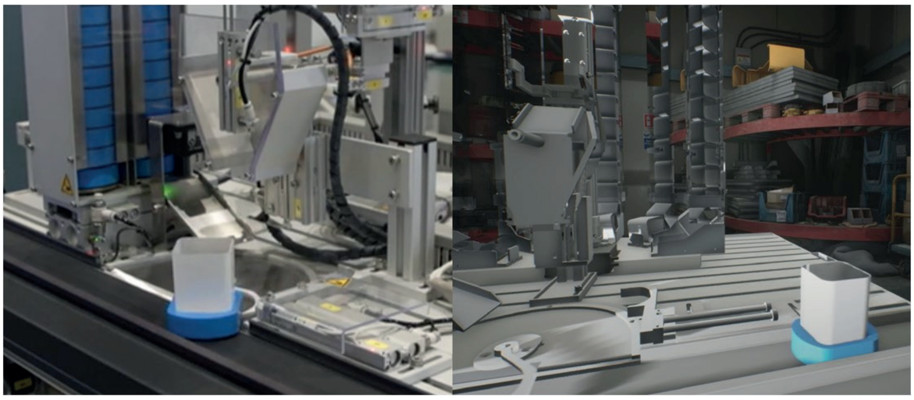

Figure 5: In the left the real machine and in the right the digital twin of the SMC SIF400 machine. Source: Tknika

One of the objectives of the Tknika digital twin workshop is to create a digital twin of the workshop equipment to allow the total simulation of processes of a real production process. The SIF-400 teaching team is working on this aspect, a SMC model that emulates a highly automated smart factory, including technologies related to Industry 4.0, advanced manufacturing concepts and the reality of the connected company.

Figure 6: Student working on a car painting digital twin. Source: Tknika

Finally, digital twins of different individual production processes are being created so that students can practice in a digital environment, as long as they need production processes that would need a large infrastructure.

The digital twin in education enables:

- Students 24/7 access to a cloud-based resource.
- Digitizing physical labs.
- Putting key engineering concepts into practice.
- Collaborating on systems in real-time.

2.2.Role of the digital twin in the EXAM4.0 CLF

The CLF that is going to be launched has divided its production process into 4 stages (product design, process engineering, production and assembly) as can be seen in the following image.

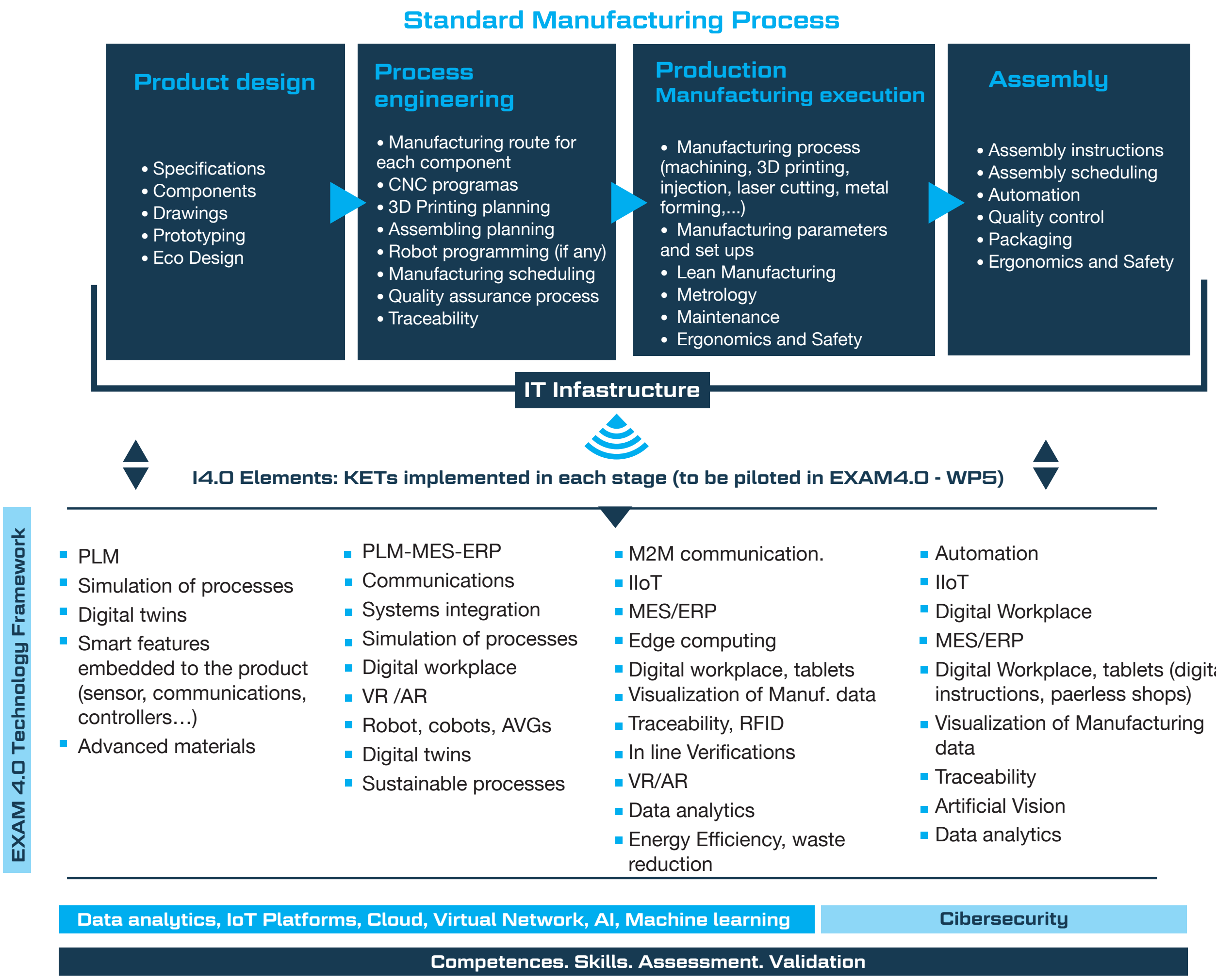

Figure 7: EXAM4.0 Collaborative Learning Factory's (CLF) Value Chain Source:Author's creation

The main role of the digital twin in EXAM 4.0 will be to have a virtual representation of the Collaborative Learning Factory process so that students can work in an Industry 4.0 environment.

To develop the virtual representation, in Tknika we have analysed various software that will allow us to build the digital twin of the Collaborative Learning Factory. Through them we will model the process, simulate it and we will be able to debug the programs that will be executed in the industrial controllers of the machines. This task is known as virtual commissioning.

The software packages that have been evaluated for these tasks have been the following:

- Industrial Controller Simulators: Siemens PLCSIM Advanced v3.0
- Robot Simulators: RoboDK
- Virtual commissioning software: Simumatik and Factory I/O

On the basis of this software, we have worked on the design of an online course. The objective has been to test the use of these tools to build industrial virtual environments with a group of teachers.

In the course, there has also been a demonstration of the digital twin with hardware in the loop configuration. This kind of configuration will allow us to run a real controller connected to the digital twin, so that it works as it would in reality, subjecting it to different contexts of conditions, shortening thus the development, validation and commissioning times of the controller in a safer, more flexible and economical way.

2.3. Benefits of using digital twin in EXAM4.0's CLF

The benefits of having a virtual model of the CLF will be several:

- Avoid breakages, safety issues, and limitations for students by moving Collaborative Learning Factory Labs online.
- Virtual sharing of equipment and resources between different centres without the need to duplicate resources.
- Support key technical concepts and allow students to put theory into practice. Enhance student learning in the basic principles of physics, including electricity, pneumatics, and hydraulics.
- Support your own lessons with access to virtual labs and give students the ability to create their own.

2.4. Competences addressed with digital twin

The competencies addressed in Digital Twin vary depending on learning goals. However, following are examples of competencies addressed within the scope of Digital Twin in the **EXAM 4.0 CLF:**

- Prepare the control programs, in accordance with the specifications and functional characteristics of the installation.
- Define the assembly protocol, tests and guidelines for virtual commissioning of automatic installations, based on the specifications.
- Build purposeful and tailored representations of complex models and their related information.
- Create Digital Twins using 3D software.
- Run simulations to measure product performance in varying conditions.
- Adapt to new work situations caused by technological and organizational changes in production processes.
- Analyse and record the interactions.
- Visualise the results of interactions.
- Deliver the security that modern services demand.

3 Collaboration opportunities opened by digital twin

Through the tools to create digital twins, a base of 3D models of machines and processes can be created in order to share them among the partners. The digital twin is a very valid tool in the field of training since it does not allow a total dependence on the equipment, making it more affordable for the centres to work on complex or very expensive aspects.

In addition, any participating centre that does not have sufficient resources to have all the machinery, will be able to work online using computers, virtual reality glasses ... simulating real machines with data in real time. All this means that different centres that are in different countries can also be working at the same time through the aforementioned devices in a collaborative way.

4 References

Simumatik. (29 October 2021). Retrieved from https://simumatik.com/education/

Xataka. (26 October 2021). Retrieved from https://www.xataka.com/pro/digital-twins-que-sirven-cuales-beneficios-problemas-gemelos-digitales

EXAM 4.0
THE EXCELLENT ADVANCED MANUFACTURING 4.0

AM 4.0 labs running I4.0 technologies

Technology 7: Machine To Machine (M2M)

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Piloting the Advanced Manufacturing workshop 4.0

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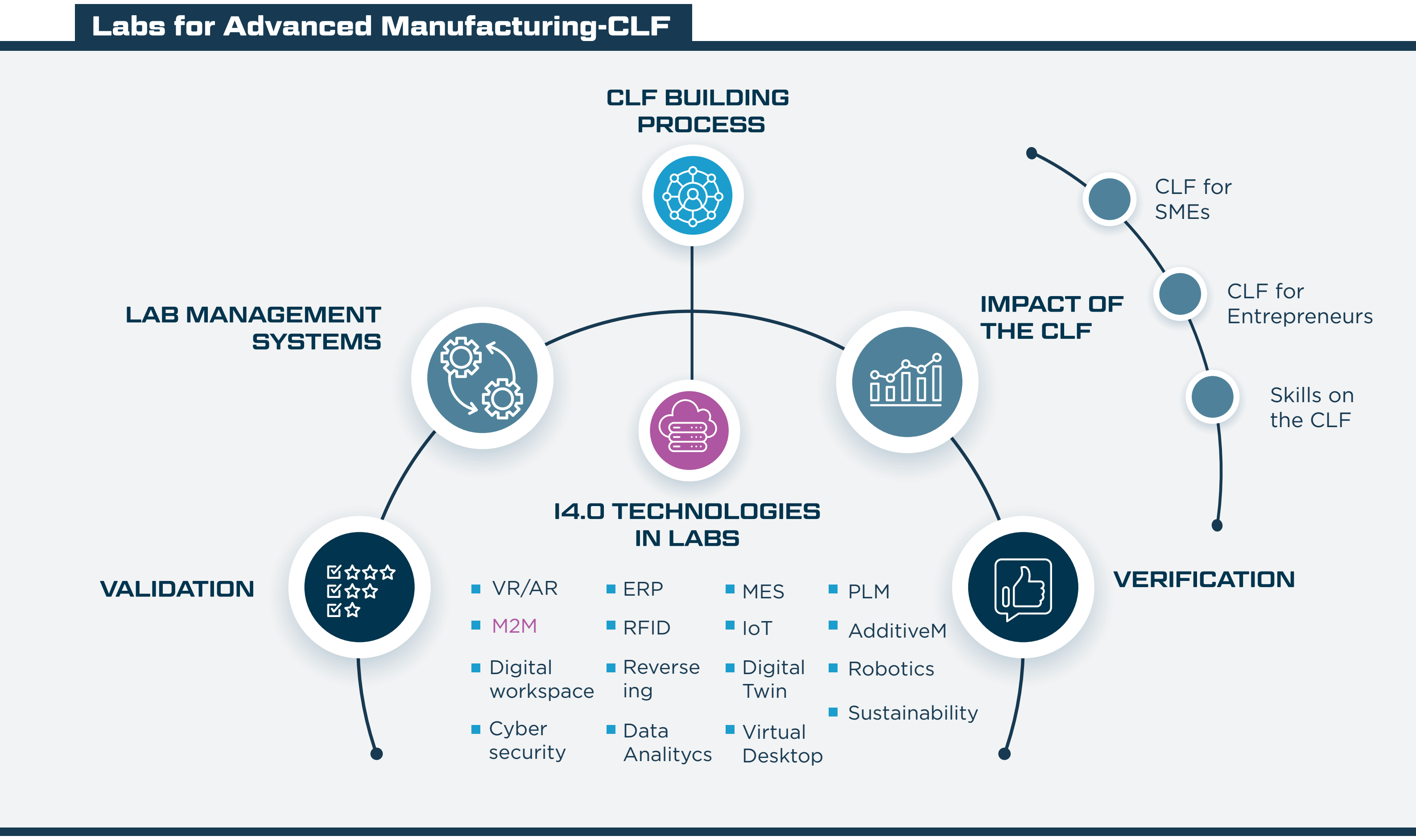

Figure 1: Overall structure of the EXAM4.0 labs piloting process. Source: EXAM4.0

The present report is the one out of 16 I4.0 technology described within the "Industry 4.0 technologies in labs" section, specifically #7 Machine to Machine Communication (M2M)

1 Definition and application of M2M in industry

M2M, central to the shop-floor, impacts Industry 4.0 and refers to technologies allowing for the automated exchange of information between the CPS, which constitute the Industry 4.0 production environment. M2M can be considered as the integral technology of the 'Internet of Things' (IoT). Through advanced embedded sensor and actuator applications technology, the entire production floor can relay meaningful information, forming the interface between the physical and the virtual worlds. This provides a level of transparency that enables huge improvements in manufacturing, from performance management to entire new business models. While the most evident usage forms of M2M will be in intra-company linking of production assets, M2M is also the key enabler when it comes to cross-company operations.

Considering manufacturing advancements supported by communication and networking technologies, manufacturing industries are ready to improve the production processes with big data analytics to take the advantage of higher compute performance with open standards and achieve the availability of industry know-how in advance. As a result of the penetration of manufacturing intelligence, manufacturers can be able to enhance quality and increase manufacturing output (Exam4.0, 2021).

M2M environments are usually made up of the following elements:

A. MACHINES TO MANAGE: Any machine that you want to control. In the industrial case, any machine involved in production.

B. M2M DEVICE: module integrated or connected to a machine that communicates with the server, which normally also consists of processing capacity. On the one hand it implements the protocol to be able to communicate with the machine and on the other hand it implements the communication protocol for sending information.

C. SERVER: Computer that manages the sending and receiving of information from the machines it manages. It is usually also integrated with the core business of the company (ERP, MES, Order system, etc.).

D. COMMUNICATION NETWORK: they can be either through cable (PLC, Ethernet, PSTN, ISDN, ADSL etc.), or through wireless networks (GSM / UMTS / HSDPA, Wifi, Bluetooth, RFID, Zigbee, UWB, etc.).

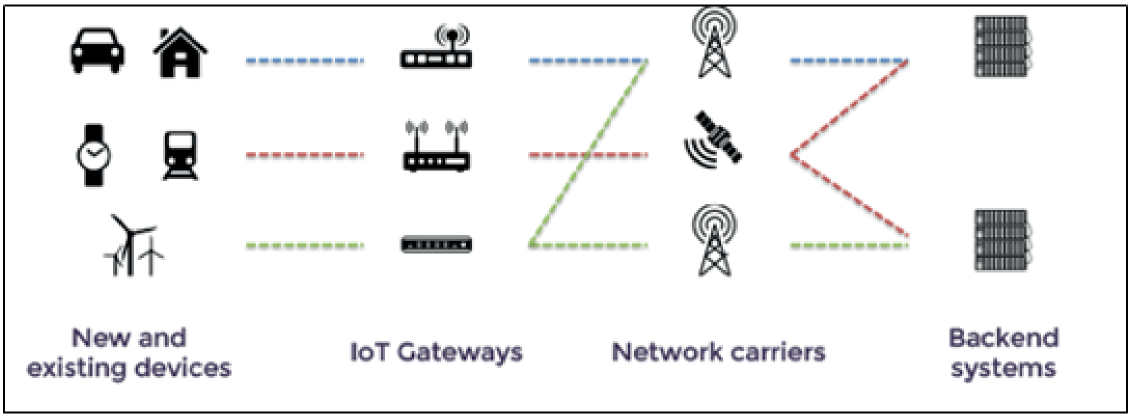

Figure 2: machine to machine communication architecture. Source: https://medium.com/predict/an-era-of-iot-machine-to-machine-communicati on-m2m-9a7861665b4c

The European Telecommunications Standards Institute (ETSI) aims to create global standards for information and communication technologies. **Establishes the following requirements for machine to machine systems (IONOS, 2021):**

- **Scalability.** The system should continue to function efficiently even if other connected devices are added to it.
- **Anonymity.** The system must be able to hide the identity of the devices.
- **Protocols.** M2M systems must be able to record failed installations, defects or erroneous data and store these records for later reference.
- **Transmission methods.** Systems must support different transmission methods such as Unicast, Anycast, Multicast, or Broadcast and must be able to switch between these methods in order to reduce the load on M2M data transmission.
- **Planning of news transmission.** The system must be able to set times for data transmission and to regulate or delay communication according to priority.
- **Selection of the communication path:** The communication paths within the machine to machine system must be optimized through regulations regarding transmission errors, delays and network costs.

In general we can establish the following industrial applications (Innovation, 2021):

- Collection of data for processing by another team
- Traceability
- Intelligent stock control
- End of process notice
- Implementation of just-in-time systems
- Automated maintenance
- Procedure for requesting spare parts

2 M2M in HVET/VET labs

2.1Integration of M2M in Miguel Altuna's lab

This section deals with how M2M can be incorporated in VET centre labs by describing different options and applications.

The implementation of M2M communication obviously requires a set-up of machines and equipment, which is adapted for data acquisition and integrates in a communication architecture.

The communication of M2M is represented in different ways in VET labs:

(A) It can be replicated on a small scale in communication between different modules in didactic cells.

(B) in a limited number of machines in the Labs

(C) Scaled up to the set to all the machines to the system

It is important to highlight that when incorporating M2M into a VET Labs, the desired information from the machine and the way to exploit it could be different from industry as long as they are in learning processes instead of production.

It would be possible to get information from:

- Traceability of learners, machine usage, tools, performance indicators
- Machine use information for scheduling, planning and also maintenance
- Monitoring of student's performance, state of project's and task execution at real time
- Tools control
- other

The learning factories implemented in VET labs are a good way to reach the industrial applications of M2M solutions listed in the previous section in learning environments

- Collection of data for processing by another team
- Traceability
- Intelligent stock control
- End of process notice

- Implementation of just-in-time systems
- Automated maintenance
- Procedure for requesting spare parts

Figure 3: Miguel Altuna's student working on the machine's HMI. Source: Author's creation

As for industry, in VET labs similar I4.0 technologies would be needed to implement M2M communication: The following paragraph describes how it is integrated at Miguel Altuna VET centre:

MACHINES TO MANAGE:	• 80 machines divided in 8 cells • 1500 tools managed by RFID	• 200 users (students & staff) managed by RFID • Users' PPEs control
SERVER:	• Local server	• Connected with ERP
M2M DEVICE:	• Groups of 6 machines are connected to a PLC. • Data is send form the PLC's to the server by wifi • HMI devices are installed in all the machines	• Cloud based Digital workplace: display information (learners documentation) Beacon displays that the machine is reserved
COMMUNICATION NETWORK:	• Different configurations are used depending the devices to be managed:	PLCs Ethernet HSDPA, wifi, RFID
BI & ANALYTIC	• Data analytic systems to exploit data	

All this is summarized in a simple scheme that can be seen in the following image.

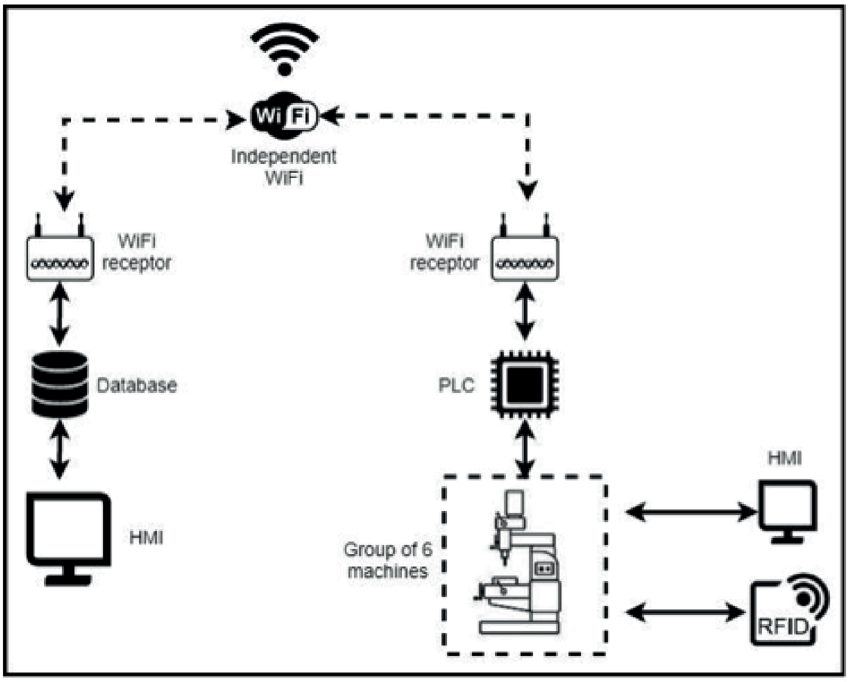

Figure 4: Miguel Altuna's M2M installation architecture. Source: Author's creation

2.2 Role of the M2M in the EXAM4.0 CLF

The CLF that is going to be launched has divided its production process into 4 stages (product design, process engineering, production and assembly) as can be seen in the following image. Within these stages, although the M2M could be incorporated in more than one of them, for now it will intervene in the production part.

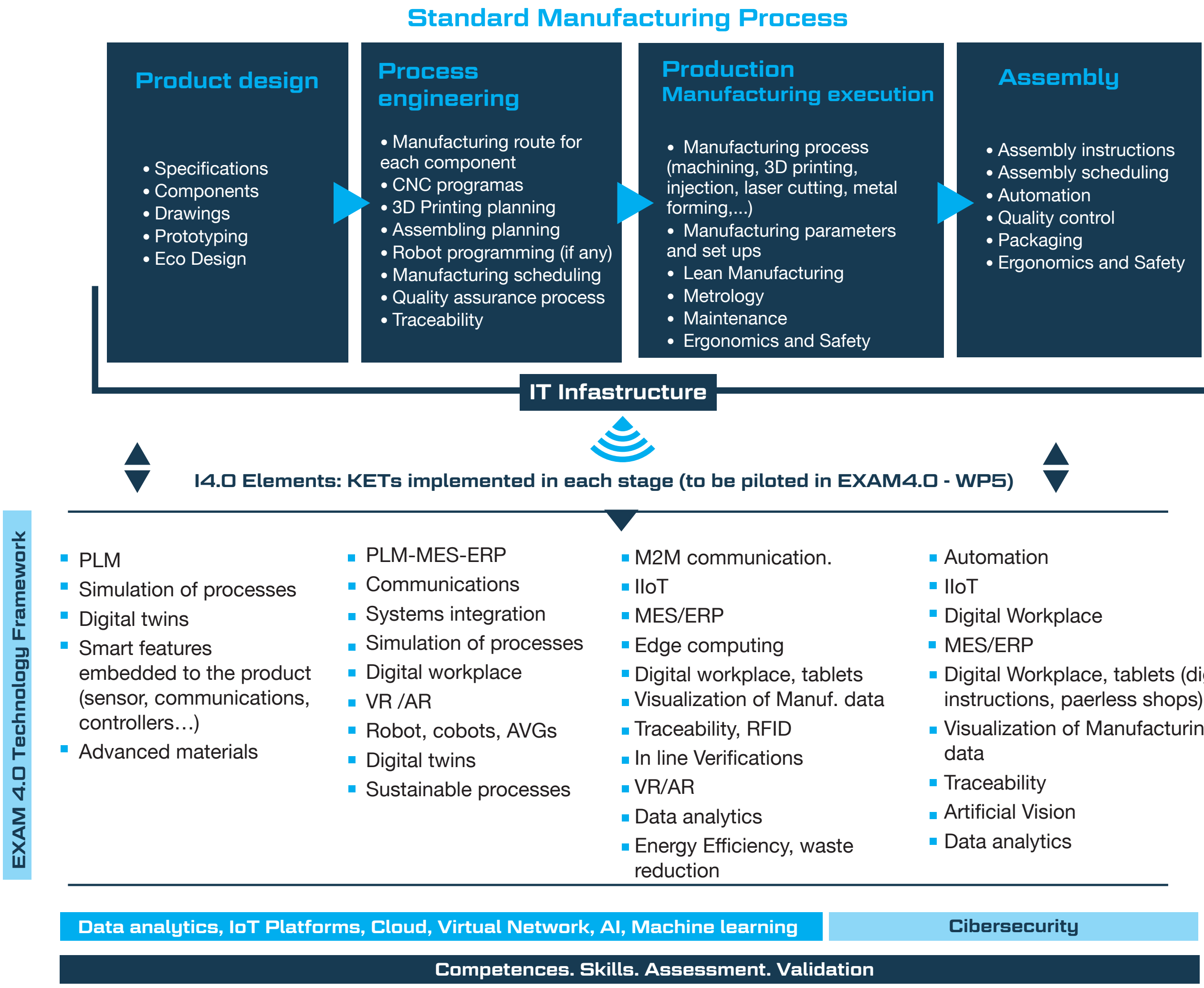

Figure 5: EXAM4.0 Collaborative Learning Factory's (CLF) Value Chain Source: Author's creation

Within production, the use of the M2M technology will be made when manufacturing the intermediate plates of the robot. **In the production process of these plates, the following inaformation will be collected:**

- User who has reserved the machine
- Machine reserved hours
- Machine running/standby hours
- Drawing and CNC programs that are being used
- Tools the user is using

Figure 6: Miguel Altuna's machine booking dashboard. Source: Miguel Altuna

2.3 Benefits of using M2M in EXAM4.0's CLF

Among the benefits that we find when inserting M2M in EXAM CLF are:

- Massive remote control managed through the use of applications. All M2M equipment is visible at all times and in real time, being able to control its operation and detect or solve problems.
- Cost reduction promoting operational efficiency, lowering production and logistics costs.
- Automation of processes due to artificial intelligence. The processes will become more and more automatic, avoiding the errors of manual operators.
- Better monitoring by obtaining information (status, consumption, etc.) in real time.
- Maximum use of resources, making them more efficient.

Figure 7: Miguel Altunas's lab occupation dashboard. Source: Miguel Altuna

2.4 Competences addressed with M2M

The insertion of M2M technologies are going to help on developing competences such 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.

3 Collaboration opportunities opened by M2M

The fact of incorporating the M2M technology in labs opens up possible collaborations with other labs.

First, you can monitor the data that comes up with this element. In this way, it is possible to work with the traceability of the parts from different labs.

All this data can be used to analyse the process and improve it using a digital twin. In addition, this digital twin with real data, can be a perfect structure; so that HVETs, that do not have enough economic capacity to be able to have certain machines, can work with them virtually through collaboration.

4 References

Exam4.0. 23 July 2021 www.examhub.eu. Retrieved from https://examhub.eu/wp-content/uploads/2021/04/WP_2_1.pdf

Innovation, A. (23 July 2021). atriainnovation.com. Retrieved from https://www.atriainnovation.com/comunicacion-m2m-que-es/

IONOS. (23 July 2021). www.ionos.es. Retrieved from https://www.ionos.es/digitalguide/servidores/know-how/que-es-la-comunicacion-machine-to-machine-m2m/

THE EXCELLENT ADVANCED MANUFACTURING 4.0

AM 4.0 labs running I4.0 technologies

Technology 8: RFID

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Piloting the Advanced Manufacturing workshop 4.0

This project has been funded with support from the European Commission. This publication reflects the views only of the author, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

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Introduction

Following the piloting process of Advanced Manufacturing Labs for HVET/VET through the Collaborative Learning Factory (hereafter CLF), the EXAM4.0 partners we have piloted 16 technologies embedded in Industry 4.0

The following image shows the overall structure of the piloting process.

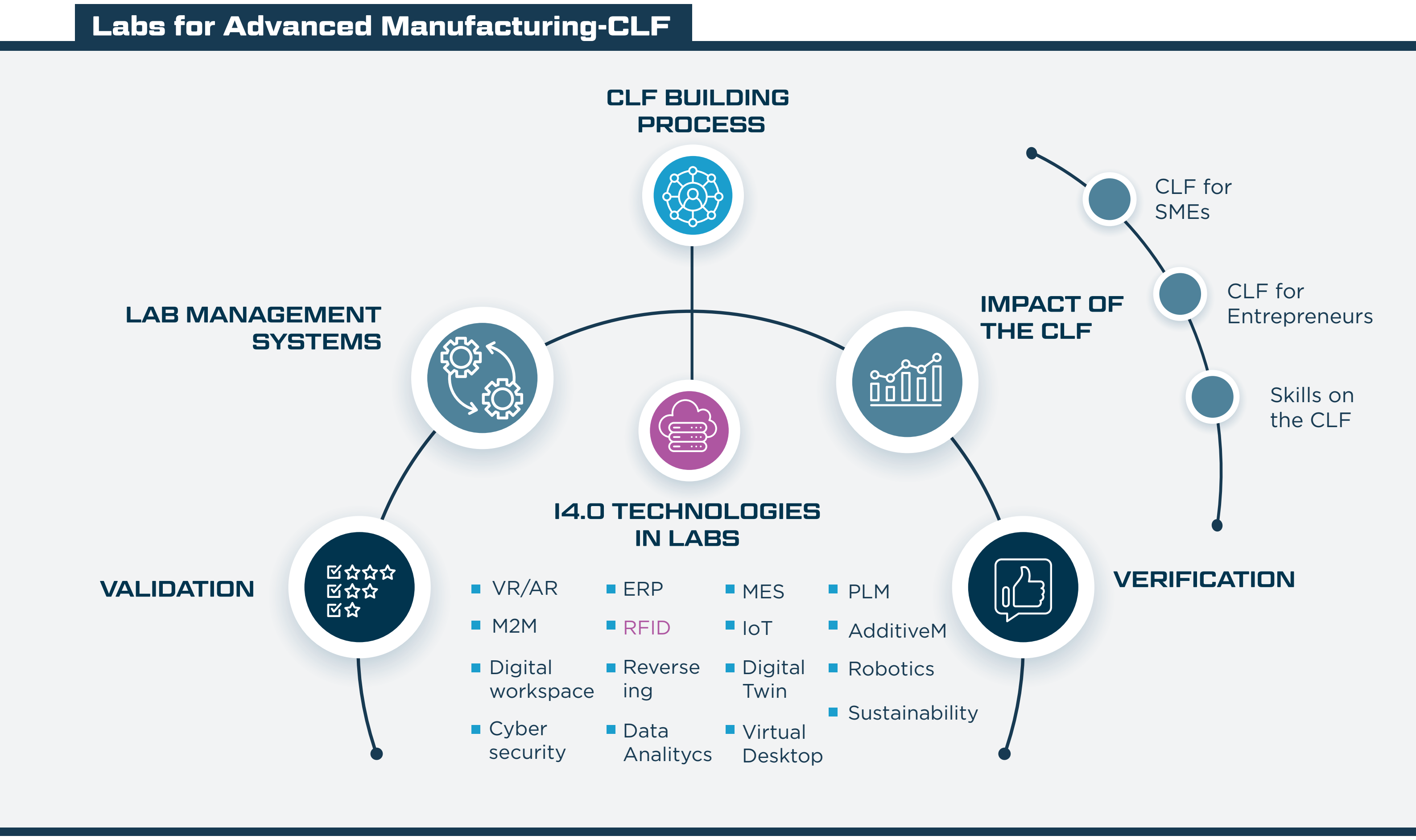

Figure 1: Overall structure of the EXAM4.0 labs piloting process.
Source: EXAM4.0

The present report is the one out of 16 I4.0 technology described within the "Industry 4.0 technologies in labs" section, specifically #8 RFID

1 Definition and application of RFID in industry

RFID technology is a form of wireless communication between a reader and a transmitter. It can be compared to a barcode, although radio waves are used instead of ink marks. In fact, tags with this technology are widely used in the industry, both to locate objects and to ensure that these are not removed from an establishment without the pertinent permits (VIU, 2021).

RFID systems are classified depending on the frequency range they use. There are four types of systems: low frequency (LF: 125 or 134.2 kHz); high frequency (HF: 13.56 MHz); ultra-high frequency (UHF: 868 to 956 MHz); and microwave (2.45 gigahertz) (RFID, 2021). In the case of Miguel Altuna, a card is used that combines an HF RFID with a UHF RFID. This is possible because a UHF-type RFID sticker has been attached to an HF-type RFID card. Through an application, the two types of RFID are registered in the name of a user.

Figure 2: Miguel Altunas teacher/student RFID card. Source: author's creation

The use of RFID technology has been expanding in recent years. Use in manufacturing is aimed at increasing the efficiency of manufacturing processes. RFID technology offers the possibility of improving efficiency in aspects such as the traceability of tools and assets, or the monitoring of devices. In another area such as the supply chain or logistics, a great commitment to RFID technology is also being done. For example, automatic quality control in the delivery of goods, or real-time checking of the status of shipments, offer new possibilities in this industry.

At Miguel Altuna, the use of RFID focuses on two main aspects, on the one hand, user control and machine booking, and on the other, tool control.

2 RFID in HVET/VET labs

2.1. Integration of RFID in Miguel Altuna's lab

At Miguel Altuna's lab the use of RFID is focused on 2 sections. On the one hand, there is the user control, where by means of an HF RFID card the booking of the machines and the entrance to the smart warehouse are controlled. On the other hand, the tool control, where the location of the tool in the smart warehouse and which student removes each tool through the UHF RFID card is controlled. Both use cases will be explained below.

When it comes to user control, inside Miguel Altuna's lab there are two login points. Machines can be reserved from independent posts or from the machine itself. For this, the independent points such as the machines are enabled with a HMI and a RFID reader (HF).

FIgure 3: Student working on CNC milling machine. Source: author's creation

Before any machine can be used, the student has to reserve it. To do this, the student will have to go to a login point and do it with their card.

FIgure 4: Student working on CNC milling machine. Source: author's creation

The machines are divided into sections and students will have to ensure that they are wearing the corresponding security elements for the use of the machine. When booking it, the colour of a beacon installed in each machine will be changed to show that it is not available. At this time, the booking time and machine running time will begin to be counted.

Figure 5: student confirming that he has the necessary PPE before manufacturing. Source: author's creation

When it comes to tool control, Miguel Altuna's lab consists of an intelligent warehouse that manages the control of the tools used by its students and teachers. This warehouse is located in the centre of the workshop to speed up people's movements and avoid wasting a lot of time wandering around.

The entrance and exit are controlled by an RFID reading device (HF, high frequency) that identifies users and (UHF, ultra high frequency) tools.

Figure 6: Smart warehouse entrance of Miguel Altuna's lab using RFID system. Source: author's creation

The tools inside are arranged in different cabinets with numbered drawers. The drawers are filled with identifiers and foam cut with the shape of the tool to make it easier to find the right place. All these tools are fitted with RFID tags for traceability.

Figure 7: Tools classified by RFID system in Miguel Altuna's lab. Source: author's creation

The inventory of the tools in this warehouse is made on a computer inside the warehouse. This computer, in addition to storing the warehouse inventories, is used to manage the warehouse itself. It identifies the exact location of each tool, the teachers and the students associated with each teacher.

The use of this warehouse is divided into three situations: Inputs, queries and outputs.

- **ENTRY.** The user has to bring the personal RFID card close to the reader and press the button to start reading. At this point, the RFID reader system will read both the user's card and the tool cards. An HMI device will display the user's data, such as the tools that have been borrowed. If there are no errors, the system detects two users or the user enters with a borrowed tool, access is given and the door will open.

Figure 8: User and tool entry detector with RFID system in Miguel Altuna's lab. Source: author's creation

- **QUERY.** Within the smart warehouse, in addition to returning or retrieving new tools, different queries can be made.

  - **Quick Enquiry without logging in**. Two types of quick queries can be made without logging in. On the one hand, searches can be made by product characteristics. On the other hand, by means of an RFID reading device, it will be possible to carry out direct searches by card codes.

  - **Consultation as a student.** The list of tools used by the user can be searched.

  - **Consultation as a Teacher.** The teacher can track the tool records; see if a tool is inside or outside the warehouse, manage tools by users, enter tools found outside and carry out card maintenance.

Figure 9: Consultation device using an RFID system within the intelligent warehouse of Miguel Altuna's lab. Source: author's creation

- **EXIT.** The user has to bring his personal RFID card close to the reader, like the tools to be removed, and press the button to start reading.

At this point, the RFID reader system will read both the user's card and the cards of the tools to be removed.

An HMI device will display the user's data, such as the tools he has removed.

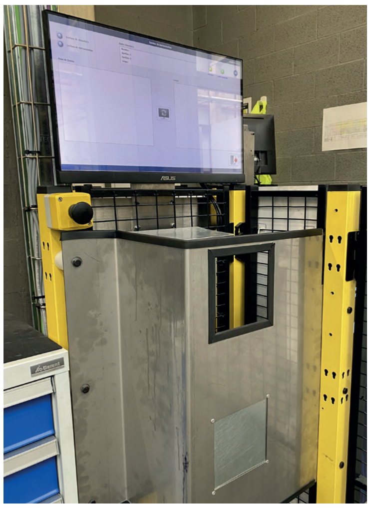

Figure 10: User and tool exit detector with RFID system in Miguel Altuna's lab. Source: author's creation

2.2. Role of the RFID in the EXAM4.0 CLF

The CLF that is going to be launched has divided its production process into 4 stages (product design, process engineering, production and assembly) as can be seen in the following image. Within these stages, RFID is going to be incorporated in the process engineering and the production part.

Within production, the use of this element will be made when manufacturing the intermediate plates of the robot.

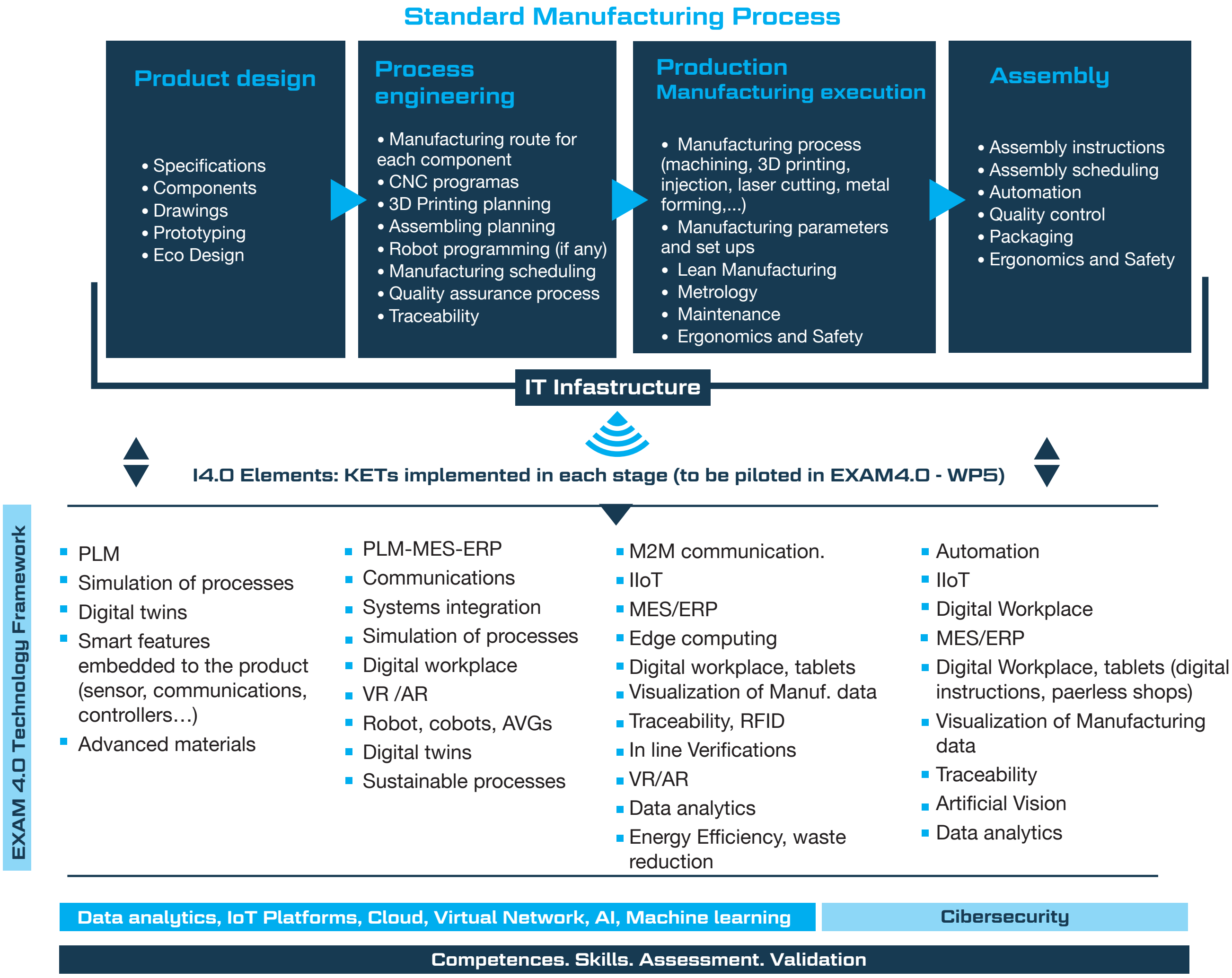

Figure 11: EXAM4.0 Collaborative Learning Factory's (CLF) Value Chain
Source: Author's creation

First, the person in charge of making the piece will have to reserve the corresponding machine. When reserving the machine, the person in charge will upload the plans and necessary programs to make the part. From this precise moment on, it is possible to control the time that the machine has been reserved to make that piece.

Once you reserve the machine, you will have to go to the warehouse to collect the corresponding tools to make the part, as well as the material. Thus, there is a record of who has each tool. In addition, the tools needed to make the part can be related to the machine.

When manufacturing, a difference is made between the number of hours that the machine is reserved and the number of hours it is operating. In this way, it is possible to trace the hours that this tool is used to control tool wear or breakage. With the record, decisions could be made about the real needs of the tools or purchase of spare parts. In turn, if we add the total time of use of the different tools, we would have the total time that is needed to make the part.

Finally, the tool is returned to the warehouse, ensuring the return of this tool to its correct place. All the information generated will be included in the tool's record.

2.3. Benefits of using RFID in EXAM4.0's CLF

The use of RFID is done in two specific processes, the control of users and tools, that is why the benefits provided by each of them will be mentioned.

When we talk about the benefits of user control, it can be said that the main benefit is to speed up the use of the workshop machines. At a glance, by means of some beacons installed in the machines, the student will be able to see which machine is occupied, damaged or free. That is why time wasted when choosing the machine is avoided.

In addition, through user recognition, each student will be assigned the machines they can use and the number of hours they can use them. In this way, the misuse of machines is avoided. As mentioned above, taking into account the issue of security, when reserving the machine, each student will have to affirm that they have all the security elements in place. With what is their responsibility to be properly equipped.

Also, it will be possible to analyse the total reservation time and the running time of the machine, thus calculating the real time that has been with each piece.

Talking about tool control & traceability, it carries a very large potential for savings, since expensive tools and components do not have to be duplicated because they are mounted in a particular assembly. In addition, having reliable information on the stock of spare parts that the workshop has is essential to minimize the amount of material in its warehouse and to be able to provide a better service to customers.

Enable knowing at any time where the tools that have been borrowed are, according to cost centre, order or machine. It also generates a complete inventory at any time and view the references most used in the workshop. Through the inventory report, it is possible to quickly obtain information on available stocks, locate references that are below stock, obtain an assessment of the stock in the warehouse, and even know the inventory of a certain date.

In addition, the control of the times of use of the tools can help in the planning of the manufacturing procedures of the different pieces.

2.4 Competences addressed with RFID

The insertion of RFID technologies are going to help on developing competences 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.
- Determine the necessary provisioning through an intelligent warehouse.
- Manage the maintenance of resources in their area.

3 Collaboration opportunities opened by RFID

The fact of incorporating the RFID technology in laboratories opens up possible collaborations with other laboratories.

First, it is an element that generates a lot of data as mentioned above (user booking, machine time, tool traceability, etc.) and all this data can be monitored. That is why monitoring this data and using tools shared with other laboratories, can give the ability to track the parts and assembly of the parts traceability (where is it, who manufactures it, how long does it take, etc.), as well as a traceability of tools that have been used. All this helps in the calculation of costs, as well as in giving direct information to the end customer.

All this data can be used to analyse the process and improve it using digital twins. In addition, this digital twin with real data can be a perfect structure for HVETs that do not have enough (RFID, 2021) (RFID, 2021)collaboration.

4 References

RFID, D. (10 July 2021). www.dipolerfid.es. Retrieved from https://www.dipolerfid.es/blog/Tipos-Sistemas-RFID

VIU. (10 July 2021). www.universidadviu.com. Retrieved from https://www.universidadviu.com/es/actualidad/nuestros-expertos/rfid-que-es-y-como-funciona

EXAM 4.0

THE EXCELLENT ADVANCED MANUFACTURING 4.0

AM 4.0 labs running I4.0 technologies

Technology 9: Robotics

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Piloting the Advanced Manufacturing workshop 4.0

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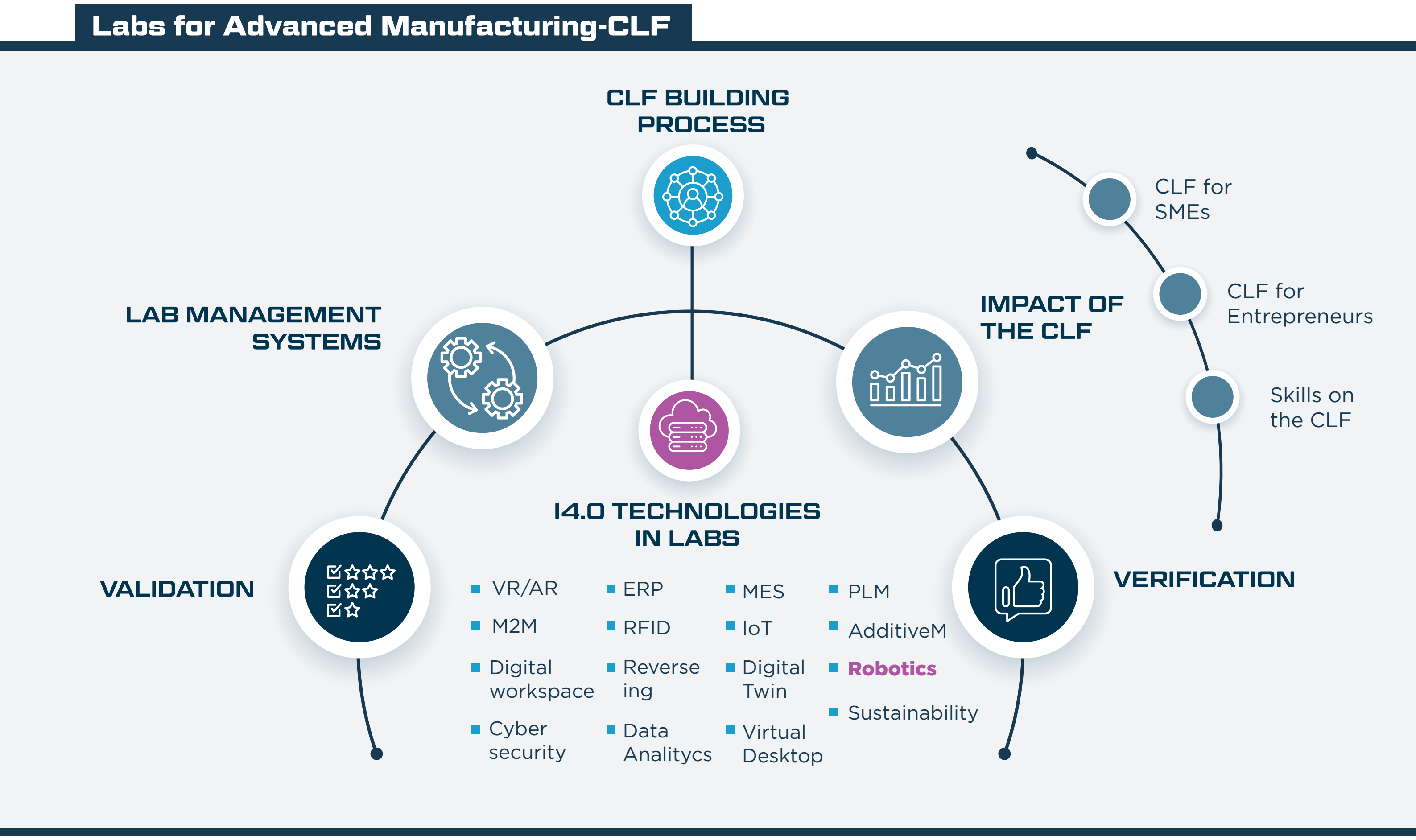

Figure 1: Overall structure of the EXAM4.0 labs piloting process. Source: EXAM4.0

The present report is the one out of 16 I4.0 technology described within the "Industry 4.0 technologies in labs" section, specifically #9 Robotics

1 Definition and application of Robotics in industry

Industrial robotics and automation are the pillars that have made the consolidation of Industry 4.0 possible, in addition to bringing along numerous benefits for the productivity and efficiency of production resources.

The different models of industrial automation that are established today, eliminate the subjective factor of human decisions, achieving lower margins of error and more precise processes, at the same time that they free human workforce from repetitive or dangerous tasks.

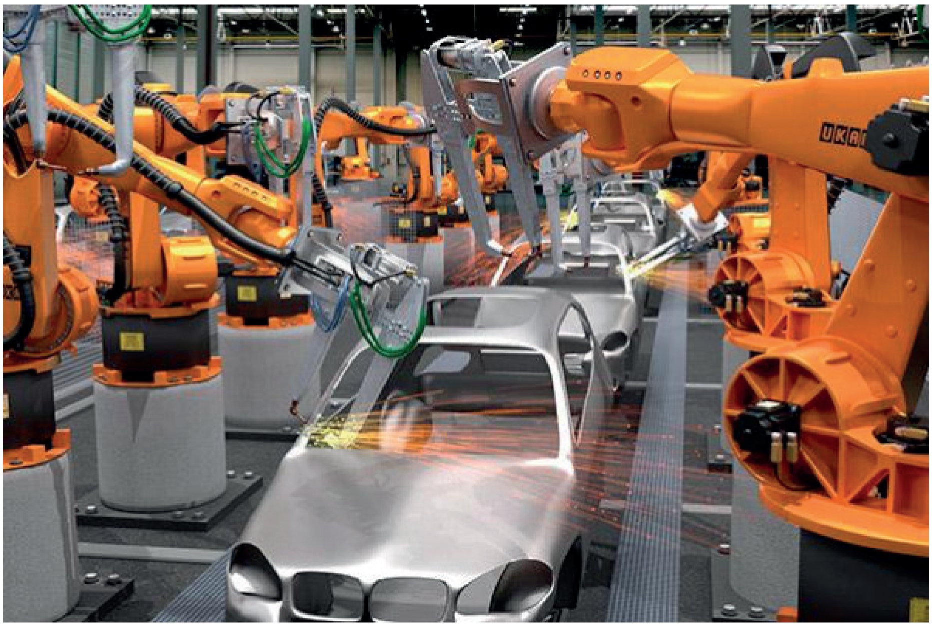

Figure 2: Robots working on a car manufacturing line. Source: https://www.atriainnovation.com/en/robotica-industrial-tradicionales-colaborativos-y-adaptativos/

Countless manufacturers use industrial robots to automate tasks, improve worker safety, and increase overall production, while reducing waste and operating costs. With the increasing prevalence of industrial robots in manufacturing environments, there has been an increase in demand for many different types of industrial robots to suit specific applications and industries (Avansis, 2021).

Depending on the type of industry and manufacturing or production needs, the types of industrial robotics or automation are:

- **Fixed:** the machine or robot is designed and programmed to perform the same task without interruption. In large-scale or mass manufacturing or production, it is the most widely used type for automating simple and highly repetitive tasks that require precision.
- **Programmable:** the machine or robot is designed in such a way that it is easy to reconfigure or reprogram it so that it can carry out different tasks. It is the most widespread type of automation in manufacturing or production lines for different product models.
- **Flexible:** industrial robots work in an orchestrated or coordinated manner by a central system that controls them based on the information they provide.

If we take into account the applications and uses of robots in industry, we can see that this is very broad. In the health field, industrial robots or automated systems are used to facilitate the work of professionals in activities or performing surgeries that require great precision and where an error can be fatal.

In the manufacturing industry, such as the automobile industry, to increase productivity and quality by automating repetitive and simple tasks in the production chain.

In other fields such as the military, agriculture, security, food production, among others, industrial robotics is beginning to be used more and more for different tasks or activities (UNIR, 2021).

If we take into account the manufacturing process, industrial robots with various intelligent and sensory capabilities are utilized there. In an Industry 4.0 factory, the robots endowed with the advanced capabilities owing to the information, networking and sensor technologies are able to collaboratively work with human workers and cooperatively with the other robots in an assembly line. The collaborative and cooperative working applications of the robots, the maintenance practices and assembly line applications using the robots shape the factories of the future (Alp Ustundag, 2018).

In the market we find several types of industrial robots, which we can classify according to the type of movement they perform in. Some of them are (Engineering, 2021):

Figure 3: Types of robots. Source: https://www.vld-eng.com/blog/tipos-de-robots-industriales/

- **CARTESIAN ROBOT:** It is an industrial robot whose 3 main control axes (X, Y, Z) are linear and form right angles to each other. Its structure can be of the cantilever or gantry type. They are very fast, precise, easy to control and have a high load capacity. They are used in applications that require high precision linear movements. Its main applications are handling, storage, palletizing, loading and unloading.

- **ROBOT SCARA:** It is an industrial robot with 4 freedoms of movement, X, Y, Z being the rotating Z axis. These robots are known for their fast working times, their high repeatability, high load capacity and their wide field of application. They are generally used for assembly or component insertion operations.

- **ANTHROPOMORPHIC ROBOT:** This robot has 3 positioning joints and simulates the movements of a human arm. The first axis corresponds to the arm, the second to the forearm and the third to the wrist. Within this type of robots, we find 5-axis, 6-axis and 7-axis robots. As for the latter, what differentiates it from the 6-axis one is that the base is mounted on a linear guide (track), which allows it to move forwards and backwards. This robot has great accessibility and manoeuvrability, it is fast and takes up little space with regards to the work field it covers. The integration of these robots is accompanied by specific security measures. They are used for welding, assembly, filler, paint and palletizing applications.

- **COLLABORATIVE ROBOT or COBOT:** Regarding this robot, we can say that it is an anthropomorphic robot, but of smaller dimensions and weight than those previously described. They are more manageable robots, easy to program and do not require specific protection measures. Due to its size, it allows it to load less volume of product and less weight. Furthermore, it's slower than industrial robots. Nevertheless, they allow greater flexibility, since they can be easily transported from one phase of the process to another.

- **AGVs (Automatic Guided Vehicle):** We can identify these robots as autonomous vehicles with an applicability closely linked to the internal logistics of the company. They are also suitable for integrating a collaborative robot, which must move from one phase to another of the production process.

2 Robotics in HVET/VET labs

2.1. Integration of Robotics in Miguel Altuna's lab

The integration of robotics in the HVET Miguel Altuna is understood from three points of view:

1. Specific robotics laboratories
2. Integration of robotics in the advanced fabrication shop
3. Integration of robotics in the CLF

In the first case, we find the creation of a specific robotics workshop where we learn the basic knowledge necessary to be able to work with robots. To do this, problematic situations are created and posed to a class configured in teams, where the work process has to train students to experience the situation as a challenge and, from there, they must have the opportunity to generate the necessary knowledge to provide the best solutions.

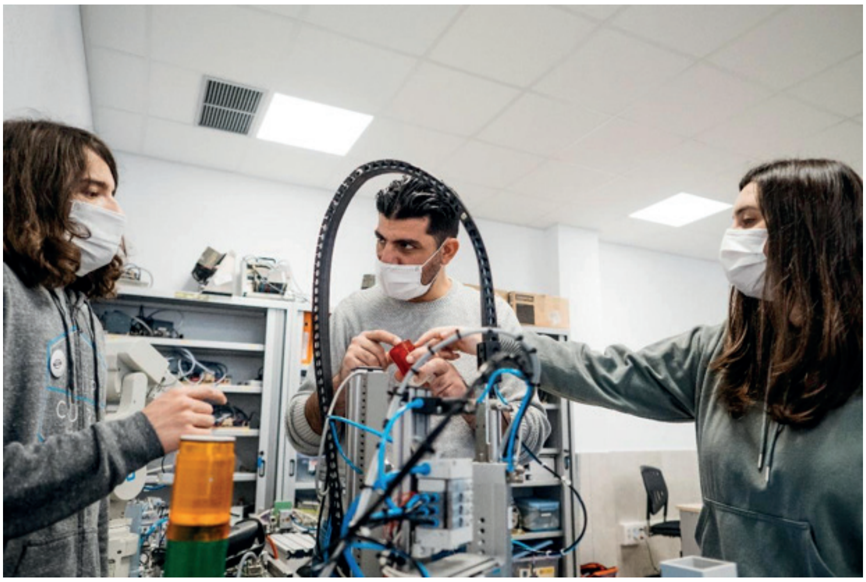

Figure 4: Students working on a project in Miguel Altuna Robotics Lab. Source: Miguel Altuna

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 industrial automation (Siemens, Omron, etc.) and they are communicated with the rest of the stations through an industrial communications bus (Profibus, Ethernet, etc).

Figure 5: Miguel Altuna's Robotics Lab. Source: Miguel Altuna

In the second stage, the objective is to transfer what has been learned in the robotics lab to the advanced manufacturing lab. To do this, an attempt is made to find possible needs that may exist in the workshop and a solution to those needs.

As practical cases of the school, the last two projects can be mentioned:

- **Integration between 3D scanner and collaborative robot for industrial metrology**

  In this project the objective has been to automate an industrial process for its optimization.

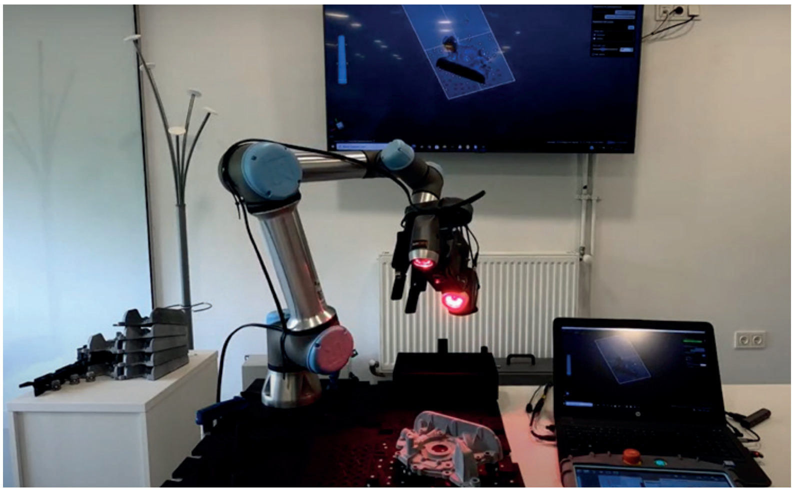

Figure 6: 3D scanner integrated in a collaborative robot. Source: HVET Miguel Altuna and HVET Tolosaldea

They have joined a 3D scanner with a collaborative robot and claws have been added to hold the pieces.

For more information: https://www.youtube.com/watch?v=zVxvvuvBc6o

- **Create a robot that transports material in the workshop**

The objective of this project was to integrate a MIR Robot in the manufacturing lab, simulating the functionalities that a MIR would have in an industrial environment. We worked on the communications and programming of the robot considering all the safety regulations.

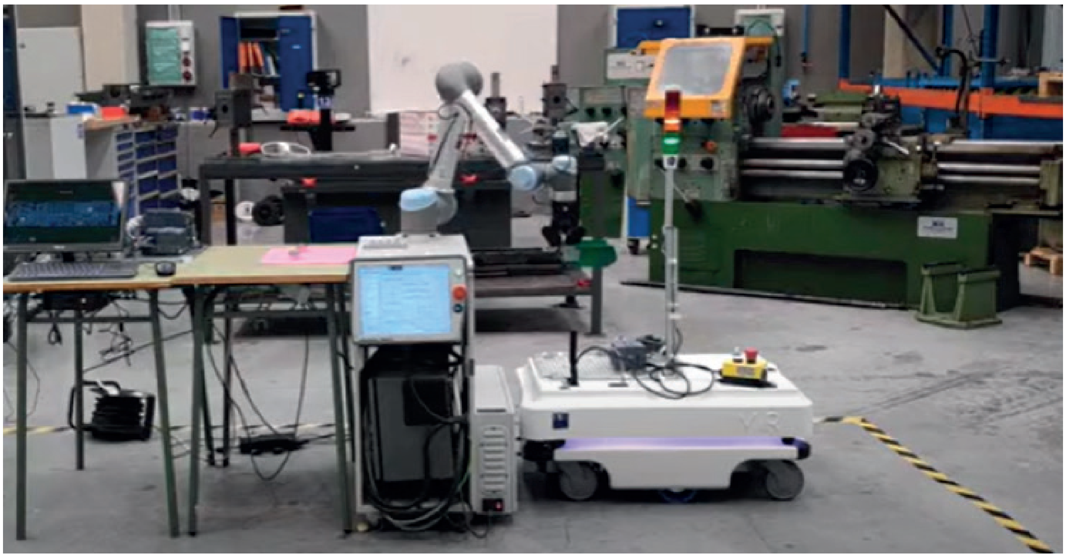

Figure 7: A MIR robot taking material from a warehouse with a collaborative robot. Source: Miguel Altuna

For this, a situation arises in which from a fixed warehouse, the robot has to feed two workstations.

More details: *https://www.youtube.com/watch?v=nrP2WeDQHZI*

- **Create an autonomous MIR robot to transport material around the school**

The last project is for a MIR robot to overcome obstacles such as elevators when transporting material through different parts of the school.

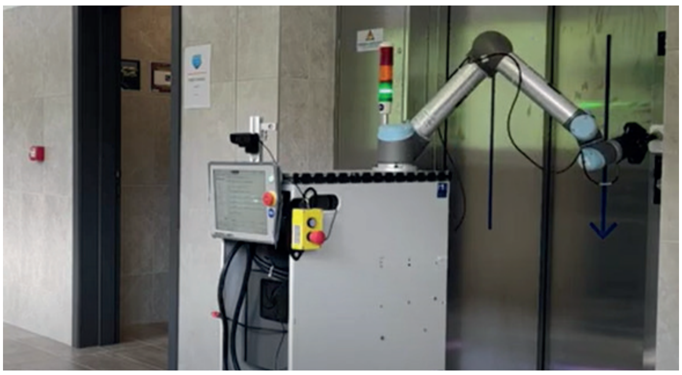

Figure 8: Robot calling to the elevator. Source: Miguel Altuna

For this, a MIR robot is joined with a collaborative robot that has to be fitted with an RFID key to be able to call the elevator and move between floors.

More details: *https://www.youtube.com/watch?v=s69xxGdPnaA*

As a final phase, everything learned in the previous two phases would have to be used in order to improve a real industrial CLF process. The insertion and role of robotics in the CLF is detailed in the following sections.

2.2. Role of the Robotics in the EXAM4.0 CLF

The CLF that is going to be launched has divided its production process into 4 stages (product design, process engineering, production and assembly) as can be seen in the following image. Within these stages, robotics is going to help in the production and assembly stages.

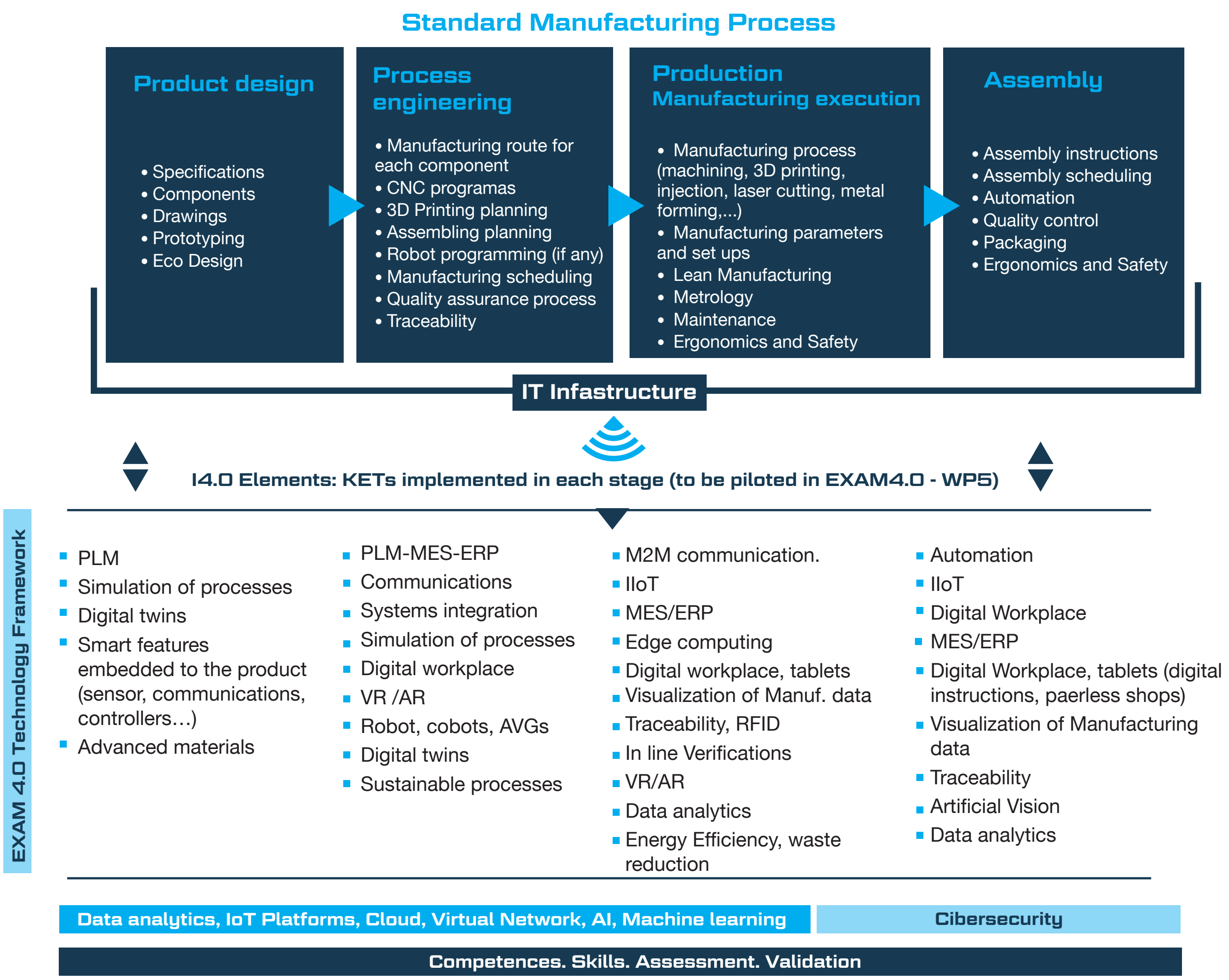

Figure 9: Exam 4.0 CLF value chain Source: Author’s creation

The main objective of the robotics in the production phase as well as in the assembly phase would be to optimize the entire process. For this reason, it would be interesting to incorporate the robots that have been mentioned above. The MIR with the collaborative could take care of the transport of the material and tool, eliminating or reducing the loss of time due to the movement of people or materials. Moreover collaborative robots could be incorporated in the quality phase, with a 3D scanner, or in the assembly phase, with different claws, to speed up repetitive work.

Finally, the product to be made at the CLF in this case has been a robot capable of moving around the workshop. The robot could serve either to move parts or material from one side to the other. This robot would be customizable, being able to add any new sensor or, as can be seen in the image, a collaborative robot.

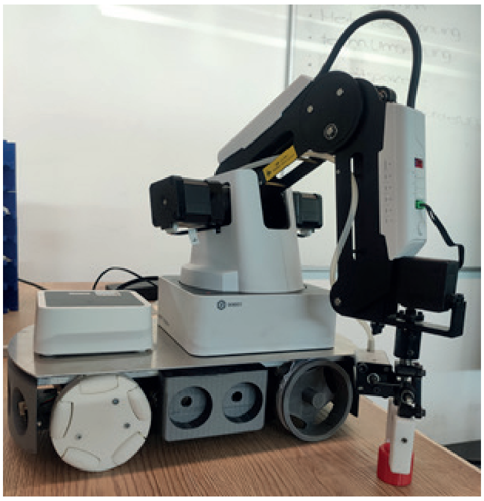

Figure 10: Exam4.0 robot in conjunction with a collaborative robot. Source: Author's creation

2.3. Benefits of using Robotics in EXAM4.0's CLF

The application of robotics in the CLF helps in the correct functioning of the manufacturing and assembly processes. **Among the benefits of inserting robotics in EXAM CLF are:**

- Cost reduction, promoting operational efficiency, reducing production and assembly costs.
- Automation of processes. The processes will become more and more automatic, avoiding errors of manual operators.
- Better monitoring by obtaining information (status, consumption, etc.) in real time.
- Maximum use of resources, making them more efficient.
- Increased safety as robots perform risky tasks.

2.4. Competences addressed with MES

The competences acquired with the robotics can be classified into two groups: Technical and soft competences.

The technical competences are the ones that are most closely related to the technical content to be acquired in the learning process of the students. The insertion of robotics is going to help in developing competences related to I 4.0such 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.

Secondly, about the soft competences that are worked with ERP are:

- **Teamwork:** being a collaborative tool, team members can plan their tasks and all have access to the production sheets, the control sheets....
- **Digital:** they get used to virtual working environments, understanding the data obtained, managing it and drawing conclusions.
- **Personal:** autonomy, initiative, critical spirit, to be aware of the importance of good planning and to see how the decisions taken in the process affect them.
- **Communication:** between students, the one who plans the production with the one who executes it, being aware of the importance of the different explanations (verbal and written) that are given within the production process and that can help achieve a better result.

3 Collaboration opportunities opened by Robotics

In the same way that the robotics domain covers a wide spectrum of technologies (mentioned in section 1), the options for collaboration also vary according to the field of robotics to which we refer. In fact, one of the branches included in robotics is called collaborative robotics.

As a general idea from the point of view of vocational training centres we will mention 2 collaboration fields

- Collaborative robotics.
- Virtualisation of robotics by means of digital twins.

3.1. Collaborative robotics

As the name suggests, COBOTS are designed to work simultaneously with people. Their characteristics offer an important number of applications in industry and also in education. The challenge in our advanced manufacturing labs is to find specific applications where students perform joint tasks for manufacturing parts and using COBOTs. Some examples are: loading and unloading of parts on CNC machines, feeding systems and assembly operations on LFs etc.

3.2. Virtualisation of robotics by means of digital twins

Virtualisation technologies, and especially digital twins technologies, offer great opportunities in the field of robotics.

The generation of virtual models of robots or robotic lines enables us to deepen in the field of robotics without the dependence on physical equipment (robots). Reader can refer to the document "I4.0 technologies #6: Digital twins" for further info.

Besides that, the digital twins of robotics systems enable the easy exchange of information, data and training solutions among different institutions.

4 References

Alp Ustundag, E. C. (2018). Industry 4.0: Managing The Digital Transformation. Instanbul: Springer.

Avansis. (19 October 2021). Retrieved from https://www.avansis.es/sin-categorizar/robotica-industrial/?cn-reloaded=1

Engineering, V. (19 October 2021). Retrieved from https://www.vld-eng.com/blog/tipos-de-robots-industriales/

UNIR. (19 October 2021). Retrieved from https://www.unir.net/ingenieria/revista/robotica-industrial/

THE EXCELLENT ADVANCED MANUFACTURING 4.0

AM 4.0 labs running I4.0 technologies

Technology 10: Additive Manufacturing

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0 Introduction

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The following image shows the overall structure of the piloting process.

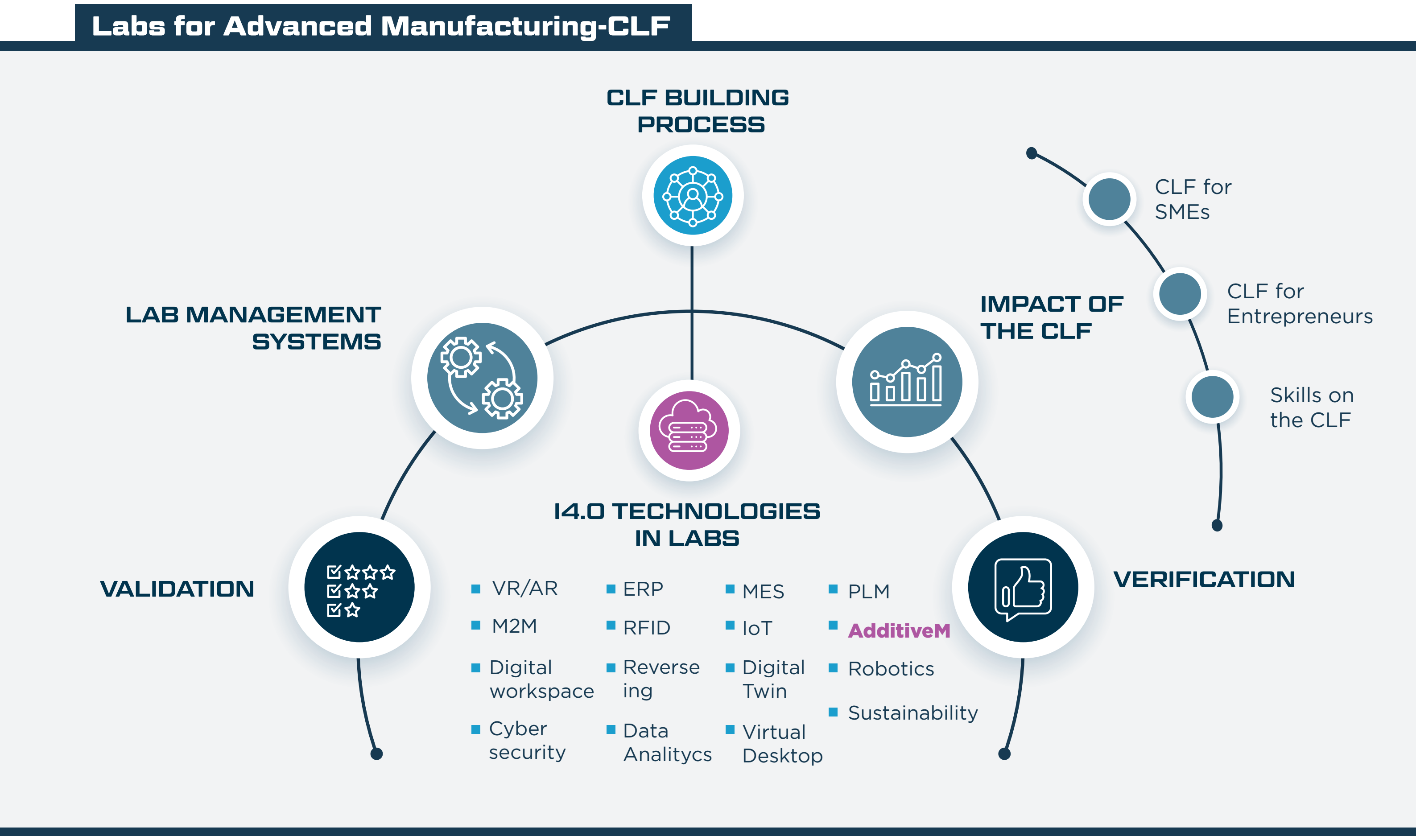

Figure 1: Overall structure of the EXAM4.0 labs piloting process.
Source: EXAM4.0

The present report is the one out of 16 I4.0 technology described within the "Industry 4.0 technologies in labs" section, specifically #10 Additive Manufacturing

1 Definition and application of additive manufacturing in industry

Additive Manufacturing, also called 3D-printing, is a production method that uses a layer by layer technique to manufacture products. Additive Manufacturing works in the most common cases, by either having a powder bed which is sintered with a laser beam or by adding material to a building plate one layer at the time. In both cases one ultra thin layer is added upon the other, ultimately resulting in a fixed 3D-object. Hence does Additive Manufacturing add material when producing components, compared to most other manufacturing methods where material is removed in order to create the final product instead. Additive Manufacturing is based on a 3D-model, in most cases CAD-files exported into STL- files. The CAD-files are simply inserted into a "packing" software that communicates with the printer, the printer will then replicate this file by adding layer after layer of material.

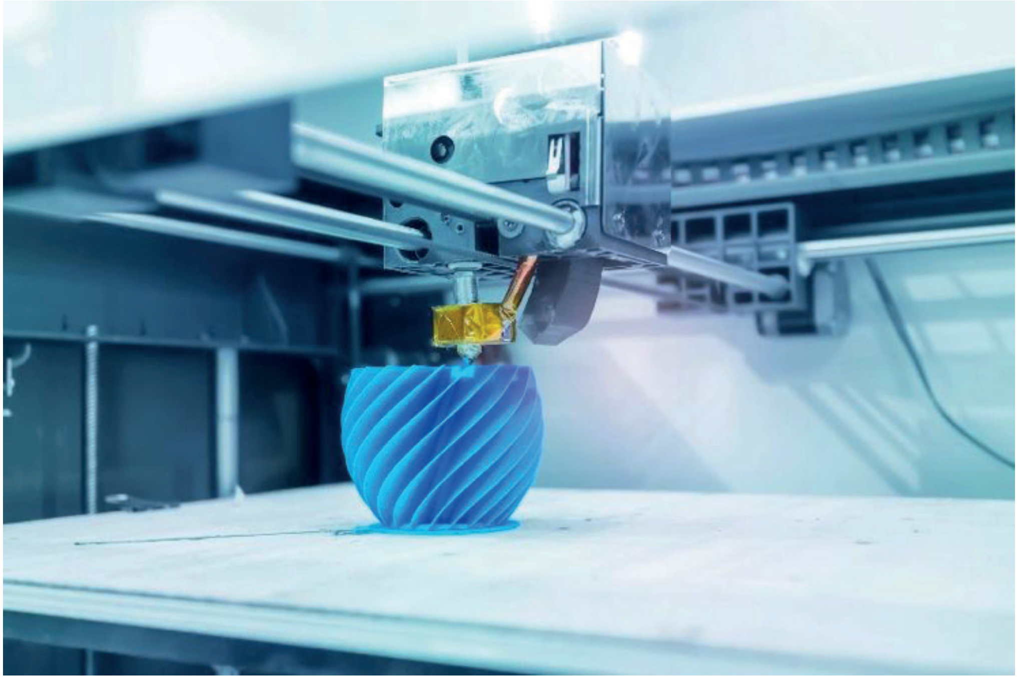

Figure 2: 3D printer printing. Source: SMC

Additive Manufacturing plays a key role in production areas such as aerospace, automotive healthcare, product development and fast prototyping (GE, 2021).

There are a variety of different additive manufacturing processes:

- **Powder Bed Fusion:** Powder Bed Fusion (PBF) technology is used in a variety of Additive Manufacturing processes. These systems use lasers, electron beams or thermal print heads to melt or partially melt ultra-fine layers of material in a three-dimensional space. As the process concludes, excess powder is blasted away from the object.

- **Material Jetting:** A print head moves back and forth, much like the head on a 2D inkjet printer. However, it typically moves on x-, y- and z-axes to create 3D objects. Layers harden as they cool or are cured by ultraviolet light.

- **Binder Jetting:** This is similar to material jetting, except that the print head lays down alternate layers of powdered material and a liquid binder.

- **Material Extrusion:** It is one of the most well-known additive manufacturing processes. Spooled polymers are extruded, or drawn through a heated nozzle mounted on a movable arm. The nozzle moves horizontally while the bed moves vertically, allowing the melted material to be built layer after layer. Proper adhesion between layers occurs through precise temperature control or the use of chemical bonding agents.

- **Directed Energy Deposition:** It is similar to material extrusion, although it can be used with a wider variety of materials, including polymers, ceramics and metals. An electron beam gun or laser mounted on a four- or five-axis arm melts either wire or filament feedstock or powder.

- **Sheet Lamination:** Laminated object manufacturing (LOM) and ultrasonic additive manufacturing (UAM) are two sheet lamination methods. LOM uses alternate layers of paper and adhesive, while UAM employs thin metal sheets conjoined through ultrasonic welding. LOM excels at creating objects ideal for visual or aesthetic modeling. UAM is a relatively low-temperature, low-energy process used with various metals, including titanium, stainless steel and aluminum.

- **Vat Polymerization:** With vat photopolymerization, an object is created in a vat of a liquid resin photopolymer. A process called photopolymerization cures each microfine resin layer using ultraviolet (UV) light precisely directed by mirrors.

2 Additive manufacturing in HVET/VET labs

In this section we describe how Additive Manufacturing can be implemented in VET/HVET-centre labs. Different options and applications are described.

There are numerous learning possibilities when it comes to Additive Manufacturing at VET-centres.

A 3D-printing machine works as mentioned previously, by inserting a 3D-file into a software that is connected to the machine, the machine will replicate this file in order to manufacture the products. Additive Manufacturing opens up new manufacturing possibilities which are difficult to obtain with other production methods. 3D-printing makes it possible to create complex designs such as internal fixtures. It does however come with requirements as well, and these requirements vary depending on the type of machine and the 3D-printing method that is used. For example, support material must be added in the majority of all 3D-printing machines. This applies, in most cases, to machines that place material on a building plate or machines that print with metal, machines with powder bed fusion do, most often, not need support material. One learning possibility is therefore for students to think beyond the traditional thinking when it comes to designing products, and learning how to design new products for 3D-printing or use the benefits that comes with 3D-printing for product development.

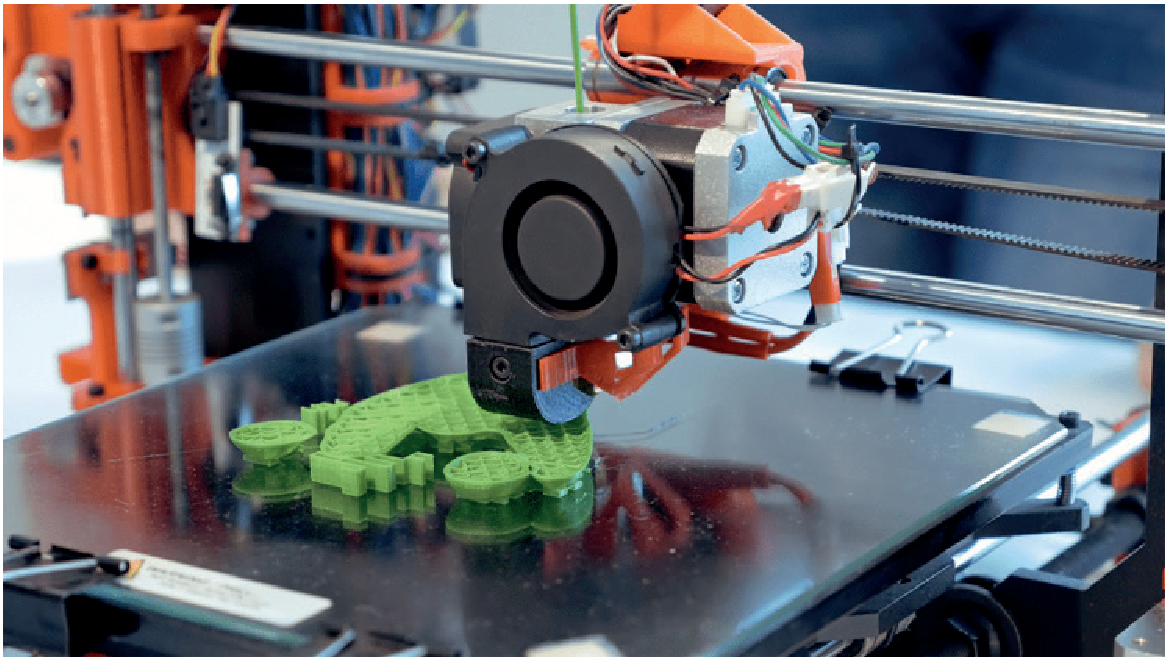

Figure 3: 3D printer working.
Source: https://ecolink.com/info/why-is-it-called-additive-manufacturing/

Another important aspect is the hands-on learning of the machines. The students will learn how to handle the machines in the lab, including aspects like manoeuvring the software and cleaning machines as well as maintenance. These factors will make the students independent in the whole process of manufacturing products via Additive Manufacturing.

2.1. Integration of additive manufacturing in Curt Nicolin Gymnasiet lab

Curt Nicolin Gymnasiet has implemented different 3D-printers in the labs at the school. The variety of printers ensures the possibility of teaching different methods.

The largest owner company of the school is heavily investing in SLM 3D-printers. Curt Nicolin Gymnasiet has a scale-down learning factory of this company's 3D-printing workshop. It uses a similar machine, from the same brand, but with nylon as material instead of metal. The process from idea to finished product in Curt Nicolin Gymnasiet's learning factory is very similar to the one at the company workshop.

Figure 4: Curt Nicolin Gymnasiet 3D printing machines.
Source: Curt Nicolin Gymnasiet

Curt Nicolin Gymnasiet has implemented numerous FFF 3D-printers in the labs. These are more economical to use and are therefore even more beneficial for education. They are useful for students to produce both prototypes and products for school projects. They also show that there are different methods regarding Additive Manufacturing available and the students will learn which method is beneficial for different purposes.

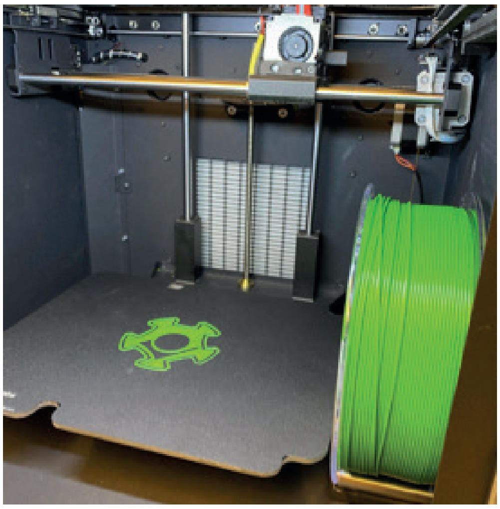

Figure 5: 3D printer adapted to I4.0 in Curt Nicolin Gymnasiet. Source: Curt Nicolin Gymnasiet

This printer has been adapted to I4.0 by connecting it to the Internet and adding a camera, making it possible to start and operate it from anywhere. The printer is also connected to a PLC, and a collaborative robot can start the printer as well as change the building plate.

2.2. Integration of additive manufacturing in Tknika's lab

Tknika's Additive Manufacturing (AM) lab is part of the net of AM lab programme IKASLAB of the Vocational Education and Training Basque System. It includes 20 VET Centers in the Basque Country.

Tknika's IKASLAB works only with teachers and it has been introducing industrial equipment in order to test, practice and learn from different **AM technologies and applications:**

Figure 6: Tknika's Ikaslab machines (FDM, Polyjet and ADAM). Source: Tknika

Stratasys FDM technology (filament), Stratasys Polyjet J750 DAP (resin), HP Multijet Fusion 4210(powder), Formlabs 3BL (resin), Markforged Metal X (metal filament).

Figure 7: Tknika's lab for HP Multijet Fusion technology. Source: Tknika

The aim of Tknika´s lab is to introduce Additive Manufacturing in education through 2 lines of work:

- The management of the net of labs, by sharing experiences where AM is introduced to teachers and students in all sorts of studies.

- Obtain knowledge of advanced applications by the development of projects including the practice with industrial additive manufacturing equipment of Tknika, by teachers of all the net of AM labs: learning by doing.

2.3. Role of the additive manufacturing in the EXAM4.0 CLF

The CLF that is going to be launched has divided its production process into 4 stages (product design, process engineering, production and assembly) as can be seen in the following image. Within these stages, additive manufacturing is going to be incorporated in the production stage

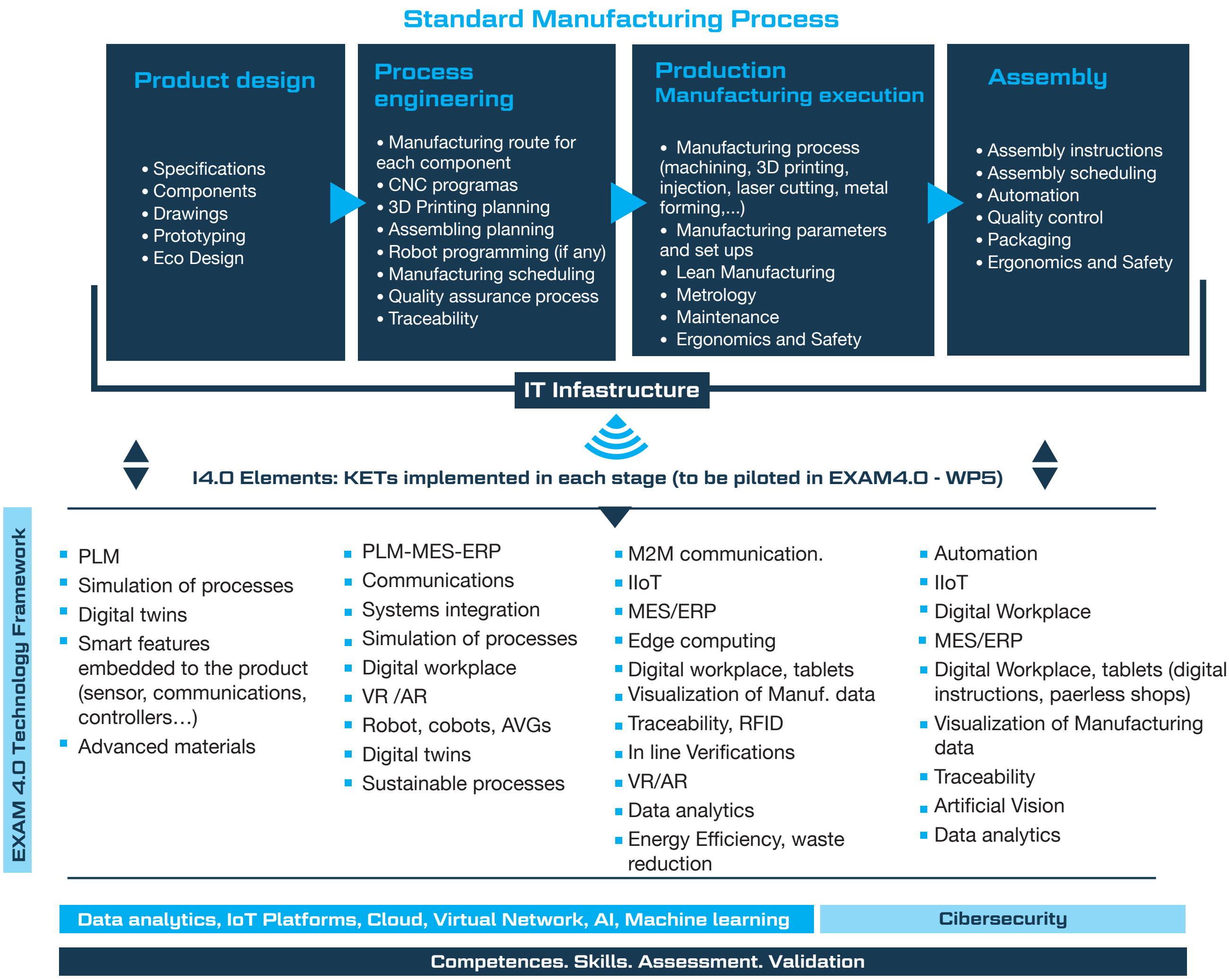

Figure 8: EXAM4.0 CLF value chain Source: Author's creation

Additive Manufacturing plays a key role in the EXAM 4.0 CLF as the main production method for the products of the EXAM robot. Additive manufacturing is used both for the production of prototypes and the actual components produced in the collaborative learning factory. Additive Manufacturing is a very effective method for producing plastic components in low quantities and is therefore the superior option for the EXAM robot.

Additive Manufacturing will have another important role within the CLF, except for producing parts for the EXAM robot. Additive Manufacturing is a growing business but yet quite expensive to invest in for educational purposes. Additive Manufacturing, together with other important technologies that are included in the CLF, will be available for partners who do not have advanced manufacturing resources themselves.

2.4. Benefits of using of additive manufacturing in EXAM4.0's CLF

When it comes to inserting additive manufacturing into the CLF it allows the creation of lighter, more complex designs that are too difficult or too expensive to build using other machining techniques. In the CLF, by not having a production of large runs, gives you the ability to create complex unit parts cheaply and with adequate mechanical properties. It is also a suitable tool when it comes to creating customizations in the robot.

It also excels at rapid prototyping. Since the process eliminates intermediate steps, modifications are possible on the fly. It offers a more dynamic process, being able to test and discover improvements.

2.5. Competences addressed with additive manufacturing

According to student's competences, they will practice their creativity skills by designing parts for Additive Manufacturing, thus thinking beyond the traditional way of designing products for production. Students will learn DfAM (Design for Additive Manufacturing). The method DfAM removes the limitations of conventional manufacturing.

Students will upskill their technical expertise by operating the additive manufacturing machines and equipment.

Critical thinking can be explained as the analysing of facts to form a judgement (Wikipedia, 2021). Additive Manufacturing is a relatively new production method, which leads to new problems and challenges. It is therefore important to have good critical thinking in order to make good decisions out of new information. New problems also result in the requirement to improve problem solving skills in order to come up with quality solutions to these issues.

It is possible to produce parts in various materials when it comes to Additive Manufacturing. This requires material handling skills. Some metal powder that is used are only the size of 0.015 to 0.045 mm, and these particles result in health risks. This requires extreme material handling skills as well as safety skills.

3 Collaboration opportunities opened by additive manufacturing

Given the need for speed, adaptation, flexibility and low costs in manufacturing processes, 'additive manufacturing' emerges. These attributes make it a suitable tool for collaboration between different centers.

First of all, it is a suitable tool for solving different problems or errors that may appear in the robot. The possibility of manufacturing complex parts quickly and easily means that any failure or improvement of the product is solved in an efficient way. As you work on CAD files, these solutions can be sent to other centers instantly.

On the other hand, robot improvements can be worked on between teams from different centers.

In addition, these attributes also make it a tool that enables product customization, since each center can create different accessories for the different uses they have. In turn, groups could be created to develop solutions to emerging needs.

4 References

GE. (25 October 2021). Retrieved from https://www.ge.com/additive/what-additive-manufacturing

Wikipedia. (29 September 2021). Retrieved from https://en.wikipedia.org/wiki/Critical_thinking

EXAM 4.0

THE EXCELLENT ADVANCED MANUFACTURING 4.0

AM 4.0 labs running I4.0 technologies

Technology 11: Virtual Desktops

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Piloting the Advanced Manufacturing workshop 4.0

03

This project has been funded with support from the European Commission. This publication reflects the views only of the author, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

Table of figures

0 Introduction

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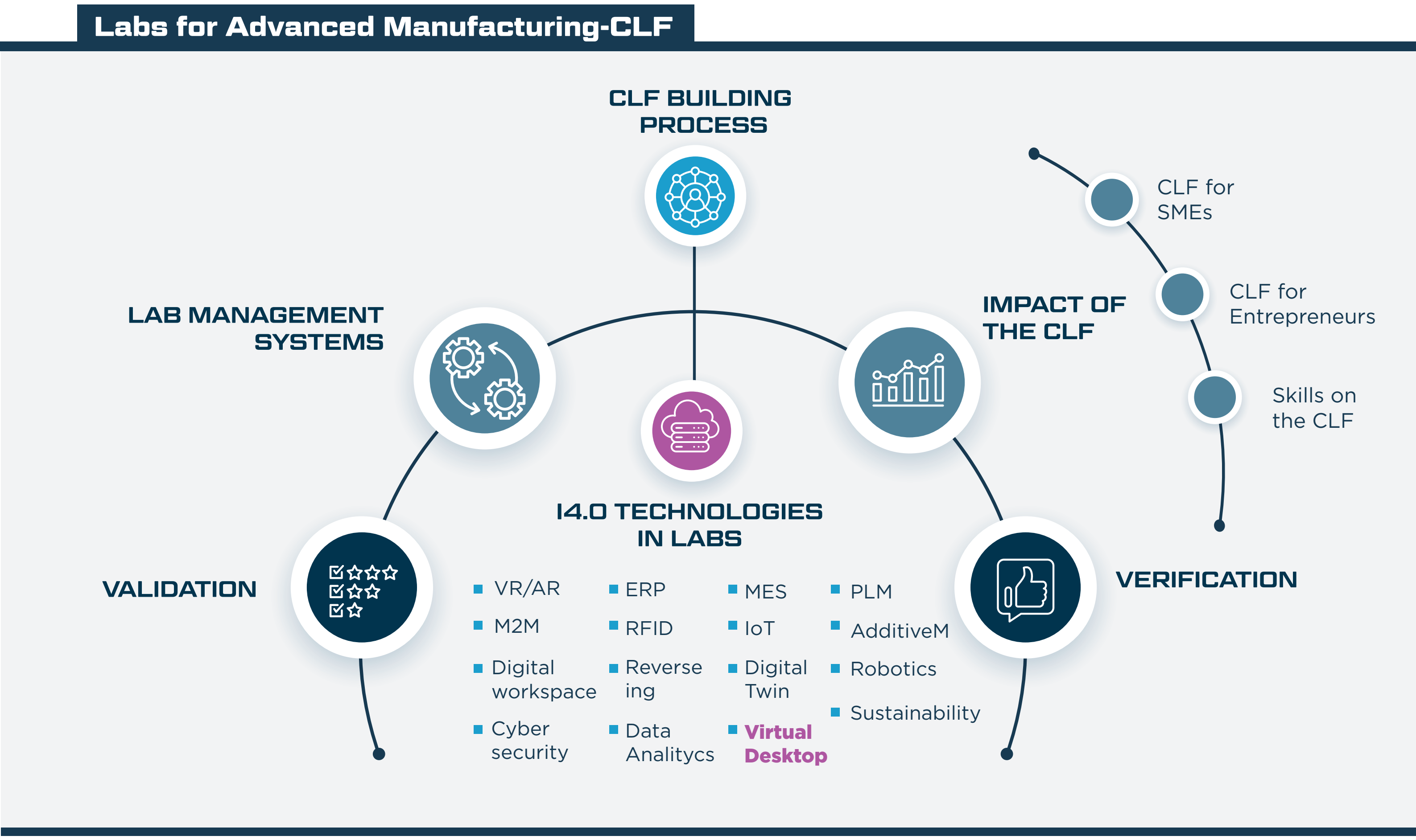

Figure 1: Overall structure of the EXAM4.0 labs piloting process. Source: EXAM4.0

The present report is the one out of 16 I4.0 technology described within the "Industry 4.0 technologies in labs" section, specifically #11 Virtual desktops

1 Definition and application of Virtual Desktop in industry

Virtual desktops are preconfigured images of operating systems and applications in which the desktop environment is separate from the physical device used to access it. Users can access their virtual desktops remotely and with any device (Vmware, 2021).

Virtual desktops are often centrally managed, eliminating the need to install updates and applications on individual machines. In addition, the access points can be less powerful, since most of the computing processes take place in the data center. Data is also stored in the data center and not on individual machines, which can improve data security.

The only restriction is that the system that supports virtualization must have sufficient resources, such as RAM memory, speed of reading, access and transfer to disk, processor speed, etc. That is, each virtualization relies on specific physical resources of a real machine, and those resources are fully reserved for each virtualization (Arsys, 2021).

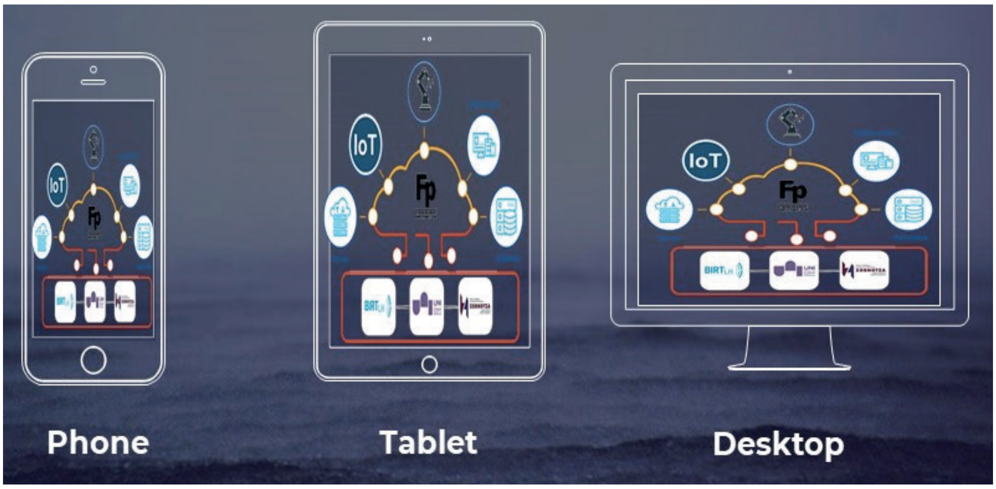

Figure 2: FProject Virtual Desktops in 3 devices. Source: FProject

There are two main types of virtual desktops: VDI and DaaS. The first type is Virtual Desktop Infrastructure, and it refers to the technology that allows organizations to run them in virtual machines installed on on-premises or external servers, such as IaaS. The second type is the Desktop as a Service, which offers basically the same thing, but with the particularity that the Cloud provider is in charge of providing resources, creating images or making the necessary updates.

2 Virtual Desktop in HVET/VET labs

2.1. Integration of Virtual Desktop in Miguel Altuna's lab

In the first place, servers that would support the virtual desktops will have to be purchased or rented. A server is a computer specifically designed to process information and programs, and distribute them among the computers that are connected to it. They are designed to support high workloads and/or so that they are always available and users can access their resources, be it software, data, etc. When designing a server/-client network it is important to take into account:

- The manufacturer
- The necessary hardware
- The needs of the company

MIGUEL ALTUNA'S LAB SERVERS

Name	Characteristics
Supermicro 1U AMD EPYC 10xNVMe 16xDDR4 server	(2x 10 Gbps / 2 PCIe 16x / 2 F.A. 750W redundante) 1 x CPU AMD Epyc 7282 (16c/32t) 512 GB (8 x dimm 64 GB 3200 MHz ECC) 2 x Samsung PM983 1.92TB NVMe PCIe 3x4 V4 TLC 2.5" 7mm 1 x SSD NVMe PM983 SAMSUNG 960GB M.2, TLC
ASUS para GPUs Nvidia server	2U Amd Rome, 8x DDR4, 8x HDD, 2x PWS 1600W 1 x CPU AMD Epyc 7282 (16c/32t) 512 GB (8 x dimm 64 GB 3200 MHz ECC) 2 x Samsung PM983 1.92TB NVMe PCIe 3x4 V4 TLC 2.5" 7mm SSD Intel D3 S4510 960GB
Nvidia Tesla A40	
Nvidia T4	

Second, the installation of the necessary software is needed. They carry their own operating system (different from a desktop computer) and they allow, among other things: the creation of user profiles, passwords, remote administration, etc. Typically, computers that perform server roles carry a server operating system. In the case of Miguel Altuna, a Microsoft software is installed. In the case of Microsoft, the family of operating systems intended for use with servers is Windows Server. Server operating systems usually do without those utilities more intended for the end user. At the same time, they incorporate their own tools for managing the network and resources.

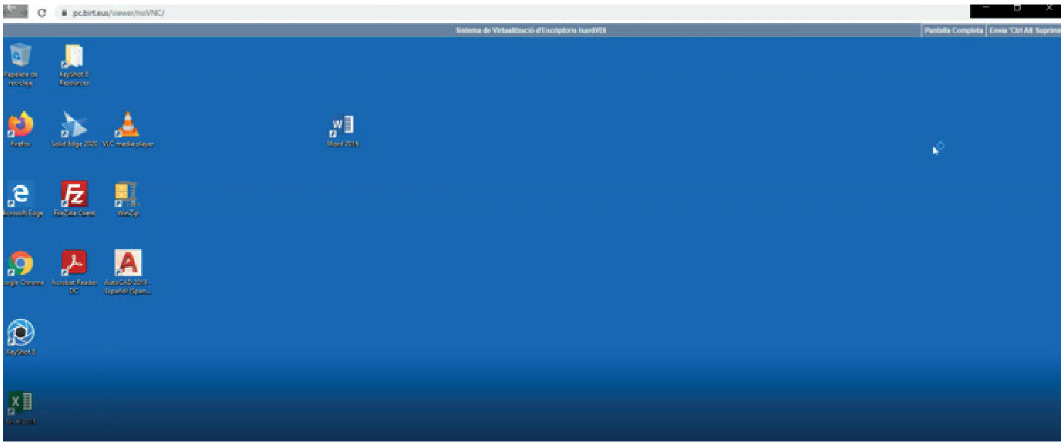

Figure 3: FProject virtual desktop with windows software. Source: FProject

Once the software is installed, the necessary applications will be installed (MES, PLM, ERP, etc.) with their respective license numbers. Depending on the use and number of users, the virtual desktop partition will have to be made. Once the partition is made, each HVET will take the number of virtual desktops that correspond to it.

Figure 4: FProject desktops partition. Source: FProject

2.2. Role of Virtual Desktop in the EXAM4.0 CLF

The CLF that is going to be launched has divided its production process into 4 stages (product design, process engineering, production and assembly) as can be seen in the following image. Within these stages, Virtual Desktop is going to be incorporated in all of those stages.

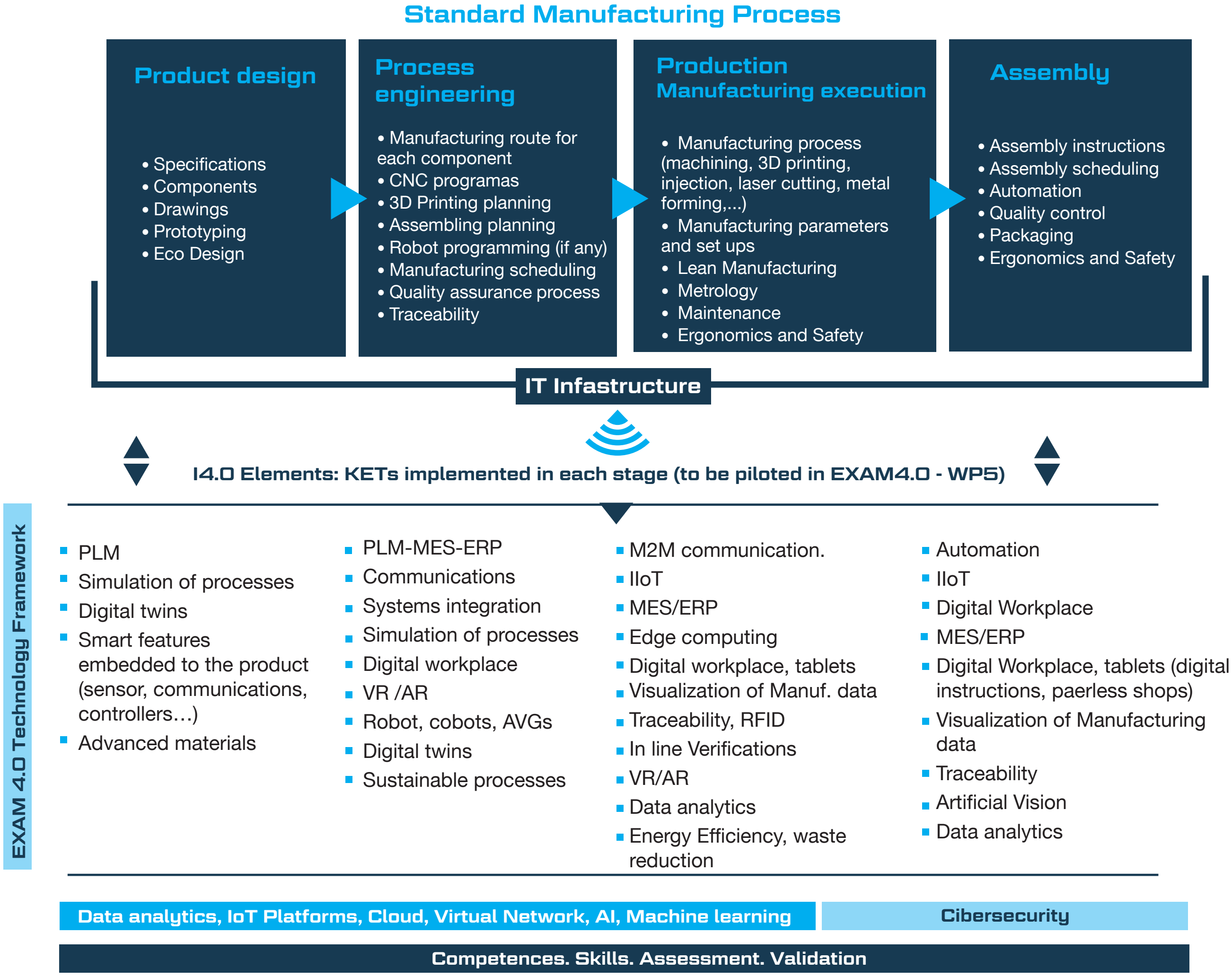

Figure 5: EXAM4.0 CLF value chain Source: Author's creation

The main function of the introduction of this element would be to support all the applications of the production process. In this way the MES, ERP, PLM and other programs would be centralized, being accessible to them from any workshop and with any device.

The situation generated by the Covid19 confinement has increased the need for access to the resources of the centers from anywhere. The lack of access to these resources has made it impossible for students to receive optimal training. In addition to confinement, for online training, reverse training and dual training, access to these resources at any time and from anywhere is essential.

On the other hand, their management wants to emphasize that the use of resources will be maximized by being accessible at all times. It will increase the longevity of the computer parks belonging to centers, students and teachers since practically all the computation will be supported by the Cloud.

Another aspect to emphasize is the opportunity that will be given to students who cannot afford the acquisition of adequate computer equipment to carry out their studies. Finally, with this solution the maintenance of classrooms with computer equipment will be greatly simplified.

2.3. Benefits of using Virtual Desktop in the EXAM4.0 CLF

The fact that the Virtual Desktops are located at one point and work from the network, brings many benefits. Among them are:

- **Reduction of support, infrastructure and hardware costs and new deployments.** All the equipment would be installed in one of the workshops or would be subcontracted, making purchase and maintenance easier and cheaper.

- **High scalability and flexibility.** Having a virtual desktop infrastructure in the cloud allows you to easily increase the number of desktops, in this way it would be easy when more HVETs wanted to participate.

- **Increased productivity and flexibility.** The individual workspace will always be available, regardless of where the employee is or what access device they use. This allows you to keep up with your work without interruptions while traveling or from home if necessary.

Figure 6 working anywhere and anytime of FProject. Source: FProject

- **More storage space.** The capacity of the cloud is not infinite, but almost. By using virtual desktop technology each user will have access to much more storage space for applications and files than they would have on a physical hard drive on their device. This is especially important if they are working with mobile devices, such as smartphones or tablets, which do not usually have a large storage capacity.

- **Increased information security.** Working with a remote virtual desktop means that the data is no longer on the device, but is stored in the cloud. Thus, in the event of a breakdown, theft or cyber-attack directed at the physical device, the information is safe and backed by one or more backup copies in the cloud.

2.4. Competences addressed with Virtual Desktop

The insertion of Virtual desktop technology is going to help on developing competences such 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. The individual workspace becomes always available, regardless of where the employee is or what access device they use. This allows to maintain the rhythm of work regardless of the devices that the HVETs have. Furthermore, in the event that a new center wanted to participate, it would not need a large investment in computer equipment.

3 Collaboration opportunities opened by Virtual Desktop

The technology itself is a collaborative facilitator. Having a unified server to pull from exempts other HVETs from having to upgrade their hardware for capacity reasons. This also helps delay scheduled obsolescence, as capacity is not associated with the hardware but with the server.

In addition, by having to install the licenses of the applications on this server, the licensing contracts will be made between all the HVETs, being able to get lower prices by hiring more quantities of licenses.

Finally, taking into account the benefits of working from wherever you want and the scalability it has, it makes it possible for new participants to participate at any time and regardless of their hardware level.

4 References

Arsys. (06 October 2021). Retrieved from
https://www.arsys.es/blog/escritorios-virtuales/

Vmware. (06 October 2021). Retrieved from
https://www.vmware.com/es/topics/glossary/content/virtual-desktops.html

THE EXCELLENT ADVANCED MANUFACTURING 4.0

AM 4.0 labs running I4.0 technologies

Technology 12: Digital workplace

12/15

Piloting the Advanced Manufacturing workshop 4.0

03

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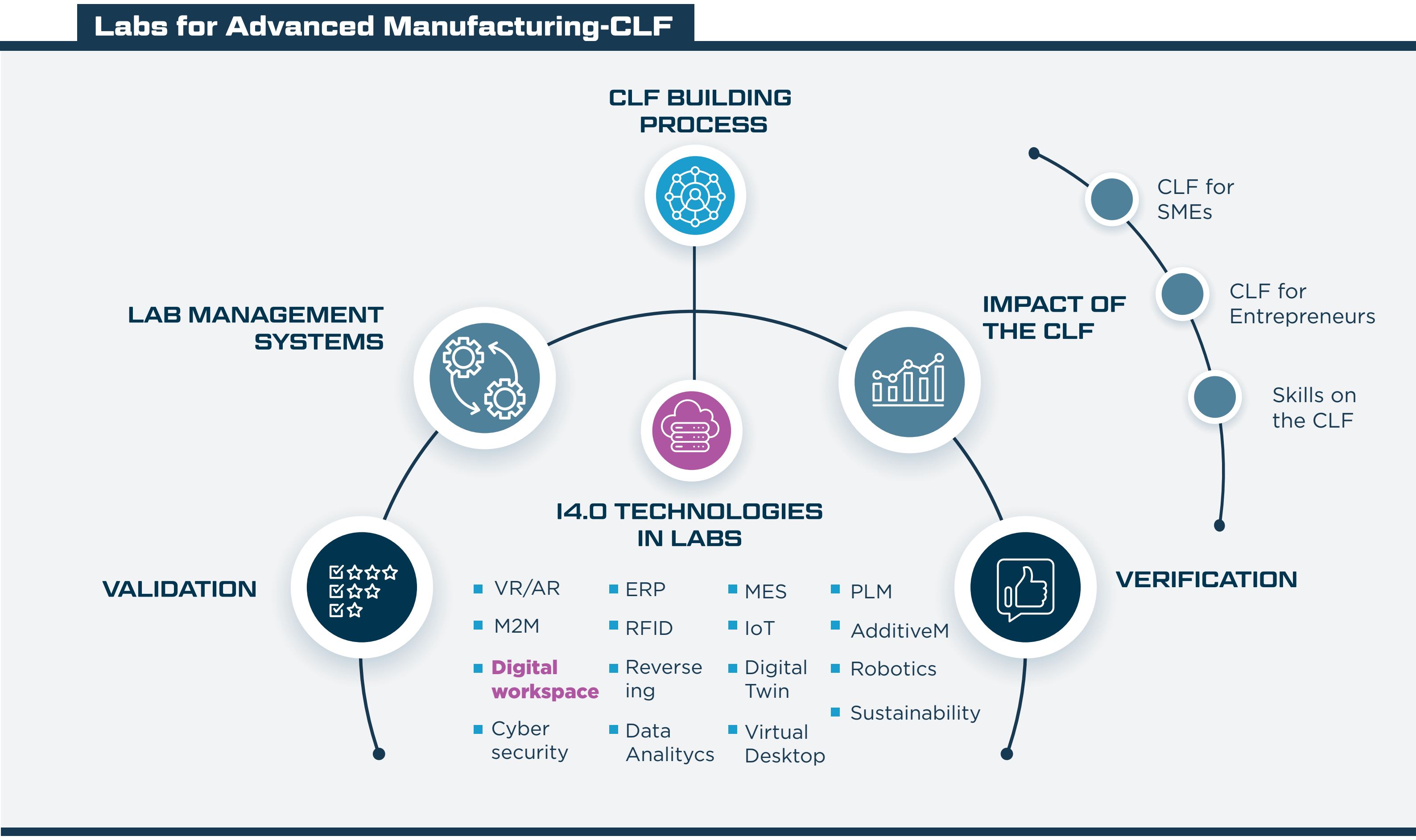

Figure 1: Overall structure of the EXAM4.0 labs piloting process.
Source: EXAM4.0

The present report is the one out of 16 I4.0 technology described within the "Industry 4.0 technologies in labs" section, specifically #12 Digital Workplace

1 Definition and application of digital workplace in industry

“The digital workplace strategically unifies an organization’s employees and the technologies they use in an ecosystem that strives to facilitate agile ways of working, improve employee engagement and deliver an exceptional experience for its users“
Simon Dance – CEO, Interact Software.

When we unpick it, we can see it comprises of three core elements (Interactsoftware, 2021):

- **People:** The employees, their digital needs and the impact that has on key indicators such as engagement, productivity and innovation – but also the resulting impact on the customers/consumers, suppliers and stakeholders.

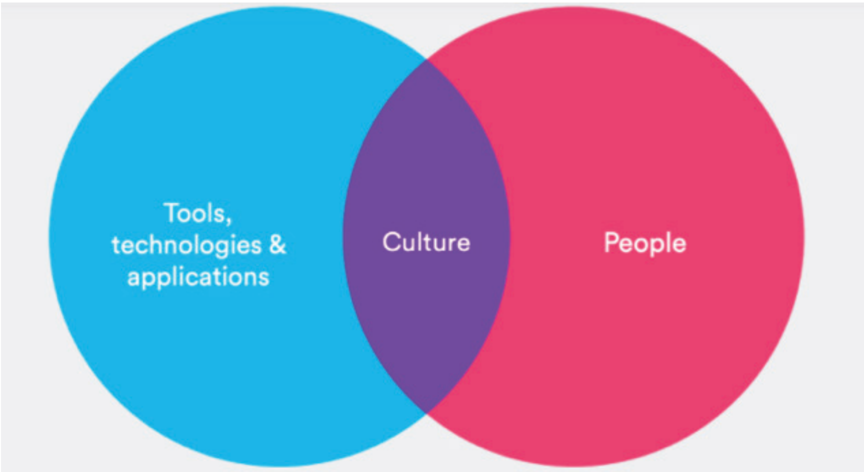

Figure 2: The 3 elements of a digital workplace. Source: https://www.interactsoftware.com/blog/what-is-a-digital-workplace/

- **Tools:** The technologies and applications that make up the ‘digital’ element of how they communicate, collaborate and work day-to-day.

- **Culture:** When these two elements – people, and tools – come together in a strategic and considered way, they collectively shape the employee experience. Aligning this with the business mission, values and overall direction, it becomes the foundation of the corporate culture and drives employee engagement.

Creating a digital workplace strategy does not have to be an overwhelming task. By asking the right questions and taking stock, their own digital transformation objectives can be figured out. **As part of the process, this has to be considered:**

- Who are our employees and what do they need to do their job well?
- What technologies already make up our digital workplace?
- What gaps are there between employee needs and available tools?
- Can every employee connect to the information and tools they need, regardless of their device or location?
- Do our employees understand our organization, its direction and purpose, and how they contribute to the achievement of the goals?
- Do our systems integrate or work effectively together?
- Are we leveraging an effective digital workplace platform or intranet solution to give our employees a central access point to our digital workplace?
- How is the employee experience of our current digital workplace?
- What do we envision for the future of our digital workplace?
- How does our digital workplace align with, or contribute to, our organization's mission, objectives and overall culture?

Understanding the people of the company and picking the right tools for the digital toolbox is just the start. Strategy considers the experience created as a result. There is a huge difference between simply having a collection of tools and technologies, labelling those as the 'digital workplace' – and taking a strategic, holistic approach to designing and nurturing an effective digital work experience.

The fact is that, the digital workplace is an ongoing process. It has existed, in one guise or another, for decades. It will continue to grow, reshape and redefine itself indefinitely.

We cannot expect to undertake a single digital transformation program – buy some new software, ask our staff what they need – and tick it off the to-do list. We have to keep revisiting it. It is critical to be flexible enough to respond to this new reality, to embrace and adapt to the new waves of change that will continue to disrupt the way we work.

A digital workplace is a conscious and ongoing commitment. It needs to combine a long-term vision, governing principles, a process of measurement and continual evaluation points. We cannot stop this evolution but we can steer and choose its direction to our convenience.

The digitalization of workplaces brings many opportunities to facilitate work tasks. The following is a non-exclusive list of functionalities of Digital Workplaces (Deloitte, 2021).

- Real-time tracking of manufacturing processes, operation times per step and progress
- Digital documentation, drawings, troubleshooting guides and checklists
- Digital work orders with detailed description of tasks and their sequence
- Automatic OEE calculation
- Digital process optimisation based on machine and quality data (data analysis)
- Digitalized Quality guidelines
- Automatic raw material/product in process management
- Predictive Maintenance instructions
- Digital assistance for corrective maintenance tasks. Remote support's option
- AR assistance tools
- Training on the flow of work
- Safety/ergonomics' instructions and guidelines

From an education perspective, digital workplaces offer a number of extra alternatives, which are discussed in the following section.

2 Digital workplace in HVET/VET labs

In the previous section we have analyzed the features of a digital workplace in a Smart Factory. If we come to an educational environment, it is possible to take the best of the digital workplace and also to enhance the learning experience of the students. Not only the features related to production aspects of a LF are easy to implement but also features related to the pedagogical process would be available in the labs.

Taking into account the students or the user, the following functions could be implemented:

- Make accessible the necessary information for the project or work such as: plans, process sheets, quality criteria, measurement processes, delays, tool states ...
- Provide content to carry out the work (video tutorials, documents, AR / VR ...)
- Facilitate maintenance instructions
- Show the degree of development of the work (% of work done, % of work to be done, delays, status of work ...)
- Show expected learning results
- Show OEE, stoppages and their reasons

Taking into account the teachers, the following functions could be implemented:

- Report on student performance: machining times, measurements, material used ...
- Report on the status of students: arrears, work done ...
- Allow to insert necessary information to aid in training
- Allow a predictive maintenance
- Allow training on the flow of the work
- Improve the quality of teaching
- Ensure safety
- Control the stock of material and tool

2.1. Integration of digital workplace in Miguel Altuna's lab

The Miguel Altuna HVET centre mainly offers training in different disciplines of machining, in addition to automation and robotics or administration and finance. That is why it has a 2000m2 machining lab, in which you can find different machines (milling machines, lathes, CNC, grinding, EDM, mechatronics, stamping and welding) divided in 8 different cells, where students from 6 study programs practice.

Figure 3: Miguel Altunas's Machining lab. Source: Miguel Altuna

The strategy of the centre is to implement Industry 4.0 technology in the Mechanical Manufacturing lab, with the aim of accustoming students and teachers to work in a digitized environment.

The laboratory, which is in evolution, has the following characteristics:

- Connected machines
- Smart warehouse
- HMI

The first step was to connect the machines. For this, each machine has been coupled with an RFID reader, an HMI and a signalling beacon; and that, together with the machine, is connected to a PLC that through a WI-FI receiver is connected to the specific network of the lab (used to work on cybersecurity) that is connected to the server where the data is stored.

Figure 4: Student booking the machine. Source: Migeul Altuna

The RFID reader is used to reserve the machine. Each student has their own RFID card that they will have to use to reserve the machine. This reservation can only be done at the machines and at the assigned time. This way, you avoid students starting up machines without supervision, reducing the number of accidents.

Once you make the reservation, the signalling beacon will change colour indicating that the machine is busy. In the event of a breakdown, the beacon will indicate a breakdown so that no one reserves the machine and the maintenance staff notices.

Before starting the machine, students will have to confirm that they are wearing the PPEs (Personal Protective Equipment). It is a way of creating awareness in order to reduce accidents.

Figure 5: Student confirming the individual safety equipment. Source: Miguel Altuna

The last function of the HMI is that each student has their personalized documentation. Through their own server, each student will have access to the documentation necessary for the manufacturing of the parts. The objective is to have 0 paper in the lab.

Figure 6: Documentation of a student for manufacturing. Source: Miguel Altuna

The second step is to have a smart warehouse. Thus, the location of each tool in the warehouse is controlled by means of RFID to speed up searches. By means of RFID detection arches, it is also possible to know who has taken them and consequently where the student is using them.

Figure 7: RFID reader arch for tools and users. Source: Miguel Altuna

2.2. Role of the digital workplace in the EXAM4.0 CLF

The CLF that is going to be launched has divided its production process into 4 stages (product design, process engineering, production and assembly) as can be seen in the following image. Within these stages, the digital workplace is going to be incorporated in all of those stages.

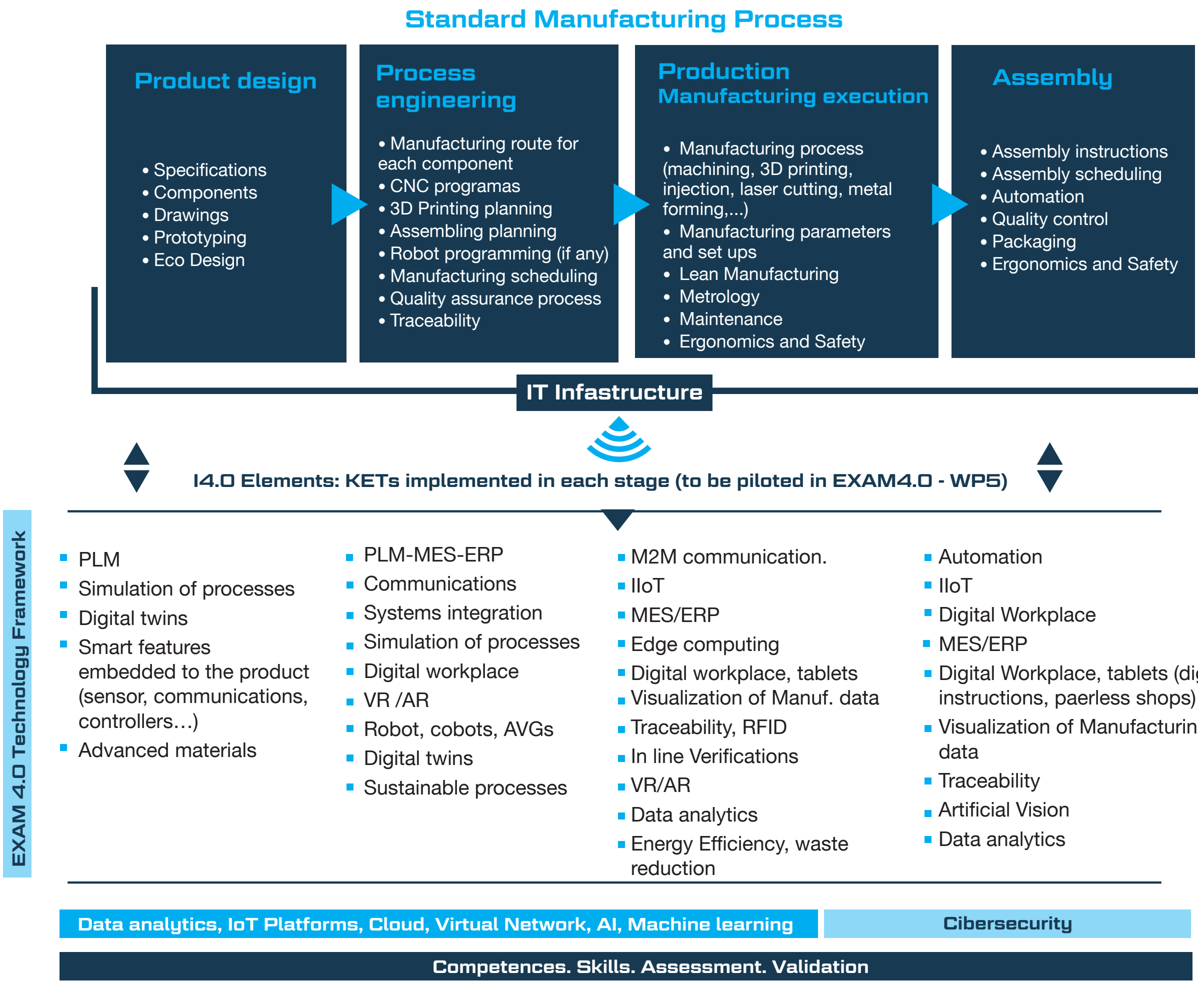

Figure 8: EXAM4.0 CLF value chain Source: Author's creation

The fact that it is a Collaborative Learning Factory (CLF) makes it essential to create a digitized working environment. For the robot's production to be done in an optimal way, it is necessary that certain data be collected and sent in real time. This can be achieved through the digitization of the machines and processes that will dump the data to apps such as MES, ERP ... that allow us to work in a collaborative and coordinated way.

Taking into account that the objective is to work with advanced manufacturing, it is impossible to achieve this without incorporating the technologies of Industry 4.0. One of the characteristics of this technology is that it is connected and that it improves the process by obtaining and analyzing the data obtained.

2.3. Benefits of to the use of digital workplace in EXAM4.0's CLF

The application of a digital workplace in the CLF helps in the proper functioning of the process. That is to say, you can make sure that students from different HVET are able to work with optimum productivity. Among other points it improves:

- Collaborate with team members
- Manage projects and tasks with full visibility
- Resolve issues, tickets, defects, and service requests
- Automate standard and repetitive business processes that require approvals
- Integrate third-party applications
- Auto-generate reports to make better data-driven decisions

2.4 Competences addressed with digital workplace

The competencies acquired with a digital workplace can be classified into two groups: Technical and soft competences.

The technical competences are the ones that are most closely related to the technical content to be acquired in the learning process of the students, in this case Machining Technicians, Mechanical Production Scheduling Staff and Industrial Design. **Among other technical competences the main ones are:**

- Greater awareness of the production process, from raw materials to part verification
- Calculation of costs and time
- Production scheduling
- Stock management (raw material, tools, etc.)
- Relationship with different suppliers
- Data analysis
- Improvements to be made in the production process

Secondly, as for the soft competences developed with ERP are:

- **Teamwork**: being a collaborative tool, team members can plan their tasks and all have access to the production sheets, the control sheets....

- **Digital awareness:** they get used to virtual working environments, understanding the data obtained, managing it and drawing conclusions.

- **Personal:** autonomy, initiative, critical spirit, to be aware of the importance of good planning and to see how the decisions taken in the process affect them.

- **Communication:** between different students, the one who plans the production with the one who executes it, being aware of the importance of the different explanations (verbal and written) that are given within the production process and that can help achieve a better result

3 Collaboration opportunities opened by digital workplace

On the one hand, when it comes to digitizing workstations, a lot of data is obtained about production, assembly and distribution processes. The accessibility to this data makes it easier for HVET that do not have such an infrastructure to work with real data. In this way, we bring the teaching-learning processes of other centers with less infrastructure closer to reality.

On the other hand, the fact that everything flows over a digitized environment makes the process scalable. With the fulfillment of certain requirements and licenses, any HVET will be able to enter and participate if they want.

4 References

Deloitte. (19 October 2021). Retrieved from https://www2.deloitte.com/content/dam/Deloitte/mx/Documents/human-capital/The_digital_workplace.pdf

Interactsoftware. (18 October 2021). Retrieved from https://www.interactsoftware.com/blog/what-is-a-digital-workplace/

THE EXCELLENT ADVANCED MANUFACTURING 4.0

AM 4.0 labs running I4.0 technologies

Technology 13: PLM

13/15

Piloting the Advanced Manufacturing workshop 4.0

03

This project has been funded with support from the European Commission. This publication reflects the views only of the author, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

Table of figures

0 Introduction

Following the piloting process of Advanced Manufacturing Labs for HVET/VET through the Collaborative Learning Factory (hereafter CLF), the EXAM4.0 partners we have piloted 16 technologies embedded in Industry 4.0

The following image shows the overall structure of the piloting process.

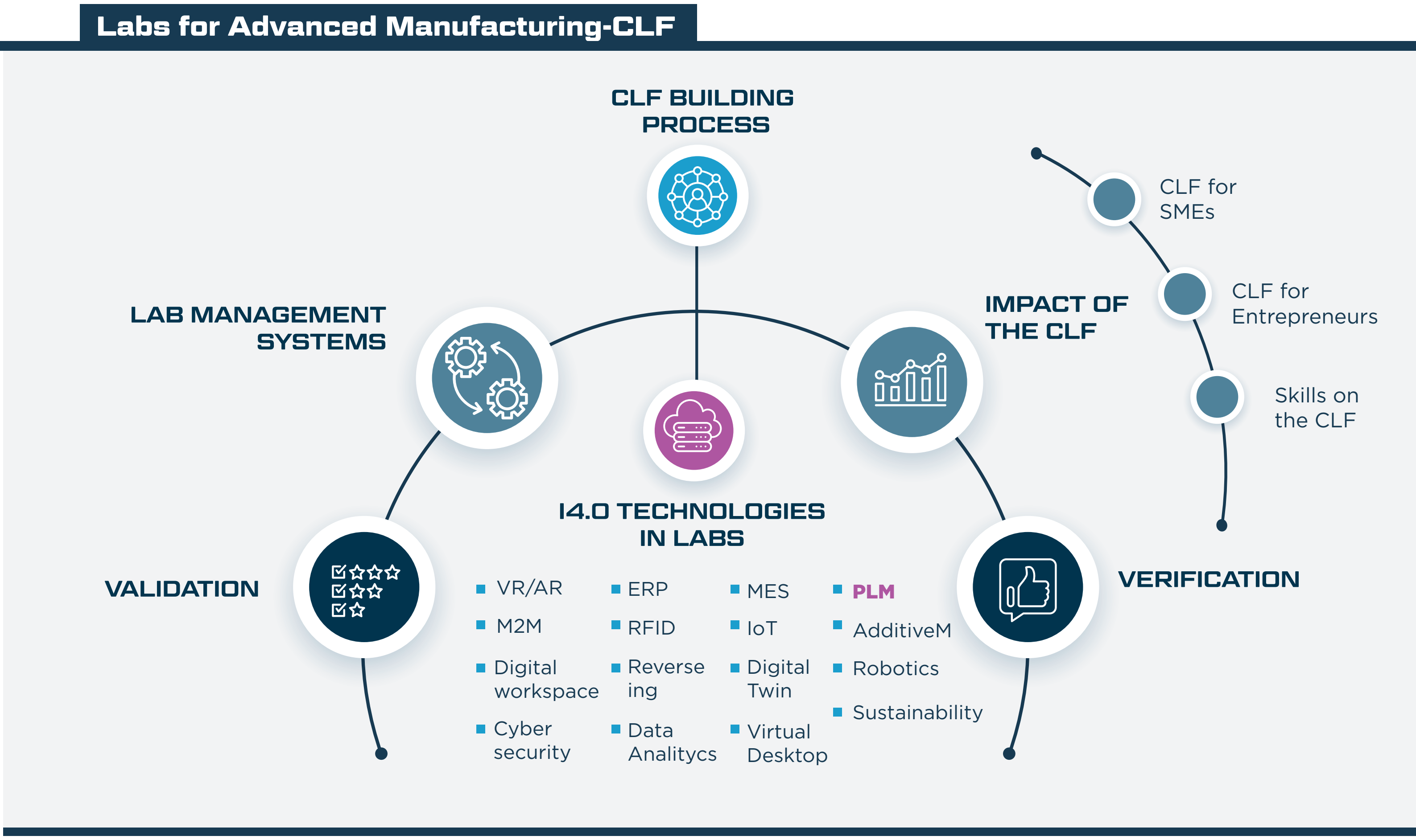

Figure 1: Overall structure of the EXAM4.0 labs piloting process. Source: EXAM4.0

The present report is the one out of 16 I4.0 technology described within the "Industry 4.0 technologies in labs" section, specifically #13 Product Life Management (PLM)

Definition and application of MES in industry

A PLM solution administers and manages the complete life cycle of a product. It promotes the final produc‘s digital definition in all its phases, starting with the conceptualization, going through the product design, the design of the manufacturing process, supply, manufacturing, distribution, after-sales (guarantees) and ending at the product end of life (Ibermática, 2021).

Figure 2: Phases of a PLM. Source: Ibermática

A PLM must integrate all the software solutions used for each of the previous stages, CAD solutions for design, CAE for analysis, CAM for manufacturing, PDM for product documentation management, ERP systems for production planning and production control or MES systems.

It manages all the information generated by each of the previous applications in a transparent way, ensuring the availability of specific information, at the right time, to the correct person.

In addition to data and information, a PLM can support all the processes that a company manages:

Design Process, Manufacturing and Purchasing process		
▪ Document management ▪ Requirements management ▪ Knowledge reuse ▪ Change Orders (ECOs) ▪ Concurrent engineering ▪ Etc	▪ Projects management ▪ Offer management ▪ Vendor management ▪ Quality management ▪ Issues management ▪ Etc.	▪ Outsourcing ▪ Spare parts management ▪ Technical assistance service ▪ Expedition ▪ Post sale

The PLM concept emerged in the beginning of the 80s of the past century, as a digitalization project of a small automobile company “The American Motor Corporation'' (acquired in 1987 by Chrysler) for the development of the Jeep Grand Cherokee. Since then PLM has evolved from two different ways: From CAD systems and from ERP systems.

In the 3D CAD systems, the relationship of assemblies, components and drawings, the reuse of parts in different products and the need to manage product configurations, unleashed to the development of PDM (Product Data Management) systems, both for data management and product documents. These PDM systems evolved to encompass other company software programs and processes, giving rise to PLMs such as Enovia PLM (Dassault systems), Siemens PLM (Siemens) or Windchild PLM (PTC) to give a few examples.

ERP systems were created for production planning, and evolved to manage more and more processes, adding document managers and PIM (Product Information Management) capabilities to reach current systems such as SAP PLM or ORACLE PLM CLOUD to name a few.

The PLM systems are aimed at product manufacturing companies, rather than distribution companies or service companies.

The higher the variability of products that a company manages and the more important the design factor is, the higher advantage it will obtain in the use of a PLM system. Because of this, ETO (Engineering to Order) companies have been the first to adopt this type of technology.

Product Life Cycle Management (PLM) is a fundamental enabler in any company that wants to tackle a **Digital Transformation**.

The Products are increasingly complex and the suppliers are more global and geographically distributed. A PLM drives and **automates digital processes** inside and outside of these companies, improving communication, collaboration and control of transactions with these providers.

A PLM provides **flexibility** for the organization and allows the optimization of the daily activity of each of the phases of the product development. This flexibility increases the capacity for innovation, both in products and in manufacturing processes.

A PLM will **improve productivity**, since it facilitates the automation of the management of product data and its integration with other business processes such as ERP for production planning and MES systems for manufacturing execution management.

A PLM **avoids information silos** that exist in companies due to the use of specific tools for specific processes not integrated between them. This ability to integrate all the relevant information of a product allows companies to **make better and more informed decisions**.

Industry 4.0 defines new technologies and manufacturing methods.

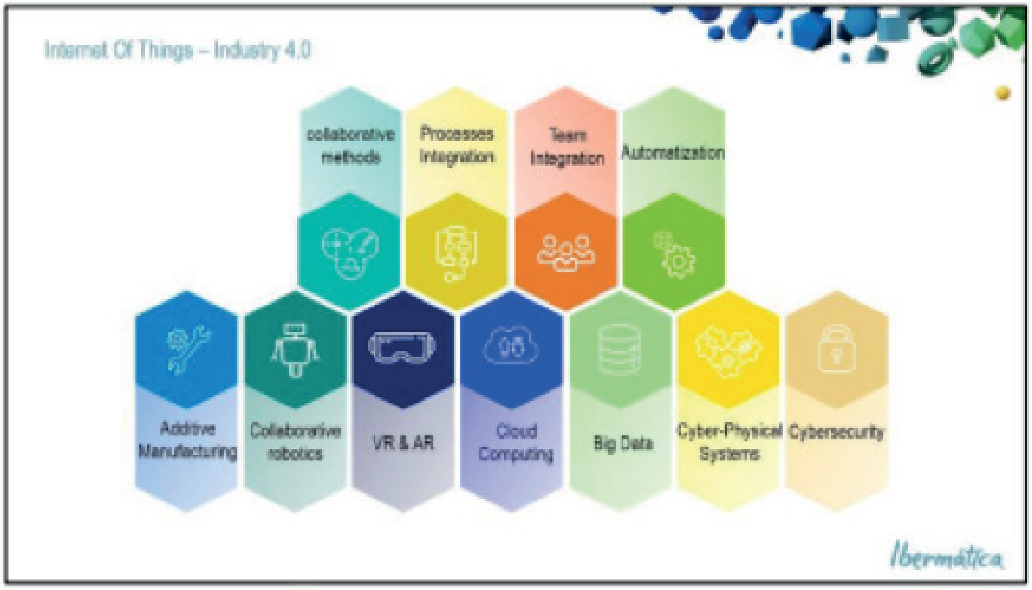

Figure 3: Industry 4.0 technology. Source: Ibermática

Collaborative methods, critical to achieving distributed manufacturing, process integration, and automation, are perfectly modelled in PLM systems.

On the other hand, technologies such as Digital twin or Big Data for data analytics need PLM systems for their support and exploitation.

The main evolution of the PLM systems is their transformation from being interconnected software tools to becoming systems that provide data services. They have gone from being a data repository to being a source of information exploitation.

These highly personalized software tools, programmed to suit the client and installed in complex hardware architectures, are evolving to more standard systems (out-of-the-box) simply configured, integrated and installed in outsourced or external hardware servers.

The access to tools, and consequently to their data, has gone from being departmental, to allowing global access.

The most current PLM systems are developed through open architectures (web services and so), which allow, beyond the exchange of data between applications, to add new capabilities to connect processes.

The high acquisition cost of PLM systems has been the main reason why only large companies have implemented these systems. The evolution of PLM towards SaaS systems (Software as a Service) with a pay per use, together with the outsourcing of the infrastructure, has allowed its expansion in small and medium-sized companies.

Another fundamental factor in the evolution of PLM systems is in the communication models they use, they have gone from sending messages and notifications to using current communication models based on social networks. A modern PLM will create communities to socialize, communicate, encourage participation, get feedback, etc.

To support the evolution of PLM systems, new collaboration platforms emerge. They are virtual workspaces, which centralize all the functionalities of a PLM, that is, the software tools, the information, the data and all the work processes defined by the organization.

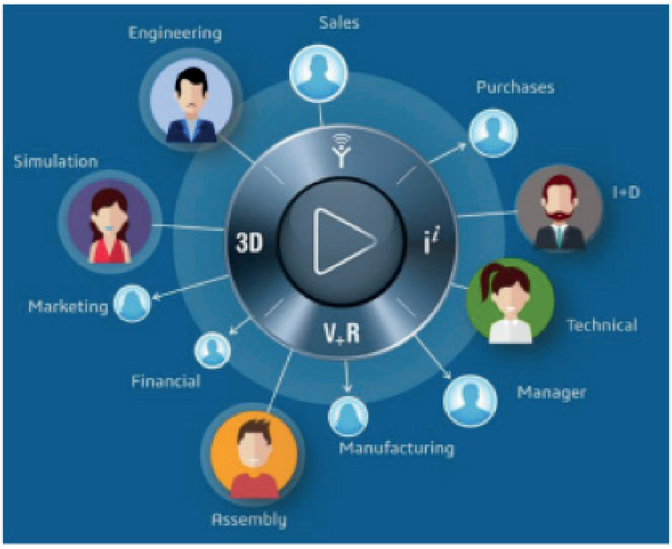

Figure 4 PLM as a collaboration platform. Source: Ibermática

This centralization allows simplifying access through a single point of entry, to all functionalities, measuring the degree of use to rationalize it and obtain process metrics.

The main objective of the platforms is to promote collaborative tasks, optimize communication and team coordination.

The collaboration platforms are generally developed on cloud servers, accessible through internet browsers to guarantee access to them from anywhere, at any time and from any device.

The main obstacle of implementing a PLM in the cloud is the security. The main fear is that confidential data could be compromised, having to protect both physical access to them and unauthorized access to data. The recovery of accidentally deleted data should also be ensured.

Figure 5: cybersecurity. Source: Dassault Systémes

- **Access protection**

In a cloud PLM, the servers are only accessible to very few people and with strict security measures. It is one of the main differences with an industrial company. In small companies, the availability of security personnel is limited. Large software development companies must protect their customers' and their own data (and they only generate data) and invest many resources to guarantee it. Therefore, most companies can delegate security to the resources of these large companies.

- **Consistency & Data Security**

The information access permissions limit the ability of any user to accidentally delete or modify information. Any access to the information is registered and stored in the history of accesses (log files) and actions carried out, being able to recover any previous state in a simple way.

In addition, the cloning of information on multiple servers and the available backup services offered by the PLM systems in the cloud, guarantee the recovery of the information in the event of any catastrophe.

Less and less backup copies are made and every day it is more common to make a "backup in the cloud" of the personal data and documents that we store to guarantee their persistence. Who does not save their cell phone photos in Dropbox, Google drive or a similar service?

• **Confidentiality of the information**

In addition to the physical protection mentioned above, all the information housed in a PLM system is protected by the user access permissions. A user will only access the information which they are authorized to and a record will be kept of all accesses that have been made to obtain a complete traceability of the use of this information.

Figure 6: Dassault Systemes security documents. Source: Ibermática

Dassault Systemes security documents downloadable at:

https://www.3ds.com/products-services/3dexperience/resources/whitepapers/

2 MES in HVET/VET labs

When implementing 3DEXPERIENCE, the following things must be taken into account:

2.1. Long-term vision

It is necessary to define a long-term vision and involve the entire organization in the need for a digital transformation and the objectives to be obtained. If the users are not participants in the objectives to get, they will not perform the tasks that are added to their usual responsibilities.

The continuous communication of project progress and milestones achieved will be critical during the adoption of a PLM system.

Figure 7: Long-term vision. Source: Ibermática

2.2. Involvement

It will be necessary to involve the management team, appoint a project leader and prioritize those departments or processes in which the benefit is clear with the use of the PLM system. It will be better to start with a small project, with a specific objective and gradually expand it.

Figure 8: Involvement. Source: Ibermática

2.3. Take decisions

The chief of each department will be involved in the change process. They should be prepared for the possibility of change, by involving them in the process as soon as possible, asking them what their goals are about the system, and considering their opinions. This will facilitate the acceptance of the system and the success of the project.

Figure 8: Involvement. Source: Ibermática

On the other hand, it is necessary to meet some requirements:

2.4. Analysis of current processes

It will be necessary to carry out an analysis of the current situation of the company, for the review of existing processes and obtain metrics in order to quantify the expected improvement.

2.5. Implementation team roles

A PLM system implementation requires the participation of many people with different responsibilities and interests, which often leads to disagreements. It will be necessary to define the different roles and assign their main competencies. Minimally, it will be necessary to define the following:

- **Responsible for PLM system implementation.** Who shall be responsible for maintaining the long-term vision and responsible for the success of the implementation by not only having a technological focus, but also a strategic one.

- **Functional manager.** There should be one per department involved. They are responsible for setting specific objectives and proposing modifications to current processes.

• **Systems manager.** Who shall be responsible for guaranteeing the intellectual property of current systems through the correct integration of the PLM with existing systems.

• **Economic manager.** Who shall be responsible for ensuring the return on investment within the established period.

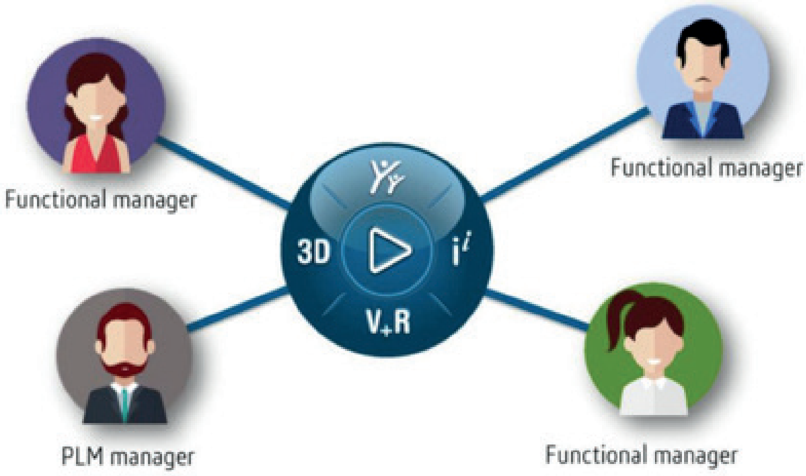

Figure 9: Team roles. Source: Ibermática

2.6. Planning the implementation process

The scope of the global project and the different phases in which it consists must be defined. For each of the phases you must:

- Define a specific, limited objective that solves a real problem.
- Identify the minimum implementation that solves the problem.
- Define simple milestones and try to get them.
- Measure the improvement with the metrics extracted during analysis.

Figure 10: Planning the implementation process. Source: Ibermática

2.7. User training

A fundamental aspect in the adoption of a PLM system is the involvement of users. They should not limit themselves to knowing the use of a PLM system, but must know it in the context of their daily work and this type of knowledge is not acquired in training courses. This approach requires an additional and specific effort for each type of user.

The ongoing support for technological changes should also be planned, by appointing experts within the team or by using the technical support service of the PLM system provider.

Figure 11: User training. Source: Ibermática

2.8. Data migration

It is one of the key factors in the implantation process. There are two different approaches: to do a gradual migration of the information from the old systems to the new one or to carry out a massive migration of data during implantation.

In the first case, the systems coexist in time, leaving gradually the old one as a data repository as the use of the new system increases. In the second case, custom development is necessary. It is necessary to analyse the source data, its organization and its structure to be able to develop a migration tool. Although there is more and more development in this regard, they are still in a premature state

In addition to PLM systems, executing product development processes require information from many different data sources and applications, ranging from 3D design (CAD), simulation (CAE), manufacturing (CAM), production management (ERP), manufacturing execution systems (MES), and a variety of in-house custom spreadsheets and databases.

The integration between these business systems is a natural step in any digital transformation initiative and it is fundamental in Industry 4.0. It allows users to access any information through a single centralized system**. It will be necessary to:**

- Identify the source where the data is generated.
- Determine what other systems require that data.
- Maintain a simple integration to share data between systems
- Review integration needs periodically

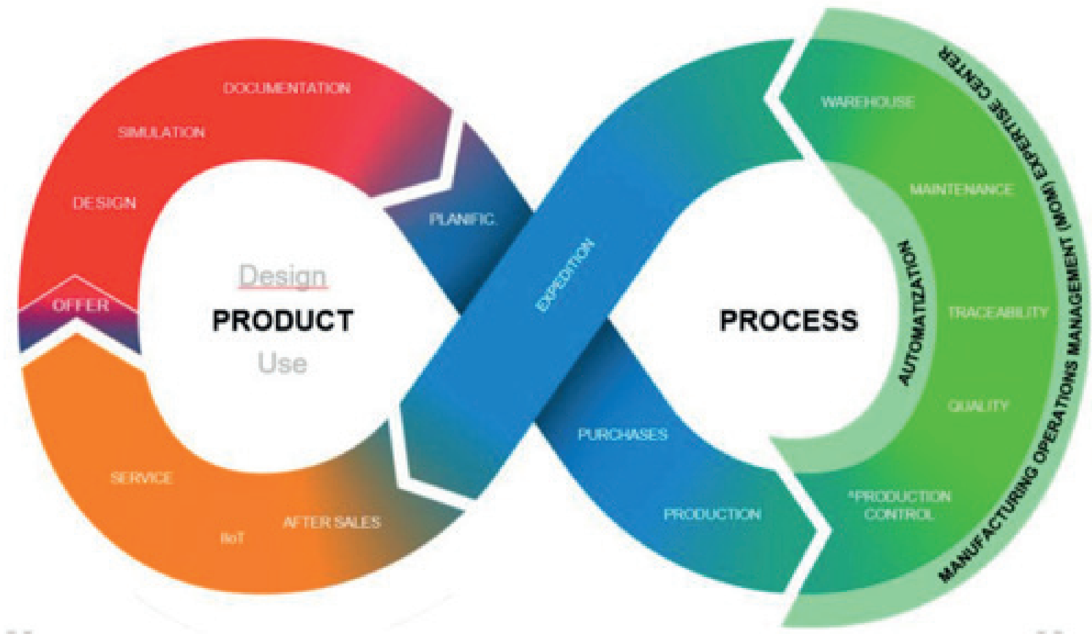

Figure 12 Integration of PLM with other systems. Source: Ibermática

The integration of the 3D parts with the articles, the bills of materials with the manufacturing structures of an ERP and the integration of the manufacturing operations of the articles with the MES systems, report benefits to each department.

2.9. Engineering Department (CAD/CAM/CAE)

The integration allows parts, assemblies, and drawings to be automatically coded based on a single company criterion.

It allows the engineering department to know the status of purchase or manufacture of a component or the expected delivery date to measure the impact of a design modification. It allows us to know the history of a part, the issues it has had and the maintenance information to consider them in subsequent redesigns.

The design engineer can know the stock of raw material and commercial components that are in the warehouse, choose the available material and commercial components knowing the price and availability instantly.

2.10. Production planning (ERP)

The items and the build structures are created automatically in the ERP from the design. The quantities of raw material required are automatically calculated from the engineering models. The mistakes made when entering them manually are avoided.

All documents are automatically associated with the article for viewing and consultation, ensuring that the correct version is always available.

Manufacturing operations are generated from CAM systems, estimating process times and productivity.

2.11. Manufacturing execution systems (MES)

The documents of the ERP article are associated with each phase and operation, being available for viewing on the production plant. When you select a work order, the drawings, assembly instructions, and all associated documents are displayed.

The inspection dimensions read from 3D models create inspection guidelines for quality control automatically.

There may be some deployment risks:

- Not defining a long-term vision.
- Non involvement of the entire company from the beginning, or consider their opinions, even if the initial scope is limited.
- To start without defining specific objectives and continue forward, even if they have not been met.
- To start without understanding the current processes of the company, or without obtaining metrics from them.
- To not assign a person responsible for the implementation, and do not assign responsibilities to the team.
- To define a complete, complex and long planning, without defining control miles-tones.
- To not train users or train them only in the tool and not in the use of the tool in their daily work.
- To not consider data migration.
- To not analyse the integration with other information systems.

Figure 13: Opportunities against risks. Source: Ibermática

Talking about the platform, 3DEXPERIENCE on the Cloud provides all organizations with a holistic real-time vision of their business activity and ecosystem, connecting people, ideas, data and solutions in a single collaborative and interactive environment available at all times.

The easy-to-use interface helps everyone involved in innovation projects interact to imagine, design, simulate and deliver differentiated customer experiences. Break free of IT constraints to scale and ramp up faster than ever with the 3DEXPERIENCE on the Cloud.

More info at:
https://www.3ds.com/3dexperience/cloud

On the other side, Dassault Systèmes is a French software manufacturer specialized in 3D design, 3D digital mockups and solutions for Product Life Cycle Management (PLM). It has more than 20,000 employees of 140 nationalities.

It was created in 1981 for the digital transformation of aircraft design. Dassault Systèmes, based on the idea of "world virtualization", has expanded its activity in the development and commercialization of professional software for all fields.

More info at:
https://www.3ds.com/about-3ds/

Referring to industry, Dassault Systèmes offers software solutions that enable customers to create new and innovative products through virtual experiences specific to each of the following industries:

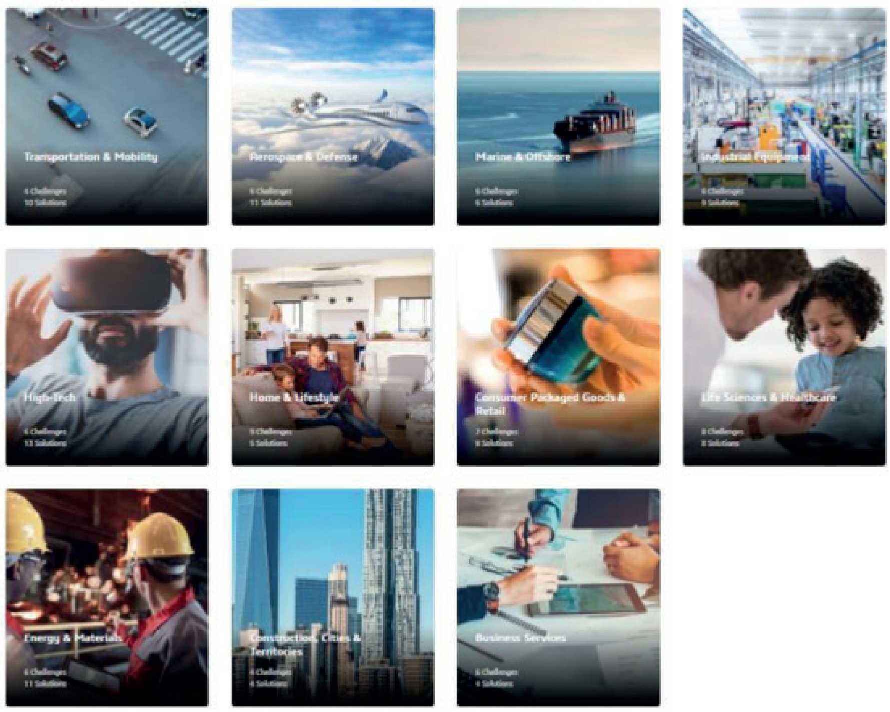

Figure 14 Industries where Dassault Systèmes offers a solution. Source: Ibermática

Inside these industries the platform works in different disciplines for Industrial Equipment. The 3DEXPERIENCE platform solutions portfolio for industrial equipment provides an organization with a seamless and collaborative product development environment in the cloud.

Figure 15: Disciplines for Industrial Equipment. Source: Ibermática

2.12. Design / Engineering

The 3DEXPERIENCE platform product development solutions help designers and engineers alike conceptualize, create, validate, communicate, manage and transform their innovative ideas into great product designs, managing all the different facets of the product life cycle

2.13. Governance

Manage the end-to-end product development from early planning through development and final release.

To meet the increasing demands of higher quality, lower cost, and shorter product cycles, 3DEXPERIENCE platform provides a proven cross-industry backbone for your every product development need.

Collaboration and governance tools provide efficient and reliable processes to involve the right people at the right time, regardless if they are part of your company or are suppliers or customers. The design work from your favourite CAD is seamlessly integrated and execution of projects with elaborate dependencies across multiple teams has never been easier.

Figure 16: Governance. Source: Ibermática

2.14. Manufacturing / Production

Great products start with great design, but even the most innovative ideas will fail if they can't be manufactured efficiently. What is required is a set of tools that enable identification of potential manufacturability issues that can be resolved earlier in the process. DELMIA Manufacturing & Production solutions allow businesses to operate in an ever-evolving world. This is accomplished by connecting all stakeholders to improve visibility into the design, manufacturing operations, and production. The result is improved agility and expanded continuous improvement across the enterprise. By providing a model-based, data-driven digital user experience, customers can establish a standard set of operational processes that can be created, managed, and governed holistically across an organization.

Figure 17: Manufacturing. Source: Ibermática

2.15. Marketing / Sales

The 3DEXPERIENCE platform marketing solutions enable you to engage with customers and the market in a realistic way to understand what a product will look like in its environmental context. All project stakeholders are kept informed throughout the collateral development process with up-to-date information from a “single source of truth”.

Figure 18: Marketing. Source: Ibermática

2.16. Simulation

The 3DEXPERIENCE platform offers an integrated suite of simulation tools that accelerate the process of evaluating and improving product performance, reliability and safety before committing to costly and time-consuming physical prototypes. With market-leading simulation applications, our customers can meet their business goals of reduced cost and time to market while delivering innovative products.

Figure 19: Simulation. Source: Ibermática

3

Role of the 3DEXPERIENCE PLM in the EXAM4.0 CLF

The CLF that is going to be launched has divided its production process into 4 stages (product design, process engineering, production and assembly) as can be seen in the following image. Within these stages, and taking into account the ERP-PLM-MES systems, the MES is going to work in the process engineering stage.

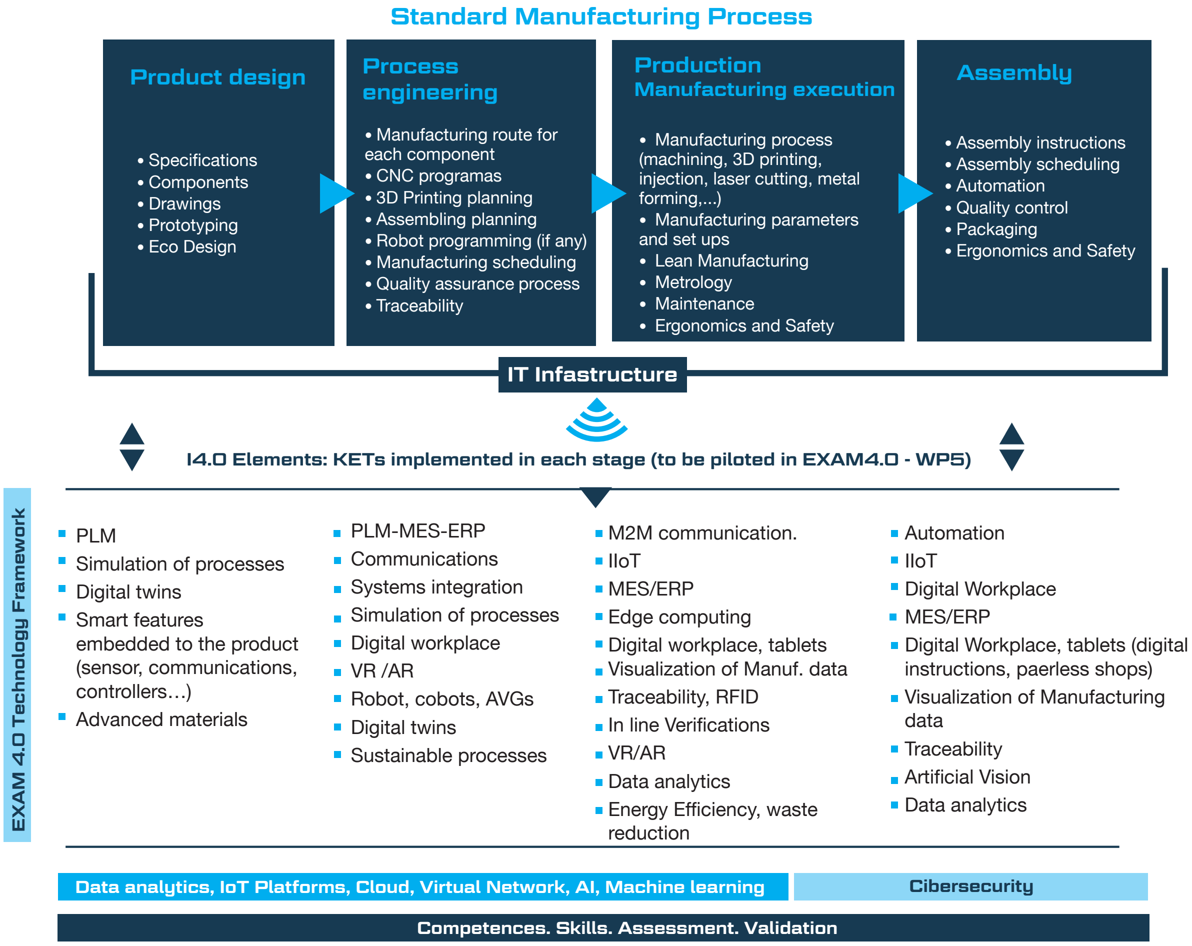

Figure 20: EXAM4.0 CLF value chain Source: Author's creation

A learning factory is a learning environment where processes and technologies are based on a real industrial site which allows a direct approach to the product creation process. Learning factories are based on a didactical concept emphasizing experimental and problem-based learning. The continuous improvement philosophy is facilitated by own actions and interactive involvement of the participants. (Reference: Laperrière& Reinhart: CIRP Encyclopedia of Production Engineering, 2015)

A product is designed, produced and assembled in different locations, following the LFs principles, i.e. in a learning environment where processes and technologies are based on a real industrial site. The co-creation process is based on continuous data & information exchange, a fully collaborative approach.

Although the most important applications of the 3DEXPERIENCE platform, in an engineering environment, are those that support its design and information management (PLM), as described in section 4, the 3DEXPERIENCE platform is an "ecosystem that connects people, ideas, information and applications in a single collaborative environment". It perfectly fulfils the requirements of the "continuous exchange of data and information, in a totally collaborative approach" of the CLF.

It can support the different communication interfaces between LABs, through the most basic 3DEXPERIENCE applications such as:

- **Virtualization of LABs:** No need to maintain a physical location.
- **Communication:** Communities, Wikis, Notifications, Virtual meetings (audio, video), etc.
- **Data repository:** Data exchange / information sharing.
- **Collaborative Tasks:** project Gant, task assignment, activity control, task status, etc.

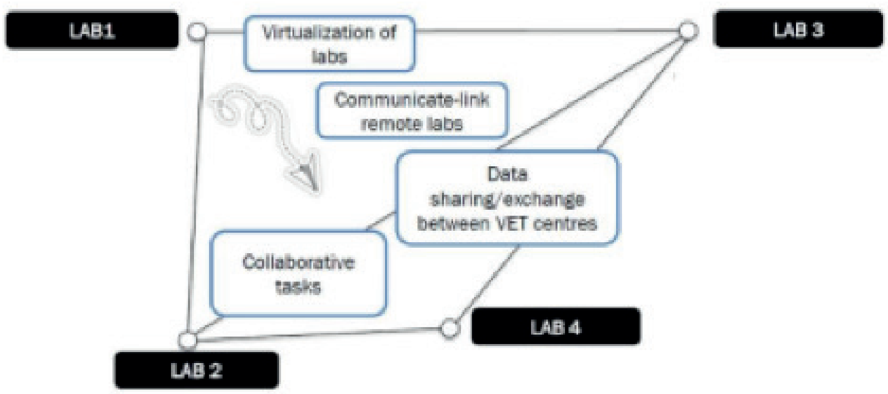

Figure 21Communication between LABs in Exam 4.0. Source: Author's creation

The 3DEXPERIENCE platform is, in turn, an application integrator, in addition to the platform itself, it has connectors for third-party applications: Catia, NX, SolidEdge, Inventor, etc. in the engineering area, up to iPaaS (Integration Platform as a Service) integration tools with ERP systems such as SAP or ORACLE.
3DEXPERIENCE functions in the CLF will be:

3.1. Communication and collaboration

The most basic roles of the 3DEXPERIENCE platform provide users with all communication and collaboration capabilities, spaces to share information, and document viewers in the cloud.

In addition, it has tools for the communication of ideas: possibility of making 3D sketches, presentation of ideas, etc.

3.2. PLM capabilities

The role of product life cycle management (PLM) in the cloud, in addition to adding all the communication and collaboration functionalities, add capabilities such as:

- Revisions Management
- Document Management. States of maturity.
- Workflows
- Product structure management (BOMs)
- Issues Management
- Engineering changes management
- Projects management
- Task management
- Others

Figure 22 PLM planification. Source: Ibermática

- **Engineering**

In addition to connectors with most CAD / CAE systems on the market, the 3DEXPERIENCE platform has roles with 3D modelling applications in the cloud. It can also work natively with CATIA and SolidWorks for design and with SIMULIA for simulation in the cloud.

- **Functions extension**

There are many roles within the 3DEXPERIENCE platform that can add functions to the CLF, such as:

  - CNC programming
  - Digital Twins
  - Simulation of manufacturing processes
  - Virtual reality, augmented reality
  - Others

3.3. 3DEXPERIENCE Edu training platform

An important function of the platform is that it can also be used as a training tool in addition to the CLF support tool.

4 Benefits of using 3DEXPERIENCE PLM in EXAM4.0's CLF

The application of a PLM system in the CLF helps in the correct functioning of the process in general. Among the benefits that inserting MES in EXAM CLF can have are:

- **Functions extension**

  With a PLM system, all relevant information of the entire product life cycle is centralized. This centralization allows extending participation in it to suppliers and customers and in general to anyone outside the company.

  The cloud-based PLM systems take this centralized access to data one-step further: The classification of information by function, process or department, adding the ability to access it from any web browser (without having to install any application), anyone can participate in a review, immediately and without any information exchange.

Figure 23: Centralization of the product life cycle. Source: Ibermática

- **Offshoring**

  The access through any web browser, without requiring VPN connections to the servers, allows delocalized access.

- **Expandability**
A cloud PLM solution is inherently scalable. Adding a user (or several) to the system is as easy as typing their name. Unlike traditional PLM systems, there is no need to reconfigure the system, licenses, or download new releases. The new user simply logs in and has access to the system.

- **Simplified maintenance**
The IT department will be the biggest beneficiary of a move to the cloud. The process of installation, configuration and updating of traditional PLM systems is laborious and the update of each application must be reviewed with the rest to ensure its integrity, being common to clone the implementations for the realization of "tests". With a PLM in the cloud, maintenance is outdated; updtes are automatic and managed by the same platform, guaranteeing the synchronization and the correct update of all applications.

- **Any device, anytime**
The way people work is changing, as are expectations of how and where they do it. With a PLM in the cloud, users are no longer tied to their office; they can access information from anywhere, at any time and on any device. Even in transit from mobile devices.

- **Lower entry costs**
You do not need to invest in hardware resources to implement a PLM in the cloud, and therefore neither in their support and maintenance. Adding that current PLMs require less customization and development, this translates into lower implementation costs. The initial investment is low, so the entry barrier for the implementation of a PDM in the cloud is low.

- **Boost collaboration and promote innovation**
The optimization of access to information, extended collaboration to external people, the simplification of implementation and training, allow focusing efforts on business goals such as improving competitiveness and innovation.

On the other hand, the disadvantages that can be:

- **Communication and collaboration**
The communication and collaboration functions are limited to users of the platform, and it is necessary to have access to it to participate in the communities, collaborate and share information.

  To download documents, users external to the platform will need to register (to access without a license) and they will only be able to view and download the document. The notifications must be received from email.

- **Cloud platform**

It is necessary to have an internet connection to be able to access the platform and its information.

Only in the case of design tools (which are installed locally) can the work be done without connection, saving the progress in a local cache until the connection is re-established.

- **User licenses**

It is a SaaS (Software as a Service) solution. It is not a purchased solution; it is paid per use on a quarterly or annual basis. Licensing is by named user (each user has the license for it) and not by concurrent users (maximum limit of users who access the system simultaneously).

In an educational environment, this can be an inconvenience because with the licenses per user, as many licenses as students are needed.

Figure 24: 3DEXPERIENCE Log In. Source: Ibermática

5 Competences addressed with 3DEXPERIENCE PLM

3DEXPERIENCE Edu is the Dassault Systèmes' Education Department – an exciting new world available in My3DEXPERIENCE to help school children, students, teachers and professionals level up their lifelong learning and boost their employability and innovation power.

The current global situation has brought challenges to every aspect of our lives, and education is no exception. These are unprecedented times and everyone – from academic institutions to teachers, students, companies and professionals – must adjust and adapt. Teachers have become students, required to learn how to move their daily job online. School children and students must complete their schoolwork and lab activities from home, working collaboratively with their classmates, while meeting deadlines set by their teachers. Professionals must continuously upgrade their skills to be ready for the much needed business transformation.

The value of 3DEXPERIENCE Edu hinges on the diversity of its community – schoolchildren, students, teachers and professionals all aiming for the same goal: reinvent the way we learn, teach, make & share to imagine sustainable innovations.

More information in https://edu.3ds.com/en

As for the student resource bank, there is a complete set of applications, content and services aimed at students:

- **Learning Portal** https://eduspace.3ds.com/
3DEXPERIENCE Edu Space is a unique online learning portal giving you access, anywhere, anytime, to thousands of learning materials to help students, teachers and professionals become proficient in using Dassault Systèmes products and solutions.

- **Certification** https://edu.3ds.com/en/be-recognized
Certifications provide talented students and individuals with the recognition of their skills in using our solutions to further increase their employability. **Two levels of certification are available:**

    1. Associate certification (attests the acquisition of knowledge and skills during learning activities)

    2. Professional certification (attests the capacity to perform in a job role in a professional environment)

- **Job Place** https://edu.3ds.com/en/job-place
Discover job opportunities connected to your Dassault Systèmes skills and get inspired by success stories from power users. Currently 459 job offers in Spain and 6,602 worldwide.

3DEXPERIENCE Edu HUB https://edu.3ds.com/en/hub

The hub is a dedicated place for those who need inspiration for their project. Every year, this is where we develop advanced projects using the 3DEXPERIENCE platform. Students will find learning content and materials here.

Figure 25: 3DEXPERIENCE Edu HUB. Source: Ibermática

Skills of the future https://edu.3ds.com/en/job/skills

Technologies are reshaping the world of work. Jobs are being transformed and new jobs requiring new skills are emerging. We have started a series of publications called "Skills Wanted for Sustainable Innovations" aimed at sharing the views of 3DEXPERIENCE Edu and our ecosystem on the ongoing changes in key roles and skills.

Challenges https://edu.3ds.com/en/challenges

Dassault Systèmes is proud to enable people from all over the world to compete international challenges. We sponsor and organize major competitions where students are asked to design humanoid robots, electric-powered submarines, solar racecars, next-generation drones and even space shuttles.

Communities, Social Networks https://go.3ds.com/studentcommunity

This is the place where all students using the 3DEXPERIENCE platform can discuss ideas, share their work and get help when needed from our experts.

Figure 26: 3DEXPERIENCE social media. Source: Ibermática

As a teacher resource bank, in addition to accessing the same content that is available to students, there are exclusive applications, content and services for teachers:

3DEXPERIENCE Edu Centers https://edu.3ds.com/en/edu-centers

3DEXPERIENCE Edu Centers are facilities run by Dassault Systèmes partners, where up-to-date, industry-relevant 3DEXPERIENCE knowledge and know-how is combined with their own expertise and provided for learners through initial or continuing learning programs.

Academy Member Program https://edu.3ds.com/en/be-recognized

The "Dassault Systèmes Academy Member Label" program acknowledges academic institutions engaged in using Dassault Systèmes 3DEXPERIENCE platform, CATIA, SOLIDWORKS or SIMULIA software in their study programs and which have shown a committed effort to leveraging the benefits of DS tools for student employability and curriculum quality. This recognition is disseminated throughout our global ecosystem.

Figure 27: 3DEXPERIENCE certifications. Source: Ibermática

Certification & Ecosystem https://edu.3ds.com/en/be-recognized

To constantly enhance our understanding of educational needs and trends, Dassault Systèmes fosters strong relationships with engineering education societies, among which. **For example:**

- American Society for Engineering Education (ASEE)
- International Federation of Engineering Education Societies (IFEES)
- Global Engineering Deans Council (GEDC)
- European Society for Engineering Education (SEFI)
- Indo Universal Collaboration for Engineering Education (IUCEE)
- Japanese Society for Engineering Education (JSEE)
- Korean Society for Engineering Education (KSEE)

6

Collaboration opportunities opened by 3DEXPERIENCE PLM

As mentioned above, the interaction of 3 main elements is essential to assure the coordination of every single element that takes part in the overall production: ERP-PLM-MES

The element itself is a collaborative facilitator but it is essential for the correct functioning of the CLF manufacturing process. On the one hand, it is the system that will give the necessary information about the product fabrication. On the other hand, it is responsible for managing all the changes that anyone does to the product. That is why, with the combination of ERP and MES, from the information it collects, it enables different production processes of different schools or countries to be known. In addition, through collaboration, these processes could be improved or new ones created.

Also, schools that do not have as much machinery or technology, could make use of the data obtained to be able to make practical cases of the different production processes.

The flexibility of the system makes it easier for other schools and other productive processes to become part of it.

7

References

Ibermática. (2021). PLM in a distributed Industry 4.0 environment.

EXAM 4.0

THE EXCELLENT ADVANCED MANUFACTURING 4.0

AM 4.0 labs running I4.0 technologies

Technology 14: Enterprise Resource Planning (ERP)

14/15

Piloting the Advanced Manufacturing workshop 4.0

03

This project has been funded with support from the European Commission. This publication reflects the views only of the author, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

Table of figures

0 Introduction

Following the piloting process of Advanced Manufacturing Labs for HVET/VET through the Collaborative Learning Factory (hereafter CLF), the EXAM4.0 partners we have piloted 16 technologies embedded in Industry 4.0

The following image shows the overall structure of the piloting process.

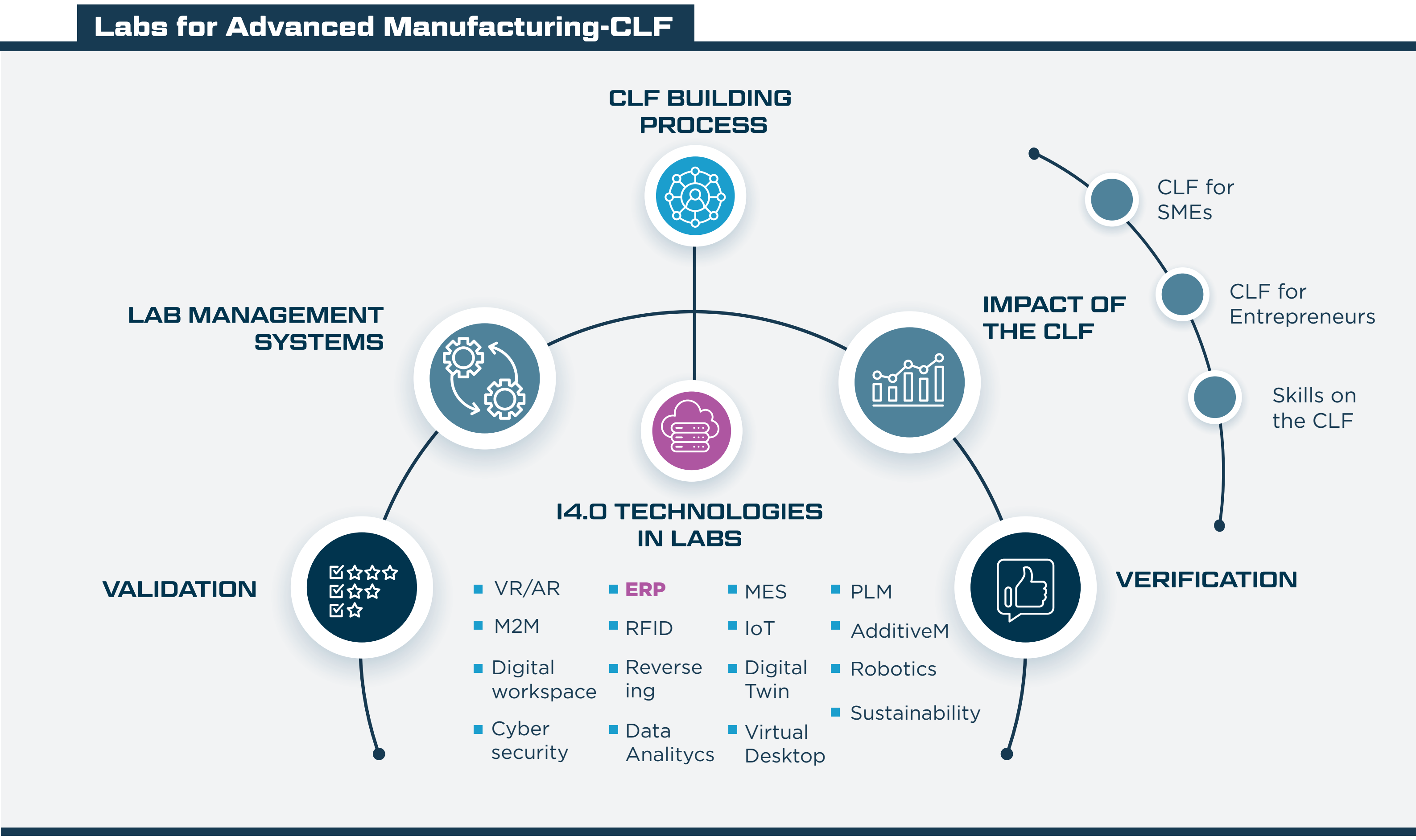

Figure 1: Overall structure of the EXAM4.0 labs piloting process. Source: EXAM4.0

The present report is the one out of 16 I4.0 technology described within the "Industry 4.0 technologies in labs" section, specifically #14 Enterprise Resource Planning (ERP)

1

Definition and application of ERP in industry

Enterprise Resource Planning (ERP) is the integrated management of main business processes, often in real time and mediated by software and technology. ERP is usually referred to as a category of business management software—typically a suite of integrated applications—that an organization can use to collect, store, manage, and interpret data from many business activities (Wikipedia, 2021).

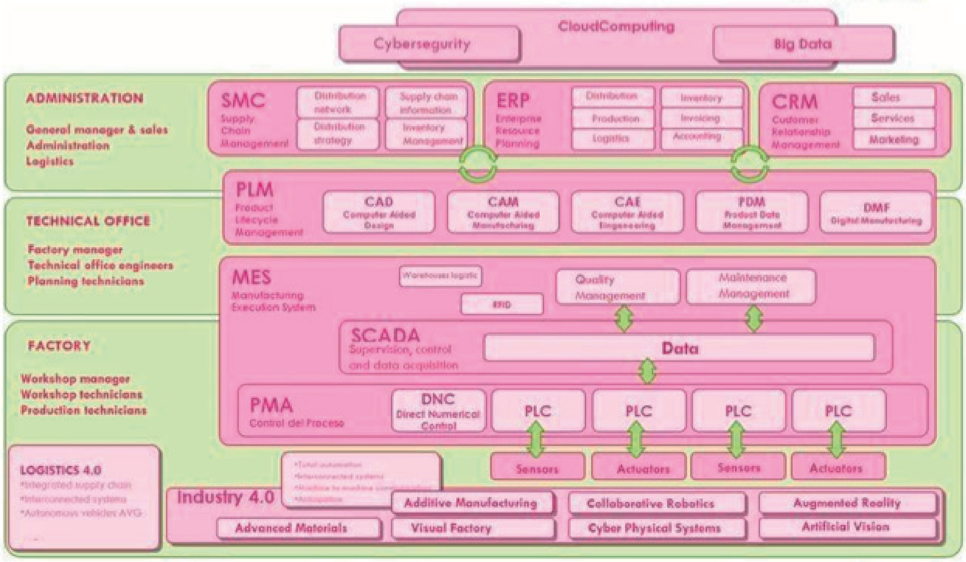

Figure 2: Integration of ERP-PLM-MES within the structure of the company. Source: Ibermatica

ERP automates more operational aspects of the business such as purchasing, sales, logistics, accounting, inventory and warehouse control, ordering, payroll, etc. The aim is to optimise business processes by connecting information linked to financial, production, cost or material demand management.

ERP is the set of processes that includes business and capacity planning, scheduling and customer order management. Accounting and Human Resources are part of these processes because they represent the management of all the resources (people, material, etc.) required to execute manufacturing.

The main functions of ERP that are relevant to manufacturing are the following:

- **Capacity management** —For every product to be manufactured, there is a defined process. There is also a maximum number of units that can be manufactured in a given time. This will affect both, the production order planning and the material procurement planning. The maximum capacity of a manufacturing plant is highly dependent on the number and mix of end products and how they are manufactured.

- **Production planning** — Adjusting the production plan according to changes in certain variables, including staff, is a major part of the production planning process. Planning must also account for changes in the current status of the production environment, as changes happen.

- **Customer relationship management (CRM)** — This function includes processes that ensure customer satisfaction with the end product. In addition, CRM anticipates the customer's future demand and then recommends changes to the product line, accordingly with any details that would affect the manufacturing process.

- **Supply chain management (SCM)** — These processes ensure all materials, including raw materials and component parts, are delivered to the plant on time and adhere to the expected quality standards.

2.1. Integration of digital workplace in Bidasoa's lab

In the case of Bidasoa, the integrated ERP system used is the software Odoo. It has an open source "community" version under the LGPLv3 license. It also has an enterprise version under commercial license that complements the community edition with commercial features and services, developed by the Belgian company Odoo S.A. (Odoo, 2021). At the moment, the ERP is used in the Mechanics department as a management tool and as an educational tool for the learning process of the students.

- **Department management:** with the aim of centralizing all actions in the management of the department.

- **Occupation of spaces:** the teaching staff can see the occupation of the different spaces used by the department in real time. In addition, as far as the Mechanics workshop is concerned, it is not only possible to know which group is there, but also who is at each machine.

Figure 3: Bidasoa LHII ERP. Source: BidasoaLHII

- **Stock management and purchasing:** the control of both the stock of tools and the stock of raw material is done with this system. The situation in real time is known. Once the minimum number of materials is reached, the person in charge will contact the distributor to buy what is needed.

- **Maintenance:** the control of both class and lab is done. All breakdowns, needs,... that occur in computers, tablets, screens, software, machines,... are managed through failure reports which reach the person in charge. In this way, all the maintenance process is controlled from the moment the action is requested until it is done; who has done it, when it has been done and how much time and money it has cost. All maintenance reports are done with students, if possible, putting into practice **corrective** and **preventive** maintenance.

- **Data exploitation:** all the data obtained is used in the management of the department. Through the analysis of data, the improvement of processes, the optimisation of resources, decrease in breakdowns.... is obtained.

2.2. Role of the ERP in the EXAM4.0 CLF

The CLF that is going to be launched has divided its production process into 4 stages (product design, process engineering, production and assembly) as can be seen in the following image. Within these stages, and taking into account the ERP-PLM-MES systems, the ERP is going to work in process engineering, production manufacturing and assembly stages.

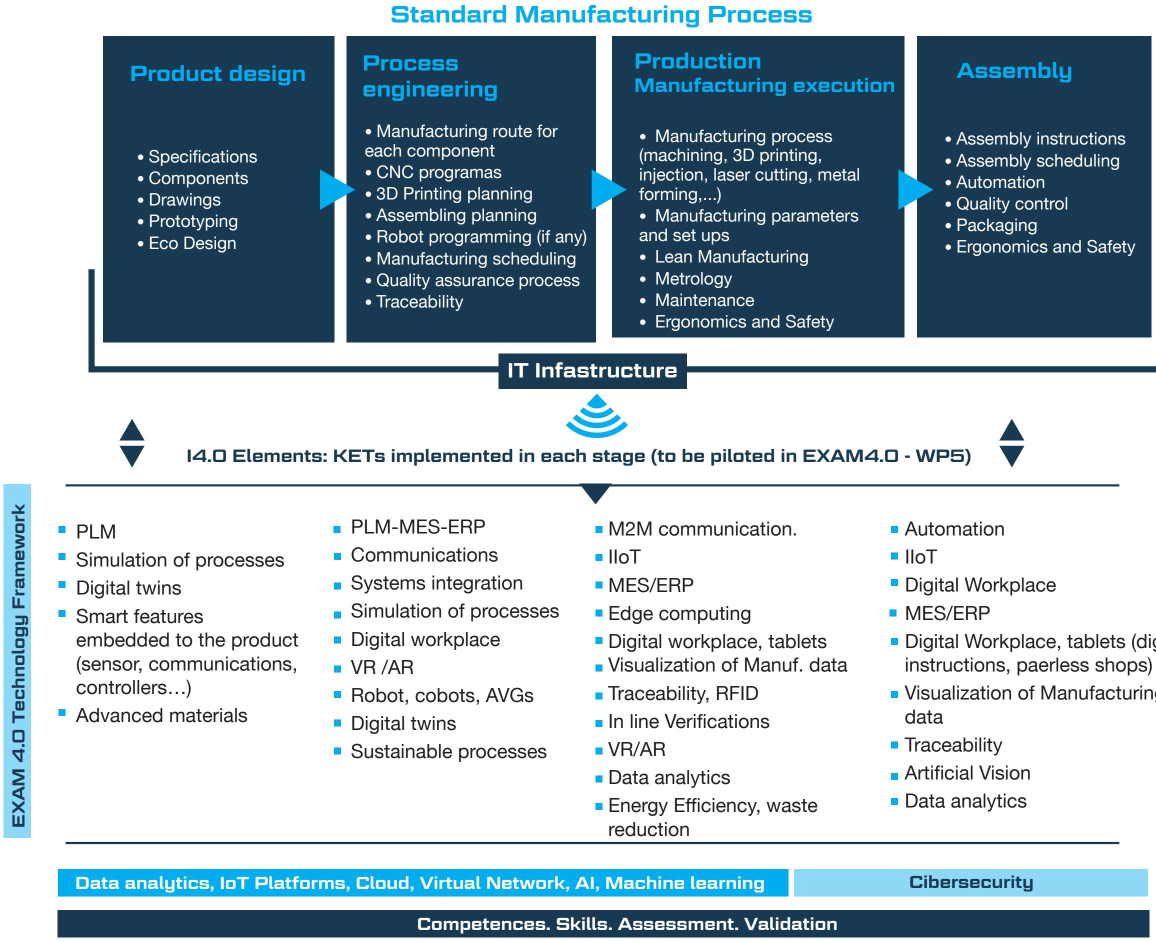

Figure 4: EXAM4.0 CLF value chain Source: Author's creation

One of the objectives of the CLF is to be able to transfer data between labs, in order to control the manufacturing process. For this purpose, in the labs, there are going to be some technologies and machines that connected with sensors would transfer data through PLCs to a MES. This MES would be connected to the technical office part through a PLM and to the administrative part through an ERP. All this data would be transferred to the cloud to be later processed, always taking cybersecurity into account.

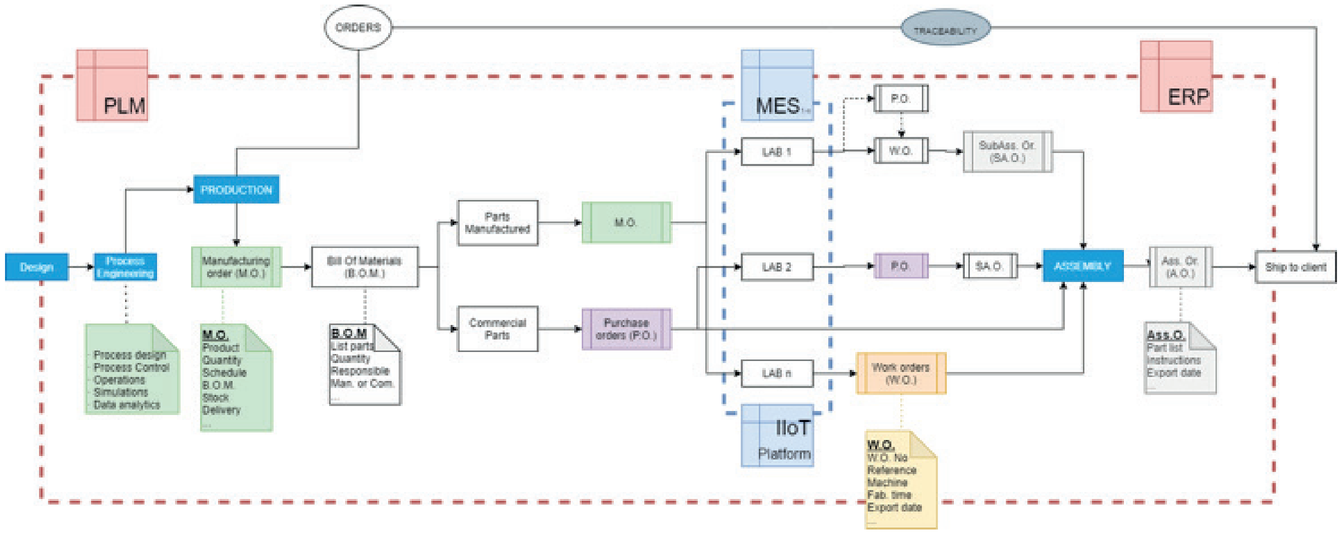

Figure 5: Possible diagram of the operation of the ERP-PLM-MES system of the CLF. Source: EXAM4.0

Taking into account all the production process, there must be a platform where orders can be placed. Here is where the ERP would start working. The order will have to reach a common ERP. This is important because it is from where the entire production process will be managed. In the first place, you will have to analyse if you have the necessary material in each lab for its manufacturing. In case there is not enough material in a lab, you will have to report it so that the corresponding purchase can be made. Secondly, taking into account the occupation of the machines in the different laboratories, you will have to send the manufacturing and assembly notice to the MES systems. At the same time, you will have to carry out the traceability to be able to follow the path and tell the customer when the product will be ready. Finally, it will take into account all the corrective and preventive maintenance of the labs; starting from the managing part, to customer data, stocks, etc.

2.3. Benefits of using ERP in EXAM4.0 CLF

The application of an ERP system in the CLF helps in the correct functioning of the process. Among other points it improves:

- **Comprehensive management:** manages and connects the desired areas (finance, purchasing, sales, warehouse, human resources and customer service, among others). In addition, this management system allows working with groups of companies, with multiple plants and different laws, currencies and languages.

- **Predictability and quality:** the data obtained from the ERP is converted into information for the improvement of the service, such as customer service, or improving the quality of the process, by anticipating breakages of stocks, machines, etc. It also provides necessary data for the correct application of continuous improvement.

- **Control and flexibility:** helps in the standardization of processes with fully customized workflows that help unify procedures.

2.4 Competences addressed with ERP

The competencies acquired with the ERP can be classified into two groups: Technical and soft competences.

The technical competences are the ones that are most closely related to the technical content to be acquired in the learning process of the students, in this case Machining Technicians, Production Programming Staff and Industrial Design. **Among other technical competences the main ones are:**

- Greater awareness of the production process, from raw materials to part verification
- Calculation of costs and time
- Production scheduling
- Management of stocks (raw material, tools, etc.)
- Relationship with different suppliers
- Data analysis
- Improvements to be made in the production process

Secondly, as for the soft competences developed with ERP are:

- **Teamwork:** being a collaborative tool, team members can plan their tasks and all have access to production sheets, control sheets....
- **Digital awareness:** they get used to virtual working environments, understanding the data obtained, managing it and drawing conclusions.
- **Personal:** autonomy, initiative, critical spirit, to be aware of the importance of good planning and to see how the decisions taken in the process affect them.
- **Communication:** between different students, the one who plans the production with the one who executes it, being aware of the importance of the different explanations (verbal and written) that are given within the production process and that can help achieve a better result.

3 Collaboration opportunities opened by ERP

The technology itself is a collaborative facilitator. It is the common system that unifies the different labs and distributes the jobs. From the information it collects, it enables different production processes of different schools or countries to be known. In addition, through collaboration, these processes could be improved or new ones could be created.

On the other hand, schools that do not have as much machinery or technology could make use of the data obtained, to be able to make practical cases of the different production processes.

The flexibility of the system makes it easy for other schools and other productive processes to become part of it.

4 References

Odoo. (13 October 2021). Retrieved from
https://www.odoo.com/es_ES

Wikipedia. (13 October 2021). Retrieved from
https://en.wikipedia.org/wiki/Enterprise_resource_planning

THE EXCELLENT ADVANCED MANUFACTURING 4.0

AM 4.0 labs running I4.0 technologies

Technology 15: Manufacturing Execution Systems (MES)

15/15

Piloting the Advanced Manufacturing workshop 4.0

03

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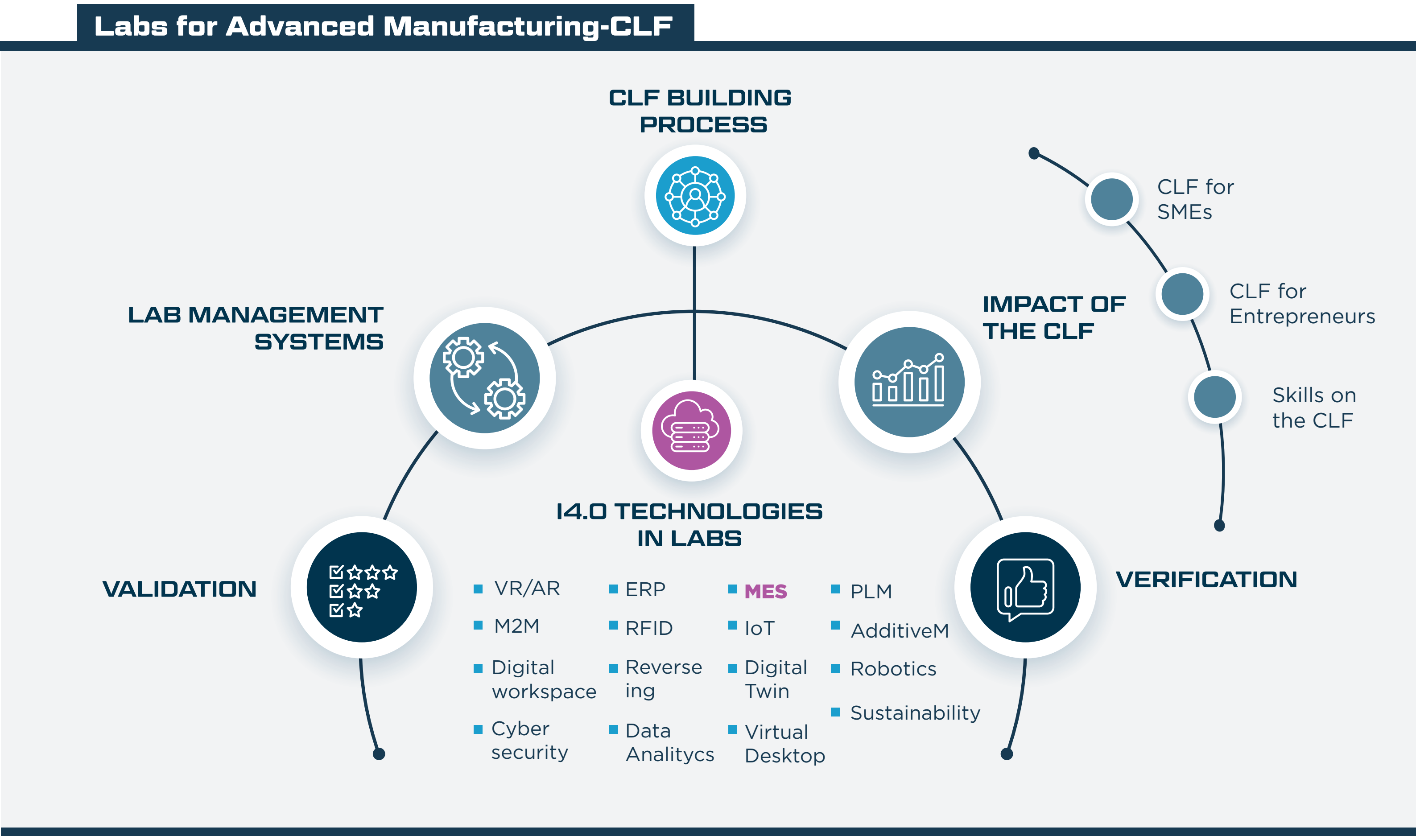


Figure 1: Overall structure of the EXAM4.0 labs piloting process. Source: EXAM4.0

The present report is the one out of 16 I4.0 technology described within the "Industry 4.0 technologies in labs" section, specifically #15 Manufacturing Execution Systems (MES).

Definition and application of MES in industry

Manufacturing Execution Systems (MES), or also denominated Manufacturing Operations Management (MOM), are systems used in production to track and document the transformation of raw materials into finished products. MES works in real time by integrating plants or lines with equipment, controllers, operators to enable control of multiple elements of the production process (e.g. consumption, personnel, machines and support services).

MOM is a holistic solution that provides visibility into manufacturing processes in order to optimise efficiency. MOM consolidates quality management, planning and sequencing, production execution and other processes (Wikipedia, 2021).

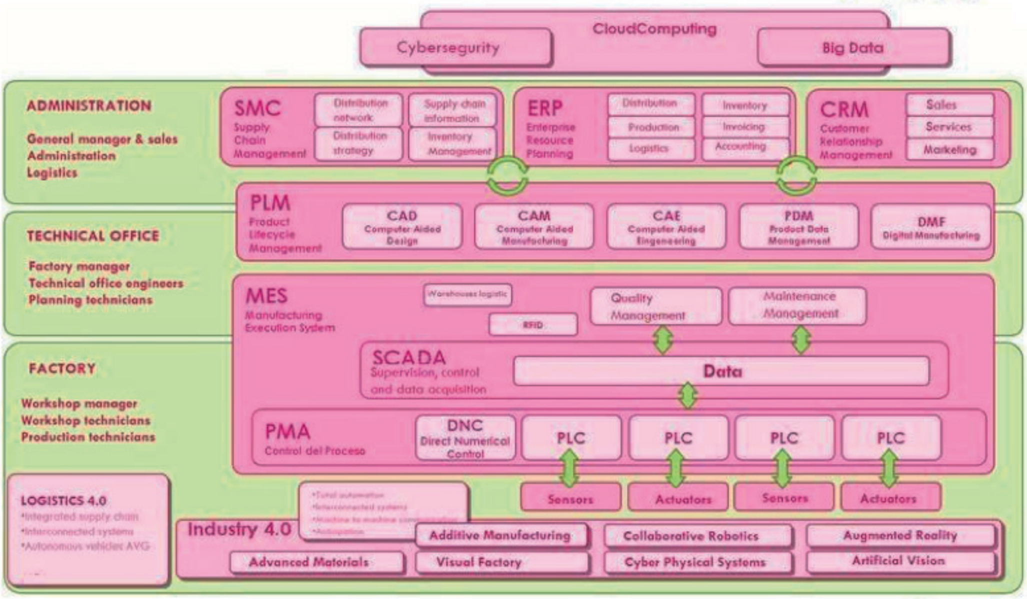


Figure 2: Integration of ERP-PLM-MES within the structure of the company. Source: Ibermatica

The MES system can operate across multiple function areas, for example: management of product definitions across the product life-cycle, resource scheduling, order execution and dispatch, production analysis and downtime management for overall equipment effectiveness (OEE), product quality or track and trace of materials. MES creates the "as-built" record, capturing the data, processes and outcomes of the manufacturing process.

Manufacturing processes are composed of a number of stages that must be coordinated. These stages require the careful coordination of material, resources and information to make and deliver the product efficiently.

The following is a generic list of the high-level processes within the scope of manufacturing (Vokey, 2020):

- **Material procurement** — When, how much, and from whom.

- **Material receipt (including incoming inspection) and storage** — Frequency of delivery, where to place the delivery once it is in-house, and verification of material quality.

- **Material and product inventory management** — All material movement within the plant.

- **Production planning and scheduling** — When to produce and how much, which includes sequencing the manufacturing processes for the product or subassembly at both the subassembly line level and the final assembly level.

- **Maintenance and readiness of tooling and conveyance systems** — Ongoing maintenance and calibration keeps the tooling and conveyance available when needed.

- **Training and readiness of operators, supervisors, and other staff** — Having both the knowledge to perform the work and the right skills when needed, in order to minimize costs.

- **Product quality assurance** - When tests should be performed on products or materials to check the product's quality while reducing potential waste if anything goes wrong.

- **Shipment scheduling and coordination** — Ensure the product is shipped on time for delivery and minimize port fees.

The interaction of 3 main elements is essential to assure the coordination of every single element that takes part in the overall production: ERP-PLM-MES.

2 MES in HVET/VET labs

2.1. Integration of MES in IMH's lab

The implementation of a MES system requires that each of the machines that want to connect to the system can communicate with the software that has been chosen. The machines and equipment, through Wi-Fi communication, transmit all the data they have to a database located in the cloud through CNC.

In IMH lab, they have communicated the following workshops:

- All the CNC machines correspond to the TKGUNE workshop, whose objectives are to offer technological innovation services to SMEs and to be a training space for the 2 specialization programs in Industrial Mechatronics and in Mechanical Production Scheduling.

- All the CNC machines and, for now, 6 conventional machines by integrating PLCs to communicate with the MES, corresponding to the general workshop aiming at the development of the teaching-learning process of vocational training cycles.

It is important to clarify that when incorporating a MES in the workshops of vocational training centres, the information management and processing will be different from the way industry does. This is because the teaching-learning processes require a different management.

The available information concerning this lab is:

- Traceability of learners, machine usage, tools, performance indicators.

- Machine use information for scheduling, planning and also maintenance.

- Monitoring of student's performance, state of project's and task execution at real time.

- Tools control.

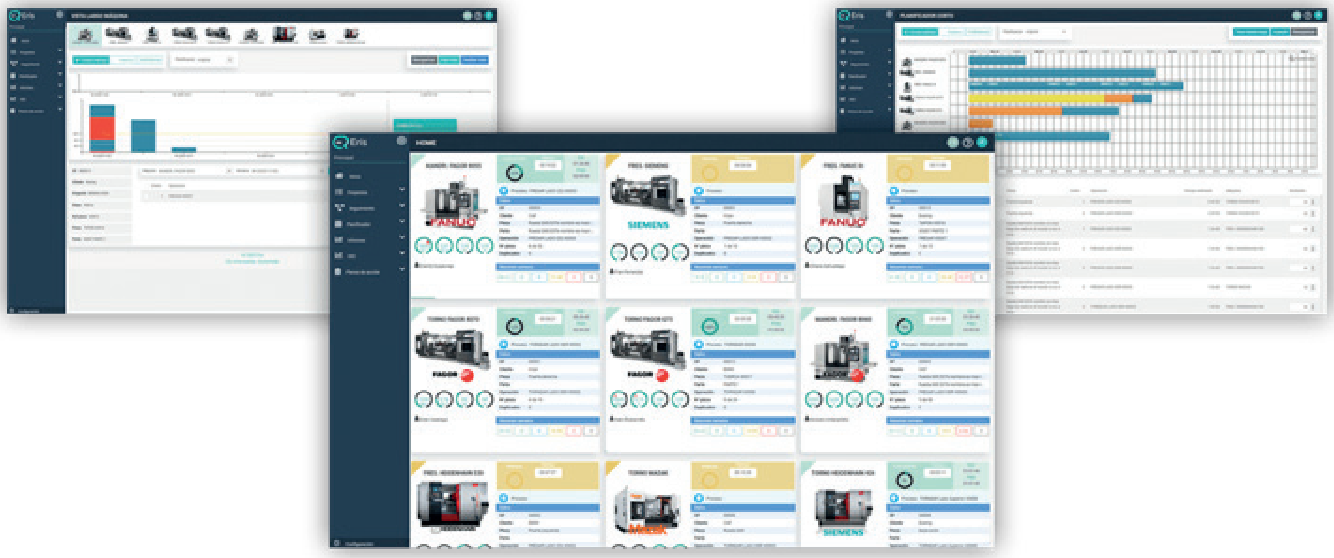
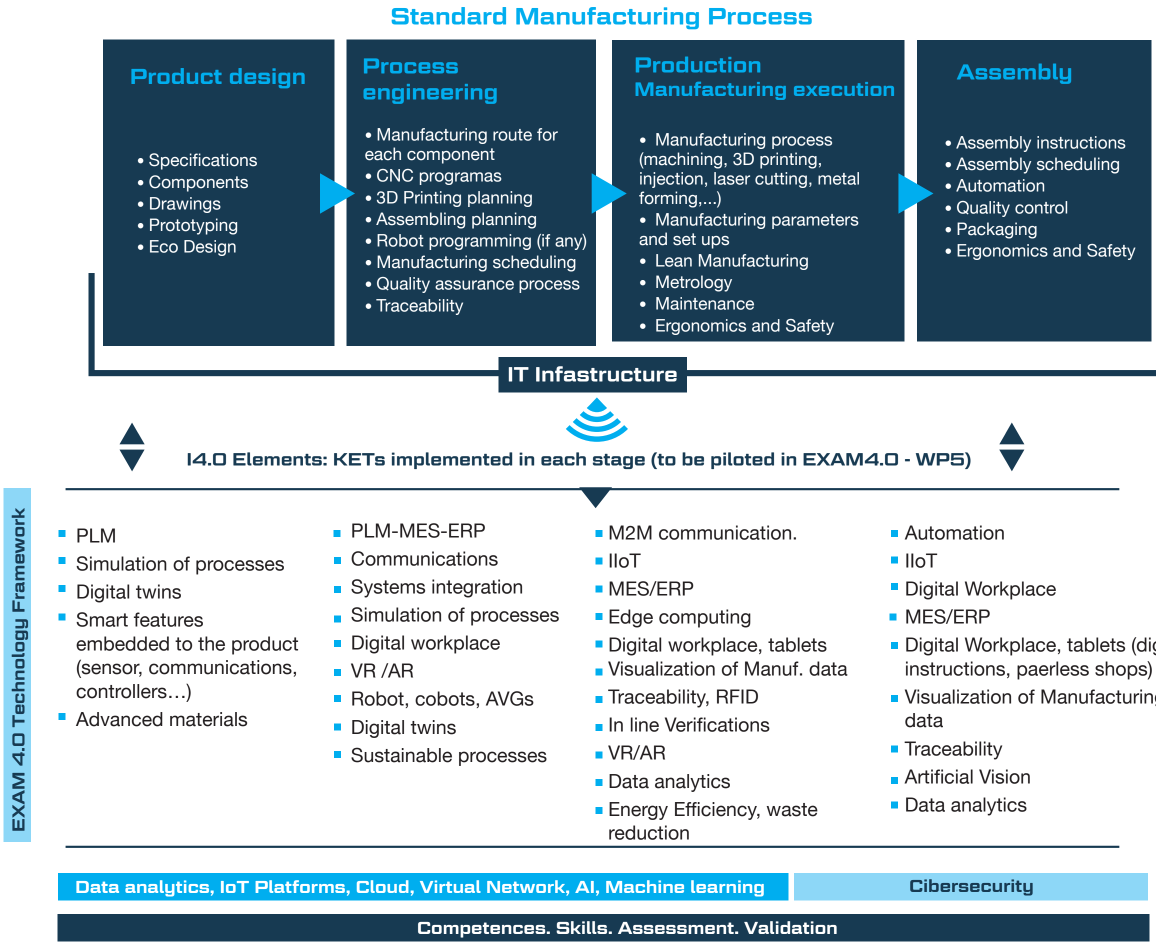


Figure 3: Monitoring of machine data Source: https://www.zitu.net/es/soluciones/eris

2.2. Role of the MES in the EXAM4.0 CLF

The CLF that is going to be launched has divided its production process into 4 stages (product design, process engineering, production and assembly) as can be seen in the following image. Within these stages, and taking into account the ERP-PLM-MES systems, the MES is going to work in process engineering, production manufacturing and assembly stages.



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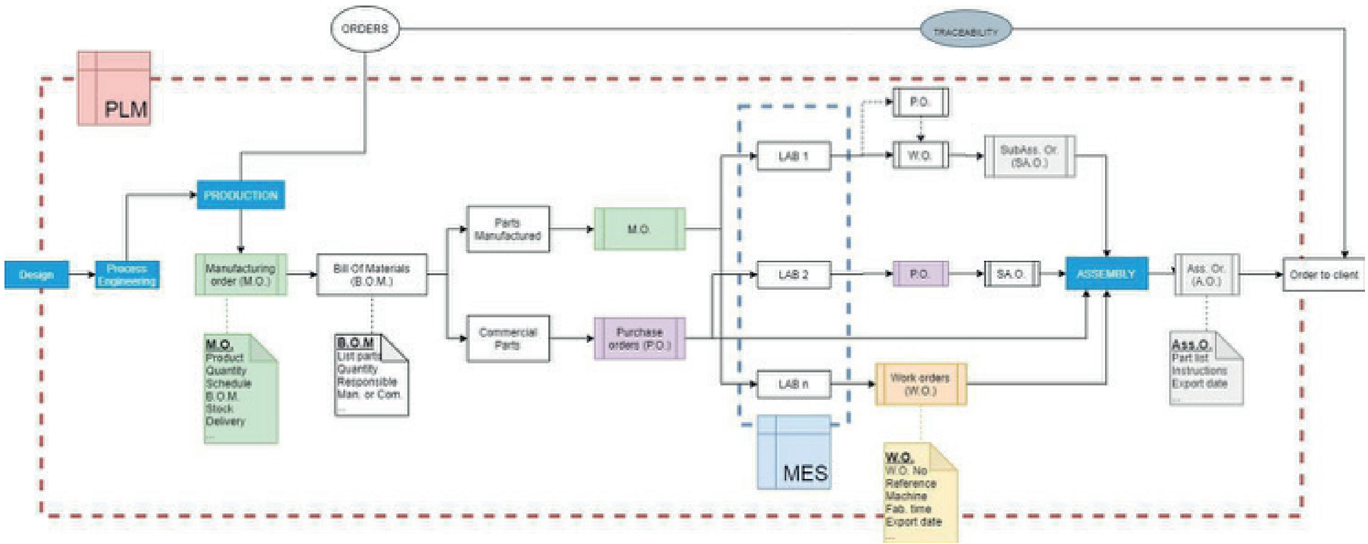

Figure 5: Diagram of the operation of the ERP-PLM-MES system of the CLF

Taking into account all the production process, there must be a platform where orders can be placed. The order will reach an ERP. It is important that the ERP is common because the entire production process will be managed from there. Unlike ERP, the MES of each lab does not have to be the same, because it will be in charge of the operations of each lab. However, all MES will have to be able to collect and send the same information that is necessary for the common ERP.

Within the operations of the MES, on the one hand it will have to organize the resources once a manufacturing order has been sent. On the other hand, it will have to collect the necessary information in real time to be able to manage the ERP's needs.

2.3. Benefits of using MES in EXAM4.0's CLF

The application of a MES system in the CLF helps in the correct functioning of the process in general. Among the benefits of inserting MES in EXAM4.0 CLF are:

- Massive remote control managed through the use of applications. All machinery and equipment is visible at all times and in real time, being able to control operations and detect or solve problems.
- Cost reduction, promoting operational efficiency, reducing production and logistic costs.
- Automation of processes due to artificial intelligence. The processes will become more and more automatic, avoiding the errors of manual operators.
- Better monitoring by obtaining information (status, consumption, etc.) in real time.
- Maximum use of resources, making them more efficient.

2.4. Competences addressed with MES

The competencies acquired with the MES can be classified into two groups: Technical and soft competences.

The technical competences are the ones that are most closely related to the technical content to be acquired in the learning process of the students, in this case Machining Technicians, Mechanical Production Scheduling and Industrial Design. **The insertion of MES elements are going to help in developing competences such 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.

Secondly, about the soft competences that are worked with ERP are:

- **Teamwork:** being a collaborative tool, team members can plan their tasks and all have access to production sheets, control sheets....

- **Digital:** they get used to virtual working environments, understanding the data obtained, managing it and drawing conclusions.

- **Personal:** autonomy, initiative, critical spirit, to be aware of the importance of good planning and to see how the decisions taken in the process affect them.

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The technology itself is not a collaborative facilitator but it is essential for the correct functioning of the ERP. On the one hand, it is the system that will give the necessary information about the production process in real time to the ERP (production, maintenance, stock, etc.). On the other hand, it is responsible for taking the orders from the ERP and distributing the tasks in the lab. That is why, with the combination of ERP, from the information it collects, it enables different production processes of different schools or countries to be known. In addition, through collaboration, these processes could be improved or new ones created.

On the other hand, schools that do not have as much machinery or technology, could make use of the data obtained to be able to make practical cases of the different production processes.

The flexibility of the system makes it easy for other schools and other productive processes to become part of it.

4 References

Vokey, T. S. (2020). MES: An Operations Management Approach. En T. S. Vokey, MES: An Operations Management Approach (págs. 1-3). ISA.

Wikipedia. (13 October 2021). Retrieved from https://en.wikipedia.org/wiki/Manufacturing_execution_system

EXAM 4.0

THE EXCELLENT ADVANCED MANUFACTURING 4.0

5 Full document References

Alp Ustundag, E. C. (2018). Industry 4.0: Managing The Digital Transformation. Instanbul: Springer.

Avansis. (19. October 2021). Retrieved from https://www.avansis.es/sin-categorizar/robotica-industrial/?cn-reloaded=1 abgerufen

Capgemini Research Institute. (2019). Smart factories @ scale. Seizing the trillion-dollar prize through efficiency by design and closed-loop operations. Retrieved from https://www.capgemini.com/wp-content/uploads/2019/11/Report-%E2%80%93-Smart-Factories.pdf abgerufen

Engineering, V. (19. October 2021). Retrieved from https://www.vld-eng.com/blog/tipos-de-robots-industriales/ abgerufen

EXAM 4.0 Framework. (2020). EXAM 4.0. Von The Advanced Manufacturing 4.0 Framework: https://examhub.eu/wp-content/uploads/2021/04/WP_4_2.pdf abgerufen

GE. (25. October 2021). Retrieved from https://www.ge.com/additive/what-additive-manufacturing abgerufen

Iberdrola. (26. October 2021). Retrieved from https://www.iberdrola.com/innovacion/que-es-iiot abgerufen

Odoo. (13. October 2021). Retrieved from https://www.odoo.com/es_ES abgerufen

Simumatik. (29. October 2021). Retrieved from https://simumatik.com/education/ abgerufen

SMC training. (26. October 2021). Retrieved from https://www.smctraining.com/en/newpage/newsdetail/2060 abgerufen

Thingsboard. (26. October 2021). Retrieved from https://thingsboard.io/docs/getting-started-guides/what-is-thingsboard/ abgerufen

UNIR. (19. October 2021). Retrieved from https://www.unir.net/ingenieria/revista/robotica-industrial/ abgerufen

Wikipedia. (25. October 2021). Retrieved from
https://en.wikipedia.org/wiki/Computer_security abgerufen

Wikipedia. (29. September 2021). Retrieved from
https://en.wikipedia.org/wiki/Critical_thinking abgerufen

Wikipedia. (13. October 2021). Retrieved from
https://en.wikipedia.org/wiki/Enterprise_resource_planning abgerufen

Xataka. (26. October 2021). Retrieved from
https://www.xataka.com/pro/digital-twins-que-sirven-cuales-beneficios-problemas-gemelos-digitales abgerufen

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