Learner Centric Advanced Manufacturing Platform

# GUIDELINES FOR THE IMPLEMENTATION OF I4.0 TECHNOLOGIES IN VET

WP6 Industry 4.0 technology absorption through the Collaborative Learning Factory

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# GLOSSARY AND/OR ACRONYMS

## ACRONYMS

**AGV** - Automated Guided Vehicles
**AR** - Augmented Reality
**ARI** - Automation and Industrial Robotics
**BI** - Business Intelligence
**CBL** - Challenged-Based Learning
**CLF** - Collaborative Learning Factory
**CNC** - Computer Numerical Control
**CoVE –** Centres of Vocational Excellence
**EQF** - European Qualifications Framework
**ERP** - Enterprise resource planning
**FDM** - Fused Deposition Modeling
**HC-R-S** - Human-centred, Resilient, and Sustainable
**HVET** High Vocational Education and Training
**I4.0** - Industry 4.0
**IALF** - International Association of Learning Factories
**ICS -** Industrial Control Systems
**IDS -** Intrusion Detection Systems
**IoT** - Internet of Things
**IPS** - Intrusion Prevention Systems
**ISA** - International Society of Automation
**IT** - Information Technologies
**KPI** - Key Performance Indicators
**LCAMP** - Learner Centric Advanced Manufacturing Platform
**LF** - Learning Factory
**LF-SAT** - Learning Factory Self-Assessment Tools
**MFA** - Multi-Factor Authentication
**MES** - Manufacturing Execution System
**MIR** - Mobile Industrial Robot
**OEE -** Overall Equipment Effectiveness
**OT -** Operational Technology
**PBL** – Project Based Learning
**PLC** - Programmable Logic Controller
**PLM** - Product Lifecycle management
**SLS** - Selective Laser Sintering
**VET** - Vocational Education and Training
**VPN** - Virtual Private Network
**VR** - Virtual Reality
**SAT** - Self Assessment Tool
**SOP** Standard Operating Procedures
**SWOT –** Strengths, Weaknesses, Opportunities, and Threats
**WP** - Work Package
**WS** - Workstation

# CONTENT TABLE

# EXECUTIVE SUMMARY

This document presents a six-step guideline for incorporating Industry 4.0 (I4.0) technologies into vocational education and training (VET) environments, as demonstrated by the Learner-Centric Advanced Manufacturing Platform's (LCAMP) Collaborative Learning Factory (CLF). The guideline begins by identifying educational needs addressed by specific technologies, followed by a feasibility study. A phased implementation plan facilitates gradual deployment, emphasizing safety, compliance, cybersecurity protocols, and onboarding training for educators. It also prioritizes integrating these technologies into curricula to provide hands-on learning aligned with industry standards. The guideline concludes with recommendations for ongoing evaluation and continuous improvement. To support the guideline 12 Key use cases, such as augmented reality, automated workstations, and water jet cutting, showcase the practical application of these steps, demonstrating how CLF environments foster real-world skills through innovative, collaborative learning frameworks.

This document provides comprehensive guidelines for implementing I4.0 technologies in VET through the Learner-Centric Advanced Manufacturing Platform (LCAMP). LCAMP's key initiative, the CLF, aims to advance the teaching of advanced manufacturing by replicating industrial processes in VET centres using both physical and virtual environments. The CLF, a collaborative project among multiple VET centres, simulates real-world manufacturing scenarios to enable students to gain practical experience with cutting-edge technology.

The CLF framework is designed around practice-based learning that emphasizes job-specific and transversal skills essential for advanced manufacturing in the context of digital and green transformations. To facilitate this, LCAMP provides open-access educational resources and a roadmap for institutions seeking to replicate the CLF model. The CLF fosters collaboration across different institutions and integrates organizational models that focus on human-centred, resilient, and sustainable (HC-R-S) approaches.

A structured six-step guideline is outlined for integrating new technologies into learning factories, beginning with needs assessment and extending through technology selection, phased implementation, and continuous improvement. This guideline ensures a streamlined approach for VET institutions to adopt relevant I4.0 technologies, covering feasibility assessments, phased deployment, safety protocols, and training resources to support the technology's inclusion in educational programs.

Additionally, the document presents 12 specific use cases, such as augmented reality (AR) in assembly tasks, automated robotic workstations (WS), and water jet cutting, each demonstrating practical implementations and educational applications within the CLF framework. These cases showcase how I4.0 technologies enhance operational efficiency, facilitate collaborative learning, and align with industry standards. Through a mix of real and virtual environments, CLF enables international collaboration among students and instructors, preparing a skilled workforce capable of adapting to modern manufacturing challenges.

# 1. INTRODUCTION

Building a Learning Factory (LF) in a (higher) Vocational Education and Training (VET) centre is a major challenge. The purpose of the LF, its educational goals, target audience, structure, the manufacturing process it will replicate, the product, and the indicators all need to be defined (Abele, et al., 2015). Moreover, selecting the right technologies to incorporate in the LF is one of the most crucial decisions. These technologies, along with their applications and interactions with people, form the foundation of the LF experience.

The choice of technology will shape the entire operation of the LF. So, how should one select the appropriate technology? What criteria should a vocational education centre consider in making this decision? How can we prioritize factors such as didactic aspects and educational versatility, industry relevance, human-centred considerations, legal and administrative obligations, sustainability, cost and budget, space constraints, staff expertise, and other factors? Are all technologies equally suitable? And once the technology is chosen, how should it be implemented within the LF?

This report provides a comprehensive guideline for considering key factors in implementing technologies within the Learning Factories. The guide proposes a six-step pathway designed to assist practitioners in effectively absorbing I4.0 technologies. The guideline also draws on the experiences gathered through the development of the LCAMP Collaborative Learning Factory (CLF), where LCAMP partner organizations are incorporating I4.0 technologies into their Learning Factories according to a predefined framework (LCAMP, 2023).

By Industry 4.0 technologies, we mean technologies of these types:

- **Internet of Things (IoT):** A network of interconnected devices that collect and exchange data to improve operational efficiency and enable smart manufacturing.
- **Artificial Intelligence (AI) and Machine Learning (ML):** Advanced algorithms that analyze data, predict trends, and automate decision-making processes.
- **Big Data and Analytics:** Tools and methods for processing vast amounts of data generated in real time to optimize production and business strategies.
- **Cloud Computing:** Secure storage and on-demand access to data and applications over the internet, facilitating collaboration and scalability.
- **Augmented Reality (AR) and Virtual Reality (VR):** Immersive technologies used for training, product design, and enhancing operational workflows.
- **Robotics and Autonomous Systems:** Smart robots capable of performing tasks autonomously, improving precision and efficiency in manufacturing processes.
- **Cybersecurity:** Advanced measures to protect systems, networks, and data from cyber threats, ensuring safe operations.
- **Additive Manufacturing (3D Printing):** A transformative process of creating objects layer by layer from digital designs, enabling customized production and reducing waste.
- **Simulation and Digital Twins:** Virtual models that replicate physical assets, systems, or processes to optimize performance and predict failures.
- **Horizontal and Vertical System Integration:** Seamless connectivity between various systems across the supply chain, from factory floors to enterprise-level applications.
- **Edge Computing:** Processing data closer to its source for faster insights and reduced latency in critical applications.

- **Advanced Sensors and Smart Devices:** High-precision devices that monitor and control industrial processes in real time.
- **Blockchain:** A secure and transparent method for managing and verifying transactions, improving trust across supply chains.

In line with LCAMP's understanding of advanced manufacturing as the application of digitalisation and cutting-edge manufacturing developments (3D printing, Additive Manufacturing, High precision Machining, etc.) to manufacturing processes with the aim of increasing flexibility, productivity, and efficiency.

# 2. LCAMP COLLABORATIVE LEARNING FACTORY

Before diving on a technology absorption process it is worth adding a context to the activity. The proposed guideline is inspired by the LCAMP's CLF model.

LCAMP proposes the key features of shop floor facilities (practical labs) in VET schools to effectively address the evolving demand for current skills triggered by the digital and green transformations, using the CLF model (LCAMP, 2023). The CLF replicates contemporary industrial processes to manufacture a specific product for educational applications and environments (i.e. VET centre labs), but within a structure that is geographically distributed between seven VET centres, each centre playing a particular role in the manufacture of a final product. The interconnections amongst and between LFs scaffold the operational arrangements of the CLF. This configuration allows for the implementation of:

- Practice-based learning environments for VET students with embedded I4.0 technologies.
- Acquisition of professional[1] and transversal skills for Advanced Manufacturing.
- Enhanced cooperation among international VET organizations.

## 2.1. FEATURES OF THE CLF

The CLF model proposed in LCAMP (LCAMP, 2023) possesses the following characteristics:

- The entire **value chain** required for the production of products is replicated, with the physical environment, including machines, equipment, and resources, and set up within workshops. Additionally, the virtualization of the value chain may also be implemented as an optional component.
  The activities defined for the CLF value chain are gathered in 5 steps: 1. Product Design/ 2. Process Engineering/ 3. Manufacturing, Quality Control and Maintenance/ 4. Logistic/ 5. Virtualization
- It incorporates a **high degree of digitization**, taking inspiration from the smart factory concepts currently being developed within industry[2].
- It is designed to **accommodate multiple technological disciplines** (either simultaneously or in sequence), necessitating the adaptation **of learning methodologies** accordingly.

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[1] According to the LCAMP competence framework, professional skills are related to all the skills under the subcategories of a) handling Production Principles; b) Competencies in STEM; c) Manufacturing; d) Additive Manufacturing; e) Simulation; f) Safety; g) Scientific work; h) Electrical engineering; i) Soldering / welding techniques; j) Human-machine interactions. Transversal refers to the skills included in the subcategories of a) Critical thinking; b) Problem-Solving; c) Analysing; d) Creativity/Innovation; e) Planning & Organising; f) Result-oriented; g) Willingness to Learn/Continuous Learning; h) Flexibility/Agility; i) Customer-oriented; j) Self-management; k) Decision Making; l) Responsibility; m) Communication; n) Cooperation/Teamwork; o) Diversity; p) Empathy

[2] We adopt a wide definition of technology. For us technology will mean (Bijker, 1994) • The knowledge required to handle a specific technology, or artifact, or a group of them. • The artifacts themselves, like a computer, a robot, or a pencil. • The reflection about the previous two, as in reflecting about I4.0, I5.0, digitalisation or advanced manufacturing.

- The model is conducive to fostering **collaboration** across various institutions, departments, and groups.
- Beyond digitization, the LF also facilitates the recreation of **organizational models found in companies**, with a focus on developing Human-centred, Resilient, and Sustainable aspects in line with the industry 5.0 paradigm (Oeij et al., 2023)

Whatever the configuration of the LF is, it offers a prominent action oriented pedagogical approach. The current study builds on the premise that most European countries are now actively using learning outcome (or competence) statements to define, review and refine their qualifications, VET curricula, and programmes (Cedefop, 2024)

The pedagogical approaches enhancing experiential learning[3] and Project-Based Learning (PBL) help to develop new ways to work simultaneously on job specific and transversal competences (OECD, 2021).

## 2.2. MATURITY MODEL FOR CLFS

The main characteristics that define a LF outlined in the previous section are difficult to assess. Moreover, VET schools may have different starting points for developing a LF model. It is worth remembering that the LF concept should align with each school's specific objectives. What works well for one institution may not necessarily be suitable for another, especially when making decisions about technology implementation.

To support technical education providers in creating or enhancing a LF, the LCAMP project has developed the **Learning Factory Self-Assessment Tool (LF-SAT)[4]** (LCAMP, n.d.) This tool provides tailored guidance based on each school's specific objectives and starting point, offering valuable insights to advance the implementation of their own LF. The LF-SAT is built upon 4 domains that represent the main characteristics of the Learning Factories:

- 1st domain: **learning methodologies**, in this domain the user asses to what extent active methodologies[5] are used in the learning activities and therefore in the LF.
- 2nd domain: technological disciplines or **technology fields** to implement in the LF. It delimitates what study programs are integrated in the LF, and by extension, what contents are planned to work out in the LF
- 3rd domain: the ability to recreate a **manufacturing value chain.** The value chain of a manufacturing process in advanced manufacturing involves a series of activities that transform raw materials into a finished product. The LCAMP CLF's value chain, the activities are clustered in 5 main steps: 1. Product design/ 2. Process Engineering/ 3. Manufacturing, Quality Control and Maintenance/ 4. Logistic/ 5. Virtualization. Indeed, these are the assessed items.

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[3] UNESCO defines "experiential learning as "Experiential learning is a process that develops knowledge, skills and attitudes based on consciously thinking about an experience. Thus, it involves direct and active personal experience combined with reflection and feedback

[4] https://community.lcamp.eu/user-login/).

[5] Active learning is a method of learning in which students are actively or experientially involved in the learning process and where there are different levels of active learning, depending on student involvement (Bonwell & Eison, 1991). It is also defined as any instructional method that engages students in the learning process. In short, active learning requires students to do meaningful learning activities and think about what they are doing (Huang, 2020)

- 4th domain: **resources, equipment, level of digitization,** this assessment aims to measure the technical capacity to create a LF using the existing equipment and infrastructure available in the school.

As a result of the assessment process the user obtains a report detailing the readiness and progress in creating an LF. The report outlines school's or organization's current level across the four mentioned domains. The maturity levels range from initial stages called "basic level", an intermediate level called "ready level" to more advanced stages called "running level", where Learning Factories are already established.

Ultimately, the results of the LF-SAT provide valuable insights into a school's journey towards LF implementation highlighting specific areas where strategic focus could accelerate progress.

In recent years, numerous approaches to design learning factories and to assess their performance have been developed (Kreß, 2021). For already established LFs the International Association of Learning Factories (IALF) published the **Maturity Model for Learning Factories** (IALF, 2024) where concrete aspects about the functionalities of Learning Factories can be evaluated systematically. "Using the maturity model, it will be possible to evaluate and compare the maturity of Learning Factories not only in the field of lean production, but also for other thematic foci" (Enke J., 2017).

From another perspective, the Learning Factory Configuration Tool developed in the University of Twente (Frielinck, 2023) proposes a comprehensive tool to preserve the lifespan and educational value of a learning factory.

In the context of vocational training, Anselmann et al. have recently laid the groundwork for an exploratory descriptive study on LFs, with a particular focus on Baden-Württemberg (Anselmann, 2024). Their research underscores both the complexity of the analysis and the limitations faced. This study emphasizes the necessity for tools that can aid VET schools in the development and subsequent evaluation of LFs.

These tools are complementary and useful to obtain a clear picture of the context where a LF is being developed or used. When it comes to integrating technologies in those systems, they offer very valuable information to support the decision-making process.

# 3. GUIDELINES TO INCORPORATE TECHNOLOGY IN LFs

Integrating technology into manufacturing workshops in educational institutions requires a strategic and well-structured approach to maximize its impact. Proper guidelines are a support tool to ensure that technologies are implemented effectively, minimizing disruptions and optimizing outcomes.

This section presents a guideline to incorporate technologies in Learning Factories (LF), based on the experience that the LCAMP team gained during the creation of the LCAMP's CLF, enriched by selected use cases from bibliography. The guideline gathers insight from the educational context of the LFs and various industrial approaches for incorporating technologies into manufacturing processes. Additionally, human-centric aspects have gained significant importance in the development of the guideline due to their critical role in achieving a successful integration.

This report primarily focuses on how to incorporate new technologies in Learning Factory (LF) environments. Given that LFs can vary from one organization to another, it is recommended that each organization conduct a diagnosis of its specific situation before beginning the technology integration process. To support this, LCAMP provides the LF-SAT, enabling interested users to establish a baseline for starting the incorporation of new technologies.

The guideline consists of six basic steps, as follows.

## 3.1. Identification of a need or a problem to solve

The process begins with identifying a need, which can vary widely in nature. From an educational standpoint, this might include addressing a new skill or curriculum requirement, improving skill development, training individuals on specific technologies, meeting upskilling demands, or leveraging didactic opportunities presented by a particular technology. Additionally, the motivation to improve the features of the LF might also drive the integration of a specific technology.

Methods for identifying needs can come from a variety of sources, including outcomes from self-assessment processes like the previously mentioned LF-SAT, skill gap detection systems, data from monitoring systems (observatories), updates in official curricula, regional skills ecosystems, partnerships with industry, and more.

Finally, during the need's identification process, the following aspects should be taken into consideration (Mullen, 2011):

- Clearly establish the requirements and goals for integrating technology, such as improving skill development, enhancing simulation capabilities, or optimizing production processes for learning purposes.
- Align the technology with the overall educational and training objectives of the learning factory

- Evaluate the existing infrastructure to ensure compatibility with the new technology.
- Identify any necessary upgrades, such as connectivity improvements, software/hardware updates, or space modifications, to support the technology.
- Assess user needs, existing challenges, and process gaps.
- Involve stakeholders to understand expectations and constraints

## 3.2. Technology Selection and Feasibility Study

When analysing which needs the educational institutions aim to address through LF an initial filter has been applied to identify technologies that could be suitable. In this step, a more detailed examination is proposed, conducting a deeper analysis of the technologies deemed appropriate. For this purpose, the following criteria are suggested:

- Choose technologies that reflect real-world industry applications to create realistic learning environments.
- Conduct feasibility studies or pilot testing to validate the technology's effectiveness and fit.
- Ensure the technology is scalable, modular, and adaptable to accommodate future developments and expansions.
- Ensure that it is integrable into the existing infrastructure.
- Evaluate the virtualization capacity of the selected technology for its later integration in virtual environments (digital twins or others)
- Evaluate the collaboration options that the technology offers for co-work and collaboration activities with third parties.

## 3.3. Develop a Phased Implementation Plan

Once the technologies are defined it is time to implement them into the LF. An appropriate planning of the implementation process is crucial to assure that the users will adopt naturally the choice made. In this step, a key factor is the human centric aspect of the technology adoption, to make the users participants of the implementation. The following criteria is recommended:

- Adapt the technology to align with user needs and workflows.
- Design user interfaces, features, and workflows that match user's requirements.
- Incorporate user feedback in the design process. Include users in the design team.
- Establish a timeline, milestones, and resources needed for deployment.
- Prepare risk mitigation strategies to handle potential challenges.
- Assign responsibilities to teams and individuals involved.
- Introduce technology gradually through pilot programs and limited deployment phases, establishing a timeline, milestones, and resources needed for deployment.
- Monitor each phase, gather feedback from participants, and refine the implementation process before scaling up.
- Prepare risk mitigation strategies to handle potential challenges.
- Ensure Safety and Compliance Standards
    - Follow safety protocols when integrating technologies to maintain a secure learning environment.

    - Comply with regulatory and educational standards related to the technology and its use within the learning factory.
    - Apply cyber security protocols to safeguard the integrity of equipment and networks.

## 3.4. Training

A smooth adoption of a technology requires a training period for the users. In LF environments, there will be different types of user profiles, from developers to common users. Training processes must be tailored and adapted to each type of user.

- Offer comprehensive training programs to equip teachers/trainers with the skills to effectively use and teach the technology.
- Develop support materials (e.g., manuals, video tutorials, and interactive modules) to facilitate student learning and engagement.
- Provide training sessions, workshops, or e-learning modules for users.
- Develop user guides, Frequently Asked Questions (FAQs), and support resources.
- Offer hands-on practice and onboarding assistance for smooth adoption.

## 3.5. Integrate Technology into Curriculum and Learning Activities

Generally, the final goal of the implementation of industry 4.0 technologies in LF is the upgrade of curriculums, always following the quality standards of each organization and national and/or regional regulations. The integration of the technology is reached by the creation of learning activities for the acquisition of the predefined set of skills linked to the use of the specific technology. The learning activities could be diverse in terms of learning methodology, contents, levels and duration.

- Design learning activities, projects, courses and simulations that incorporate technology to create hands-on, immersive learning experiences.
- Align these activities with industry standards and practices to ensure they are relevant and valuable for students.
- Define the assessment systems for the learning activities. The assessment should follow the quality standards of the organization and usually should include not only technical skills but also personal, social, digital and green skills. Moreover, the assessment system should be tailored for different types of users.

## 3.6. Evaluation and Continuous Improvement

- Assess effectiveness and refine the integration process.
- Collect data on technology usage, efficiency, and user satisfaction.
    - Analyse performance metrics and compare them with initial goals.
    - Collect feedback from instructors and students to identify areas for improvement and continuously update the technology’s integration.
- Plan for periodic updates and future technology enhancements to keep the LF up-to-date with industry advancements.

# 4. INTEGRATED TECHNOLOGIES, USE CASES

This section provides a comprehensive analysis of all the technologies that have been integrated into the CLF, exploring in detail their functions, modes of installation and contributions to the collaborative learning and production environment.

The CLF, conceived as a dynamic ecosystem that promotes collaboration and knowledge sharing, has been equipped with a wide range of technologies ranging from assistance technologies to advanced manufacturing systems. Each of these technologies plays a crucial role in the operation and continuous improvement of processes within the CLF.

12 use cases about technology implementation carried out by LCAMP partners in their own LFs are described hereafter. The focus is on describing in depth the specific functions of each technology, including their ability to improve operational efficiency and their role in facilitating communication and collaboration between participants. The integration of these technologies in the CLF has followed the guidelines proposed in section 3.

This detailed analysis provides a fuller understanding of how the technologies embedded in the CLF are transforming the way learning and collaborative production are conducted, and how they are contributing to the ongoing evolution of this innovative approach to manufacturing and knowledge.

## 4.1. USE CASE 1: ASSISTANCE TECHNOLOGIES BASED ON AR

| USE CASE | **Assistance technologies based on AR** |
|---|---|
| Author: | Miguel Altuna LHII, Basque Country |
| Description | The assistance technologies for advanced manufacturing are designed to enhance productivity, quality, and efficiency in manufacturing processes. In particular, the LCAMP CLF is using AR as assistance technology to support user (either students or workers) in performing complex tasks more accurately and efficiently.<br>This AR-based system overlay digital information onto the physical environment in real time, enhancing the user's ability to perform tasks, monitor processes, and make decisions. The system integrated guide users through the assembly processes by displaying step-by-step instructions directly in their field of view. This reduces errors and training time. (see Figure 1)<br>Furthermore, the system is equipped with artificial vision cameras to assist in quality control tasks by checking deviations from the standard instructions on the CLF product. Last but not least the ergonomic aspects of the WSs are improved. |
| Location | • Miguel Altuna LHII – Basque Country<br>• Tknika - Basque Country<br>• DHBW- Heidenheim- Germany<br>• CMQ- France |

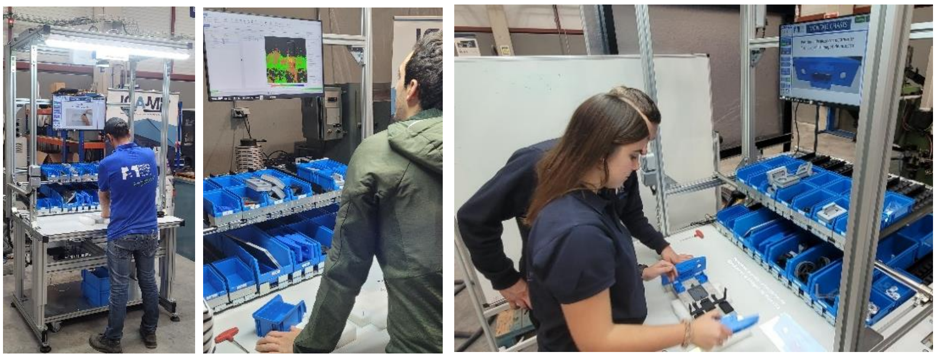

*Figure 1 WS from Miguel Altuna LHII's LF equipped with the ARKITE system*

| | |
|---|---|
| **#1. Identification of a need or a problem to solve,** | |
| Purpose (technical) | The aim of this system is to digitalize to same extend the manual assembly WSs of the LF to get digital signals from them, assuring assembly quality and allowing traceability of the process.<br>The purpose is to improve productivity, quality, and operational efficiency in manufacturing. |
| Purpose (didactic) | The purpose is to learn, trial and afterwards create learning contents about concrete digital solutions used in industry to improve productivity, quality, and operational efficiency in manufacturing.<br>Besides that, we aim to research human centric aspects in manual assembly tasks and to raise the awareness of students on human centric practices.<br>As a result, we aim to integrate learning activities into the following programs<br>• PM, Mechatronics, Automation and industrial robotics (ARI), Smart manufacturing (Miguel Altuna LHII) |
| **#2. Technology Selection and Feasibility Study** | |
| | The selected technology, called ARKITE (ARKITE, n.d.) is a real-world industry application used in several industries where manual assembly operations are difficult to automatize and operators carry out manual tasks.<br>**Technology's effectiveness and fit**.<br>The selected system uses a 3D sensor and infrared sensor technologies for detections supported by the AR projection functionalities. Other object recognition technologies have been evaluated without achieving such satisfactory results (Raj, 2024),for different reason (process, service, technology, conditions).<br>**Adapt the technology to align with user needs and workflows**<br>This system enhances the Learning Experience of users by transform abstract concepts of lean manufacturing into interactive, 3D visualizations, making them easier for students to understand. It turns theoretical lessons into immersive experiences.<br>The selected AR solution allows the tailored configuration for different users, work modes for training, allow to determinate the degree of assistance needed depending on the user's experience. It's also configurable considering physical aspects laterality, posture and movement, distribution of elements and lay out, tool's distribution and others.<br>At the same time, the flexibility offered by system allows it to be reconfigured for the assembly of a variety of products. This aspect is important, as the system can be used in parallel for several assembly processes either within the LCAMP CLF or in other activities. In Miguel Altuna LHII's case the language and instruction's modes were adapted to the target user's needs.<br>**Scalability**<br>Once LCAMP is finished, the AR system offers the possibility to continue working on a number of other projects, depending on the predominant technological fields of the universities using them. Undoubtedly, one area of study that will prevail is the digitisation |

of workplaces and manufacturing processes, the communication systems needed, the maintenance of such environments and its cybersecurity. Besides that, an important study field is related with the integration and use of digital technology by people in the shopfloor, the so call human technology integration, covering aspects like ergonomics, wellbeing, empowerment, participation. The system allows the inclusion of such elements in student projects, enriching this type of increasingly relevant competences.

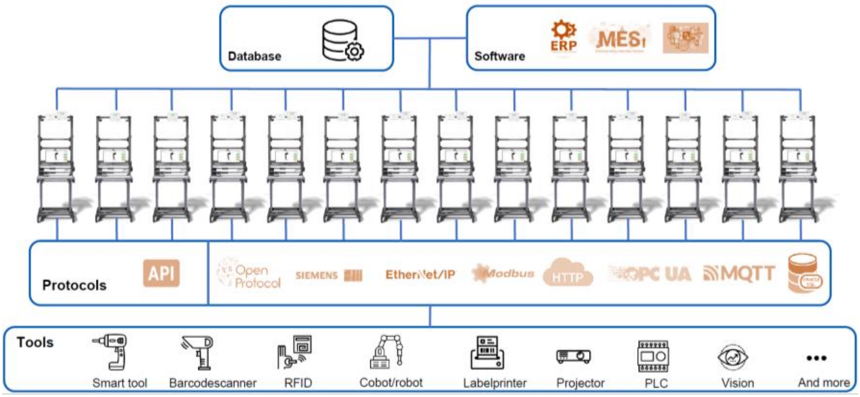


*Figure 2 Communication options for the ARKITE system*

**Evaluate the virtualization**

The AR system gathers signals collected during manual assembly and stores them in a database. This data is later used by other devices for purposes such as process analysis or visualization, for instance, in the creation of digital twins.

**Collaboration opportunities**

Within the LCAMP consortium, the integrated AR system will be used in 4 partners' LF. Therefore, the setup of assembly instructions are fully shareable among the 4 partners. The work made in 1 lab is automatically transferable to the others with slight adjustments. This feature allows big collaboration opportunities. Students from different countries can work together in projects and to share their set up.

The use of alternative systems would difficult such collaboration. The results of the market research carried out show that the communication (data exchange) between different systems would be possible. However, the sharing of full set ups and configurations would not be possible. Furthermore, the testing feature of Arkite is not possible in other analysed alternatives, therefore technological solution would not be so complete

## #3. Develop a Phased Implementation Plan

**Implementation and testing**

The implementation of the AR system has been carried out as follows:

First, the system was delivered by the supplier, who also performed the equipment calibration. A group of 3 teachers from the school received an initial training to understand the system's details. The designated teachers team oversaw and validated the setup. For this purpose, in addition to set up the assembling of the LCAMP CLF product, the teachers did also program other sub-assemblies used in the school for learning porpoises.

**Communication campaign, users' needs**

Once the system is validated and ready, in parallel of the progression in its use, a communication plan was performed to inform the potential users (teachers) of the systems of the didactic opportunities that the system brings to them. Besides that, the communication campaign serves to open a channel to understand the needs of the potential users and to align the system with their needs and workflows.

**Pilot training, roll out technology in small team**

As a results of the communication campaign, two more teachers joined the core team to roll up the technology. The adaptation of the system to the users needs include:

- Adapt user interface by translating it into Basque language and adding requested features

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| | • Include users in the design team and incorporate their feedback in the design process.<br>A training is planned for November 2024 with the participation of 10 teachers of Miguel Altuna LHII.<br>**Gradual expansion. Support team. (in progress)**<br>The teachers attending the first internal training are the responsible of the gradual expansion at Miguel Altuna LHII.<br>The use of the system is planned for 3 more programs during the scholar year 2024-25. The systems will be available not only as a part of the CLF but also independently for external PBL activities in other to maximize its use.<br>**Ensure Safety and Compliance Standards**<br>The systems was set up following a safety plan provided by the supplier. The specific safety plan of the system will be included in the general safety plan of the advanced manufacturing workshop at Miguel Altuna LHII.<br>A similar protocol will be applied for the Cybersecurity plan (in progress) |
| **#4. Training** | |
| | The training for the implementation team was place at October 1-2-3-4, 2024 at Miguel Altuna LHII. Teachers from Miguel Altuna LHII and Tknika took part on the sessions, provided by the supplier.<br>The first onboarding course for further teachers is planned for November 2024.<br>Another training session for LCAMP partners will be delivered in January 2025<br><br><br>*Figure 3 Training session for teachers (2024 October 2nd)* |
| **#5. Integrate Technology into Curriculum and Learning Activities** | |
| | At Miguel Altuna LHII, learning activities are structured around the Challenge-Based Learning (CBL) methodology, embedded within the Ethazi pedagogical framework. Consequently, the integration of the AR system into the curriculum is achieved through two approaches: embedding AR-based tasks within existing CBL projects or developing new CBL projects specifically focused on utilizing AR technology. The choice of approach will depend on the specific requirements of each study program.<br>The roll out of the technology implies the adaptation or creation of CBL projects.<br>**Courses foreseen for the WS**<br>• Programming of AR assistance systems<br>• Lean Manufacturing.<br>• Production management.<br>• Projects management in LF environments.<br>• Maintenance of automated lines.<br>**Assessment methods**<br>Upon the conclusion of the pilot period, the courses developed for this WS will be incorporated into the quality system of Miguel Altuna LHII. This quality procedure encompasses the student evaluation system, which will also apply to the learning activities conducted within the AR system<br>Finally, for the assessment of activities integrated within the CLF, the LCAMP skills framework (LCAMP, 2023) will serve as a unifying mechanism, in addition to the assessment methods employed by individual schools. This framework encompasses not only technical skills but also transversal skills, digital skills, and green skills, thereby |

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| | facilitating the development of a common assessment method. This task is currently ongoing and is expected to be completed by November 2024 |
| **#6. Evaluation and Continuous Improvement** | |
| In progress | |
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## 4.2. USE CASE 2: AUTOMATED ASSEMBLY WS: SENSOR BOX WS

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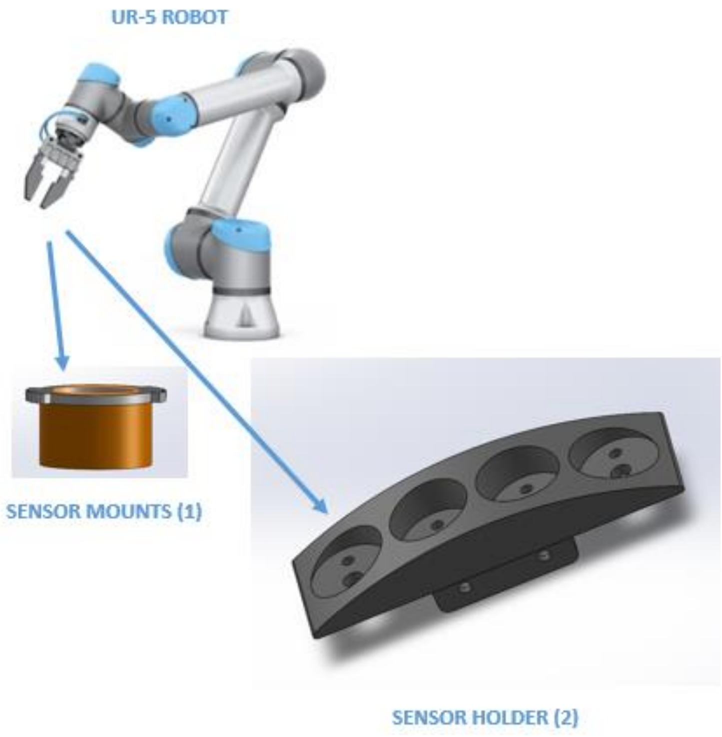
| USE CASE | **Automated Assembly WS: Sensor Box WS** |
| Author | Miguel Altuna LHII, Basque Country |
| Description | The automated assembly WS known as the Sensor Box WS is part of LACMP's Learning Factory, where sensor mounts (1) are assembled onto the Sensor Holder (2) components on the front and rear parts of the LCAMP Robot. See Fig 4. Assembly is carried out automatically by a UR5 collaborative robot. The WS features a system for detecting and sorting defective parts.<br><br><br>*Figure 4 Schematic process for mounting the sensor mounts on the sensor holder.*<br><br>This station not only enhances the operational efficiency of the LF but also provides a comprehensive educational platform for developing automation skills within a practical, interdisciplinary learning environment.<br>When integrating these technologies into the CLF, the steps outlined in Section 3 of this guide were followed.<br>The WS Sensor Box automated assembly WS consists of a Siemens S7-1500 PLC, a Cognex artificial vision camera, a UR-5 collaborative robot, and an AMR mobile robot |

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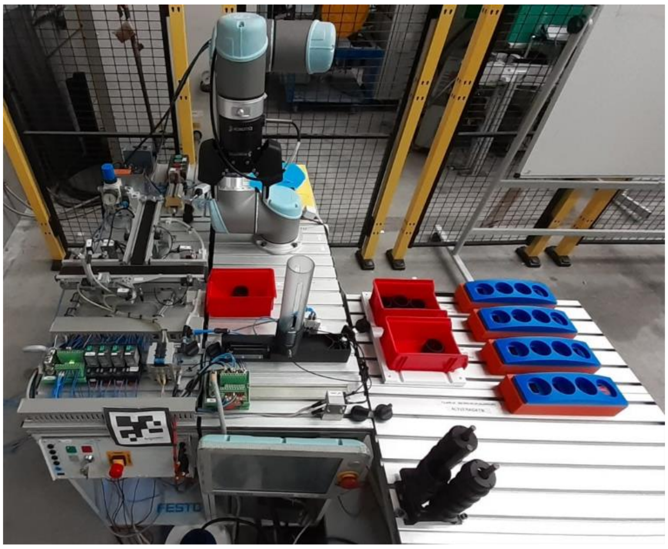
| | (MIR), ensuring a high degree of automation, precision in part classification, and resource optimization. |
| Location | • Miguel Altuna LHII – Basque Country |
| <br>*Figure 5 Automated Assembly WS: Sensor Box WS at Miguel Altuna LHII* | |
| **#1. Identification of a need or a problem to solve,** | |
| Purpose (technical) | The objective of this system is to automate the assembly of an LCAMP robot subsystem, specifically the sensor box, eliminating the need for manual assembly. This automation is achieved through the integration of a collaborative robot, guided by a machine vision camera and controlled by a PLC. Additionally, various components are transported using a mobile robot. This setup improves efficiency in part classification and handling, ensuring product quality. Furthermore, the flow and quality of processed parts are monitored and recorded to ensure traceability and control. |
| Purpose (didactic) | The system provides hands-on experience in programming and setting up an automated system, promoting real-world problem-solving and collaborative work. The intended learning outcomes align with the following vocational training programs:<br>• Industrial Mechatronics: Combining mechanics, electronics, and computing to design and maintain automated systems.<br>• Automation and Robotics Industries (ARI): Integrating automated systems and programming PLCs and robots.<br>• Smart manufacturing: Integration of automated systems in smart manufacturing production lines. |
| **#2. Technology Selection and Feasibility Study** | |
| | To implement this WS in LCAMP's CLF, the Siemens S7-1500 PLC, Cognex machine vision camera, UR-5 collaborative robot, and AMR (MIR) mobile robot were selected. These components ensure a high degree of automation, precision in part classification, and resource optimization.<br>**Justification for Material Selection**<br>• Siemens S7-1500 PLC: Selected for its reliability, flexibility, and integration capabilities with other systems. It is widely used in industry, making it ideal for learning with real-world technology.<br>• Cognex Machine Vision Camera: Chosen for its high precision and ability to perform detailed inspections. Its In-Sight software allows for easy programming and adjustments. |

- UR-5 Collaborative Robot: Known for its safety features and ease of programming. It is ideal for close collaboration with humans and handling delicate parts.
- AMR Mobile Robot (MIR): Selected for its autonomous mobility and efficient material transport capabilities, improving internal logistics.

**Feasibility Study**

**Technical aspects:**

Compatibility: The selected components are compatible with each other, facilitating integration and centralized control.

**Reliability:** All components come from recognized manufacturers, ensuring a high level of reliability and technical support**.**

- **Economic Aspects**
  - **Initial Cost:** The initial investment may be high, but it is justified by the durability of the components and the reduction in operational costs in the long term.
- **Didactical aspects**
  - **Educational relevance:** The selected material is extensively used in the companies of the region, so it is expected that its didacticization will have relevant use also in parallel courses outside the LF.
  - **Versatility**: They enable the teaching of multiple disciplines, ranging from PLC and robot programming to the implementation of machine vision systems and automated logistics**.**

**Improvement Options / Potential Future Implementations**

- Expansion of Artificial Vision System: Upgrade the artificial vision camera to one with higher resolution, or add additional cameras to provide various inspection angles.
- Additional Robots: Add more collaborative or mobile robots to optimize the handling and transport of parts.
- Internet of Things (IoT) Integration: Connect all components to an IoT platform for real-time monitoring and cloud-based data analysis.
- Predictive Maintenance: Integrate sensors and software to predict failures and schedule equipment maintenance.
- Remote Control and Monitoring: Develop a remote interface to control and monitor the station from any location.
- Modular Expansion: Design the station to allow for easy addition of new functions and equipment as needs evolve.

**System Virtualization**

This station has been virtualized using the Simumatik platform to replicate the physical system created. This approach facilitates testing and simulations prior to real implementation, reducing costs and risks, while enhancing the system's flexibility and scalability.

Simumatik is the emulation platform that provides a flexible digital environment for building and exploring physical, electrical, pneumatic, and mechatronic systems. It allows users to program robots and PLCs in a virtual world, creating “digital twins” that can later be transferred to real systems.

**Collaboration opportunities**

The physical setup, utilizing standard equipment, facilitates collaborative work with external stakeholders. Additionally, the virtual setup built on Simumatiks allows for collaboration with partners who do not have the physical setup of the system. The anticipated collaboration opportunities include:

The foreseeing collaboration opportunities include:

- Sharing of didactic material
- Join projects among international students
- Hosting of international students in mobility activities

## #3. Develop a Phased Implementation Plan

1. **Planning and Preparation:** With the technical and instructional goals of the LCAMP CLF in mind, this WS was designed to support learning activities for students in *ARI*.

The implementation was led by one teacher from the ARI group, with a team that included two teachers and the CLF coordinator.

2. **Acquisition of Equipment and Software:** The team selected equipment commonly used in the ARI lab to be integrated into the CLF: a Siemens S7-1500 PLC, a Cognex camera, a UR-5 robot, and an AMR robot. They configured the necessary software for each component to ensure compatibility.
3. **Integration and Initial Configuration:** The team installed and connected all components, then programmed and the PLCs and robots, test each component separately, and conduct integrated tests to ensure the overall functionality of all the system.
4. **Development and Testing:** After the first testing a pilot activity was carried out in May 2024. An interdisciplinary pilot course was conducted in May 2024.  15 students from 6 study programs participated in a 50 hours PBL activity using all the equipment of the station.


*Figure 6 Students from Miguel Altuna LHII*

5. **Implementation and Monitoring:** Following the first pilot experience, the use of the station has been scheduled for inter-cycle activities throughout the 2024-2025 academic year. The assessment and monitoring system designed for the pilot experience will be reused in future editions, with relevant improvements added.
6. **Integration in the LCAMP CLF:** The Sensor Box WS is the first assembly station in the LCAMP CLF. The assembly line consists in 2 more assembly WSs. The components assembled in the Sensor Box WS are then feed to the WS01 Chassis assembly where the CLF's main products mechanic components are assembled. I part under the guidance of ARKITE. The electronic part will be carried out at a third WS. The tan
7. **Preventive and Corrective Maintenance:** A preventive and corrective maintenance plan is stablished to maintain the system operative.

**#4. Training**

Teachers from the automation department are already familiarized with the equipment integrated in the WS**.** There is an onboarding training material for new users as well as instructions on the operation and maintenance of the system. This learning material is adapted and used also with students.

1. Introduction to LCAMP's CLF: Overview of the product and to the entire process.
2. Function and scope of the system assembled in the sensor box WS.
3. Set up of the sensor box WS. Programming and configuration of the Siemens S7-1500 PLC, Cognex camera, UR-5 robot, and AMR robot.

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| | **4.** Operations in the sensor box WS. Production, quality control and intra logistics. Scale up options.<br>**5.** Digital twin of the sensor box WS: Use of Simumatik for preliminary testing.<br>**6.** Maintenance protocol |
| **#5. Integrate Technology into Curriculum and Learning Activities** | |
| | At Miguel Altuna LHII, learning activities are structured around the CBL methodology, embedded within the Ethazi pedagogical framework. Consequently, the integration of the Sensor box WS system into the curriculum is achieved through two approaches: embedding related tasks within existing CBL projects or developing new CBL projects specifically focused on utilizing technologies from this WS. The choice of approach will depend on the specific requirements of the involved study program.<br>The roll out of the technology implies the adaptation or creation of CBL projects.<br>To ensure the effective implementation of the technology in CBL activities, a series of courses has been developed, focused on the equipment included in the system. The following is a list of these courses.<br>1. Programming and configuration of the Siemens S7-1500 PLC (40h) and the UR-5 robot. (20h) EQF 5<br>2. Integration and use of the Cognex camera and its In-Sight software. EQF 5 (20h) EQF 5<br>3. Logistic automation with AMR (MIR) robots to optimize transport routes in simulated factories (30h) EQF 5<br>4. Integration of PLC, robots and vision cameras. (20h) EQF 5<br>5. Predictive maintenance techniques and fault diagnosis using data obtained from the integrated systems. (30h) EQF 5<br>6. Managing interdisciplinary projects to design and improve automated systems through collaboration across mechanics, electronics, and programming. (40h) EQF5<br><br>**Assessment methods**<br>Upon the conclusion of the pilot period, the courses developed for the Sensor Box WS will be incorporated into the quality system of Miguel Altuna LHII. This quality procedure encompasses the student evaluation system, which will also apply to the learning activities conducted within the Sensor Box WS.<br>For learning activities conducted within CBL projects, the current established assessment method will be prioritized. The introduction of new tasks into existing CBL projects will necessitate an update of the Key Performance Indicators (KPIs) used for evaluation. The Ethazi framework includes assessment of technical and transversal skills.<br>Finally, for the assessment of activities integrated within the CLF, the LCAMP skills framework (LCAMP, 2023) will serve as a unifying mechanism, in addition to the assessment methods employed by individual schools. This framework encompasses not only technical skills but also transversal skills, digital skills, and green skills, thereby facilitating the development of a common assessment method. This task is currently ongoing and is expected to be completed by November 2024. |
| **#6. Evaluation and Continuous Improvement** | |
| | To assess the operability of the Sensor Box, a combination of surveys, interviews, direct observation and analysis of usage data is carried out. These techniques allow us to collect and analyse data on user satisfaction (both student and teacher), ease of use, and system performance. KPIs include student satisfaction, achievement of objectives and difficulty level.<br>This comprehensive approach ensures a thorough understanding of the system´s effectiveness and areas for improvement. |

## 4.3. USE CASE 3 : DIGITAL TWIN

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| USE CASE | **Use Case: Digital Twin of part of the Sensor Box Workstation (WS)** |
| Author | **Simumatik Sweden** |
| Description | A Part of the Sensor Box WSs was developed on the Simumatik Platform. This digital twin mirrors part of the automated assembly process, where sensor mounts are sorted in the conveyor system. This simulation replicates the actions performed by a UR5 collaborative robot, and the conveyor system<br>The system is using a generic PLC that can be connected to a various amount of PLC, brands including Siemens, Codesys, Allen Bradley and more. The robot, UR5, can also be connected to RoboDK and UR-Sim. The Festo conveyor system replicates the physical, electrical and the pneumatic characteristics, allows users to interact with the system as they would with the physical station. |
| Location | • Available at the Simumatik Platform. |

*Figure 7 Automated Assembly WS: Sensor Box WS in Simumatik*

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| **#1. Identification of a need or a problem to solve,** | |
| Purpose (technical) | The purpose of this digital twin system is to model the automated assembly workflow for the sensor box within an LCAMP robot subsystem. By providing a virtual alternative to physical prototypes and hands-on assembly trials, the digital twin minimizes the need for real-world testing. In this simulated setting, the operations of a collaborative robot, guided by a programmable logic controller (PLC), are recreated to mirror actual automation processes. |
| Purpose (didactic) | As a didactic tool, the digital twin offers hands-on experience with an industrial automation system in a safe, flexible virtual environment. Students and instructors can engage in programming and troubleshooting without impacting physical hardware. This platform supports learning in:<br>• Industrial Mechatronics: Automation system design, maintenance, and programming.<br>• ARI: PLC and robot programming.<br>• Smart Manufacturing: Process optimization and integration with smart manufacturing systems. |
| **#2. Technology Selection and Feasibility Study** | |

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| | **Strengths, Weaknesses, Opportunities, and Threars (SWOT) analysis of the use of waterjet cutting technologies in teaching:**<br>**Strengths**<br>• **Cost-Effectiveness**: Virtual simulation via Simumatik is significantly more affordable than purchasing real hardware, making it an attractive option for educational institutions.<br>• Remote access enables students to engage with the system even if they cannot physically access the equipment.<br>• **Collaborative and Remote Accessibility:** Facilitates global collaboration and joint projects by allowing students from different institutions to work together in virtual environments, promoting international mobility and exchange programs.<br>• **Integration and Flexibility:** The system is adaptable, with the ability to connect to various PLC brands (Siemens, Codesys, Allen Bradley, etc.) and robot simulators like RoboDK and UR-Sim, enhancing flexibility for different use cases and preferences.<br>**Weaknesses**<br>• **Limited Physical Interaction:** While the digital twin provides a simulation environment, it lacks the tactile interaction and real-world sensory feedback that physical systems offer. This might limit the ability to learn certain hands-on aspects of assembly and troubleshooting.<br>**Opportunities**<br>• **Further Development and Innovation:** This technology facilitates cooperative efforts in the fields of engineering, science, and information technology, contributing to the cultivation of diverse skill sets. (Gruyter, 2019)<br>• **Augmented and Virtual Reality (AR/VR) Expansion**: Leveraging existing AR and VR capabilities within the digital twin can deepen the immersive training experience. By using VR headsets to interact with the simulated environment, learners can engage with complex processes in a realistic, hands-on manner, boosting engagement, practical understanding, and knowledge retention.<br>• **Remote Learning and Upskilling**: Given the increasing demand for online learning, this digital twin platform could be marketed as a remote training solution for professionals seeking to upskill in ARI.<br>**Threats**<br>• **Reduced Industry Adoption of Virtual Training:** If industries prioritize physical, hands-on training over virtual simulations, there may be a risk of decreased demand for this kind of virtual tool, especially if tactile learning remains essential for certain skills.<br>**Improvement Options / Potential Future Implementations**<br>• **Camera Equipment Development:** Integrate existing 3D cameras within the Simumatik platform and connect them with Cognex Machine Vision software. This requires replacing the physical camera in the lab with a model that includes an integrated simulator.<br>• **AGV and Additional Structure Development:** Development of AGV (Automated Guided Vehicles) and missing structures: Develop rest of the equipment to get a validated state in comparison with the physical system. |
| **#3. Develop a Phased Implementation Plan** | |
| | 1. **Planning and Preparation:** Effective implementation of a digital twin platform requires preparation, particularly for teachers who need to become proficient with the software. Simumatik offers an online learning platform, the Simumatik Academy, which provides structured courses and resources for educators to develop the necessary skills to manage and teach with the software confidently.<br>2. **Integrating Additional Software:** Decide on complementary software to enhance Simumatik's connectivity and functionality. For example, Codesys, which offers a free trial version with soft PLC capabilities, can be used for PLC integration. Similarly, for robotic control, URSim is a free software option that can simulate robot programming, enabling students to gain hands-on experience with robotics. |

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| | 3. **Pilot Project for Hands-On Learning:** Once educators are trained and familiar with Simumatik, initiate a pilot project with students to test the platform's integration into the curriculum. Simumatik provides "Getting Started" courses, which can be assigned to students as a preliminary exercise. This allows students to become comfortable with the software before they begin hands-on work in the virtual lab.<br>4. **Continuous Improvement:** Establish a process for ongoing development of the virtual lab and training materials. Regular updates based on student feedback and industry trends will help keep the curriculum relevant and maximize the educational benefits of the digital twin platform. |
| **#4. Training** | |
| | The training has not yet taken place, but the first session is scheduled for next semester at Miguel Altuna LHI |
| **#5. Integrate Technology into Curriculum and Learning Activities** | |
| | Despite the limitations associated with digital twin technology, the application of learning activities, as proposed in Chapter 4.2, remains feasible, albeit with some restrictions related to vision cameras and AGV's. |
| **#6. Evaluation and Continuous Improvement** | |
| | To assess the operability of the Digital Twin, a combination of simulations, data analysis, user feedback, and system diagnostics is employed. These methods allow us to gather and evaluate information on system reliability, user interaction quality (from both operators and end-users), and the fidelity of the digital model in mirroring real-world conditions. KPIs include user satisfaction, accuracy of simulations, and efficiency in achieving operational goals. |
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## 4.4. USE CASE 4. MANUFACTURING EXECUTION SYSTEM

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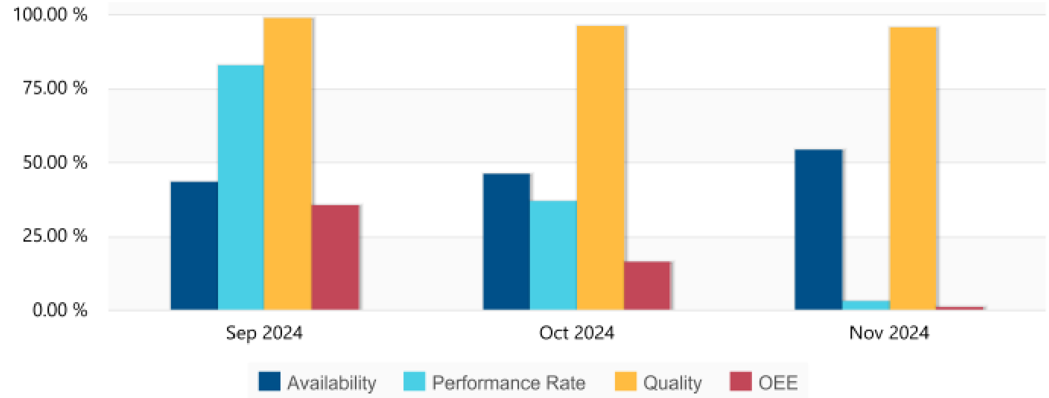
| USE CASE | **Manufacturing Execution System (MES)** |
| Author | Miguel Altuna LHII, Basque Country |
| Description | In today´s competitive environment, manufacturing companies face constant challenges to improve efficiency, reduce costs, and maintain high-quality standards. The adoption of a Manufacturing Execution System (MES) has become a strategic solution to achieve these objectives. An MES provides real-time visibility into production operations, facilitating decision-making and process optimization. |
| Location | • Miguel Altuna LHII – Basque Country |

**OEE Development (Workplace)**

**Workplace:** CC 9120, FINASSE1
**Time:** September 2024 - November 2024




| **Date** | Sep 2024 | Oct 2024 | Nov 2024 |
|---|---|---|---|
| **Availability** | 43.46% | 46.4% | 54.71% |
| **Performance Rate** | 83.11% | 37.27% | 3.07% |
| **Quality** | 99.19% | 96.32% | 95.67% |
| **OEE** | 35.83% | 16.66% | 1.61% |

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*Figure 10 Screenshot taken from FORCAM*

## #1. Identification of a need or a problem to solve,

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| Purpose (technical) | A MES in a LF facilitates system integration and real-time data collection, optimizes processes, ensures complete traceability, provides practical training, allows for strategy simulation and modelling, and efficiently manages resources, thereby improving production efficiency and quality while offering a valuable educational environment. |
| Purpose (didactic) | The educational objective of a MES in a LF is to provide a practical learning environment where students and professionals can acquire knowledge and skills in the management and optimization of manufacturing processes, develop technical skills, improve data-driven decision-making, and foster continuous innovation and improvement. |

## #2. Technology Selection and Feasibility Study

FORCAM has been chosen as the MES for the Learning Factory for several key reason:

1. **Integration and flexibility:** FORCAM offers us versatile solutions that adapt to different production and educational needs, allowing perfect integration with existing infrastructure.
2. **Advanced Data Analysis Capabilities:** It provides robust tools for real-time data collection and analysis, essential for optimizing processes and improving operational efficiency.
3. **Educational experience:** Its solutions are designed to provide practical educational experiences, enabling students and professionals to learn how to manage and optimize manufacturing processes in a controlled environment.
4. **Continuous Improvement and Traceability:** It facilities continuous improvement by enabling complete traceability and offering detailed analyses that help quickly identify and correct issues.

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| | 5. **Innovation and Support:** Its innovative strategies and robust technical support ensure that the Learning Factory stays at the leading edge of manufacturing technology. |
| **#3. Develop a Phased Implementation Plan** | |
| | 1. **Planning and Preparation:** To implement the FORCAM MES, educators should first complete training using available resources to become proficient with the software.<br>2. **Pilot Project for Hands-On Learning:** After training, initiate a pilot project with students to apply the MES system in real world scenarios, using introductory courses to help students get started.<br>3. **Continuous improvement:** Continuously update the curriculum and training materials based on student feedback and industry trends to ensure the learning experience stays relevant and effective. |
| **#4. Training** | |
| | Teachers from de automation department are already familiarized with the equipment integrated in the WS. There is onboarding training material for new users and students, including instructions on the operation and maintenance of the system.<br>1. **Introduction and Scope:** Overview of the MES and its application.<br>2. **Setup:** Instructions for initial configuration and integration with existing systems.<br>3. **Operations:** Supervision of production, quality control, and intra-logistics management.<br>4. **Maintenance:** Maintenance protocols and technical support. |
| **#5. Integrate Technology into Curriculum and Learning Activities** | |
| | In process |
| **#6. Evaluation and Continuous Improvement** | |
| | In process |
| | |

## 4.5. USE CASE 5: OT CYBERSECURITY

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| USE CASE | **Operational Technology (OT) Cybersecurity** |
| Author | Zubiri Manteo BHI Basque Country |
| Description | This use case describes the protocol to assure OT cybersecurity in the regional LF's. The protocol aims to create a secure network to connect the regional LF's into an international CLF. The applicable protocol for OT cybersecurity is not strictly the implementation of a technology but the integration of certain elements and the setting up of security practices. The International Society of Automation (ISA) defines OT cybersecurity as the practice of protecting Industrial Control Systems (ICS) and cyber-physical systems from cyber threats. This involves implementing security measures to prevent unauthorized access, manipulation, and disruption of these critical systems, ensuring the safe and reliable operation of industrial processes. (ISA, 2024) |
| Location | Miguel Altuna LHII |
| **#1. Identification of a need or a problem to solve,** | |
| Purpose (technical) | To understand and apply the appropriate cybersecurity protocols to create secure IT and OT networks in the CLFs. The protocol describes the network configuration and elements that should be used to that aim. |

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| Purpose (didactic) | For students of ITC and Cybersecurity in Operation Technology Environments Specialty, the purpose is to design and integrate cybersecure networks in industrial environments. Mitigating penetration risks and external threats. Configuring network devices with this objective.<br>For Mechatronics, Manufacturing, Robotics, Maintenance related learning programs the aim is to integrate cybersecurity protocols and practices in their curriculums. |

### #2. Technology Selection and Feasibility Study

This section shows the different measures and practices to create secure environments in operational facilities, normally production lines, shopfloors, labs and LFs:

**Consider security from the design phase of the network and industrial line**

- **Segment** networks according to needs**:**
  - Logical segmentation (VLAN, Layer 3 switch ACLs)
  - Physical segmentation to separate IT and OT (Firewall)
- **General Policies:**
  - Least privilege, minimize attack surface
  - Restrictive access policies, especially concerning communication with the OT network

**IT network:**

- Logically segment IT network's subnets (VLANs).
- Fortify the domain controller and servers.
- Protect domain endpoints (PCs, laptops, etc.): Antivirus, EDR, etc.
- Update policies (WSUS).

**OT network:**

- **Monitor** network activity**:**
  - Implement an Intrusion Detection System (IDS) or an IPS Intrusion Prevention System (IPS).
  - Set up and properly configure a SIEM (Security Information and Event Management) system.
- **Remote access** to the OT network **(VPN):**
  - Properly configure remote access (e.g., to access TIA Portal ensure connection is on the same network).
  - Enable Multi-Factor Authentication (MFA).
- Restrict USB connection capabilities on devices and establish usage policies.
- Place additional protection devices between vulnerable devices (those with outdated or unpatchable operating systems) and the network.
- Protect OT network servers (such as those with MES, OPC-UA, etc.)
- **Regularly scan the network** to detect new devices and analyse vulnerabilities in known devices' systems and services (Nozomi).
- **Incident response plan.**
- **Provide proper training** to all individuals interacting with the Learning Factory and communicate risks.

**Physical Security:**

- This section has been left out of the current analysis. Elements in this section include:
  - Ensuring power supply (UPS/SAI, generators, etc.).
  - Controlling physical access to elements that make up the network infrastructure (access restrictions, video surveillance, etc.).
  - And so on.

### #3. Develop a Phased Implementation Plan

The first action on the Cybersecurity protocol that is "Consider security from the design phase of the network and industrial line" does not apply as far as the LF networks are already designed. Therefore, the implementation plan begins studying the existing networks by means of cybersecurity protocols.
Partners are individually applying the protocol in their LFs.

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| | At this stage (December 2024) the stablishment of the protocols are in progress in all the labs. |
| **#4. Training** | |
| | Training on cybersecurity for IT and maintenance staff.<br>Awareness-raising campaigns among teachers and labs managers |
| **#5. Integrate Technology into Curriculum and Learning Activities** | |
| | At Miguel Altuna LHII, learning activities are structured around the CBL methodology, embedded within the Ethazi pedagogical framework. Consequently, the integration of the AR system into the curriculum is achieved through two approaches: embedding AR-based tasks within existing CBL projects or developing new CBL projects specifically focused on utilizing AR technology. The choice of approach will depend on the specific requirements of each study program.<br>The roll out of the technology implies the adaptation or creation of CBL projects.<br>**Best Practices for Configuring Network Devices for Cybersecurity**<br>**1.Implement Strong Access Controls**<br>Ensure all network devices, such as firewalls, PLCs, and monitoring systems like Nozomi, are protected with strong, unique passwords and MFA wherever possible. Limit access based on the principle of least privilege to reduce exposure to unauthorized users.<br>**2.Keep Firmware and Software Updated**<br>Regularly update the firmware and software of your network devices to protect against vulnerabilities. Use vendor-recommended patches and updates, and establish a process for applying them promptly.<br>**3.Network Segmentation and Zoning**<br>Use network segmentation to isolate critical systems, such as PLCs, from less secure or public-facing networks. Deploy firewalls to control and monitor traffic between these segments, minimizing the risk of lateral movement during an attack.<br>**4.Enable Logging and Monitoring**<br>Configure all devices to log activities and send these logs to a centralized monitoring solution, like a Security Information and Event Management (SIEM) system. Leverage tools such as Nozomi for real-time visibility and anomaly detection within industrial and operational environments.<br>**5.Disable Unused Services and Ports**<br>Reduce the attack surface of your devices by disabling unused ports, protocols, and services. Conduct regular audits to ensure that only necessary features are enabled and properly configured. |
| **#6. Evaluation and Continuous Improvement** | |
| | In progress |

## 4.6. USE CASE 6. INDUSTRIAL BUSINESS INTELLIGENCE PLATFORM

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| USE CASE | **INDUSTRIAL BUSINESS INTELLIGENCE (BI) PLATFORM** |
| Author | Tolosaldea LHII, Basque Country |
| Description | “An Industrial BI Platform is a specialized tool designed to help businesses in industrial sectors collect, analyze, and visualize data to make informed decisions. These platforms integrate data from various sources, such as manufacturing equipment, provide real-time analytics to monitor production processes. They offer custom dashboards for |

<table>
<tr><td></td><td>visualizing KPI, enable predictive maintenance by analysing historical data, and enhance decision-making by providing comprehensive data insights, ultimately improving efficiency and reducing cost”. (Pauli, 2021)<br>In this use case the implementation of the platform Fagor Digital Suite (Fagor Automation, 2024) in learning environment (VET) is described. The aim is to offers real-time problem-solving aligned with real-world industrial processes, providing the students skills in production monitoring, quality assurance, data analysis.<br>The selected Industrial BI platform, is modular, scalable, and targeted for I4.0 environments, serving both industrial and educational needs in digital manufacturing setup. Additionally, when implementing this platform in a VET environment, the focus is on the learning process rather than solely on improving efficiency.<br>The goal is to execute the teaching-learning process based on Project Based Learning (PBL) methodology but following I4.0 standards. So, when the execution phase of the PBL comes, the platform is used to translate machining operations and maintenance tasks into work orders, to manage, monitor and analyse the processes/machines.<br>To achieve this goal, 30 conventional machines (18 lathes and 12 milling machines) have been connected via a PLC and 6 CNC machines to the Fagor Digital Suite platform. This platform is not only designed and managed in the workshop itself but also from the classroom.</td></tr>
<tr><td>Location</td><td>Tolosaldea LHII – Basque Country</td></tr>
<tr><td colspan="2">


*Figure 8 Workshop from Tolosaldea LHII connected to Fagor Digital Suite platform*

</td></tr>
<tr><td colspan="2">#1. Identification of a need or a problem to solve,</td></tr>
<tr><td>Purpose (technical)</td><td>Enhance manufacturing efficiency, minimize downtime, and ensure product quality with real-time machine monitoring, optimized production scheduling, and predictive/corrective maintenance. Close the gap between production and educational environments, transforming PBL challenges into work orders.</td></tr>
<tr><td>Purpose (didactic)</td><td>Aims to provide students and trainees experience in real-world manufacturing challenges. By using the platform learners gain skills in monitoring machine performance, optimizing workflows, applying quality control measures, and conducting data-driven decision-making.<br>• Integrate learning activities into the following programs:<br>• Production by machining<br>• Mechatronics<br>• Management of computer systems on network</td></tr>
<tr><td colspan="2">#2. Technology Selection and Feasibility Study</td></tr>
<tr><td></td><td>Implementing an Industrial BI platform in VET requires a focused Technology Selection and Feasibility Study. In this case the process has been as follows:<br>The selected industry-relevant technologies, aimed at mirroring real-world applications to enhance learning, include CAD/CAM, CNC machining, and conventional machining processes. The technologies selected represent accurately those used in industry settings, offering students a realistic training environment. This makes the transition from education to the workforce smoother and gives students relevant, job-ready skills.<br>Collaborate with industry professionals to confirm that these tools meet current market requirements.</td></tr>
</table>

1. **Feasibility and Pilot Testing.** Conduct small-scale tests to validate the suite's effectiveness within the educational setting. That pilot projects in select VET courses, closely monitoring performance indicators like student engagement, learning outcomes, technical compatibility, and instructor satisfaction. These metrics will provide insights into the suite's overall impact and inform adjustments before broader deployment.
2. **Adapt to User Needs.** Customize the suite to align with existing workflows, ensuring relevance for both students and instructors. Map the VET curriculum to the suite's capabilities, identifying which features support targeted learning goals. Modify simulation tools or PBL applications to replicate scenarios that students will encounter in their specific vocational fields.
3. **Design for Usability**. Involve users in designing intuitive workflows, ensuring ease of use. Because, well-structured workflows are crucial for both student engagement and instructor effectiveness. Assemble a design/driving team with a cross-section of users, including students, instructors, and technical experts. Together, create workflows that support course flow and make key features easily accessible.
4. **User Feedback**. Establish a feedback loop with students and educators to refine the suite workflow. Including students and educators directly in the design team ensures the suite evolves based on real-world needs.
5. **Scalability and Modularity**. Ensure components/connections are adaptable for future expansions and industry updates. Select modular elements within the suite, ensuring they can be adapted to integrate new technologies or address emerging skills.

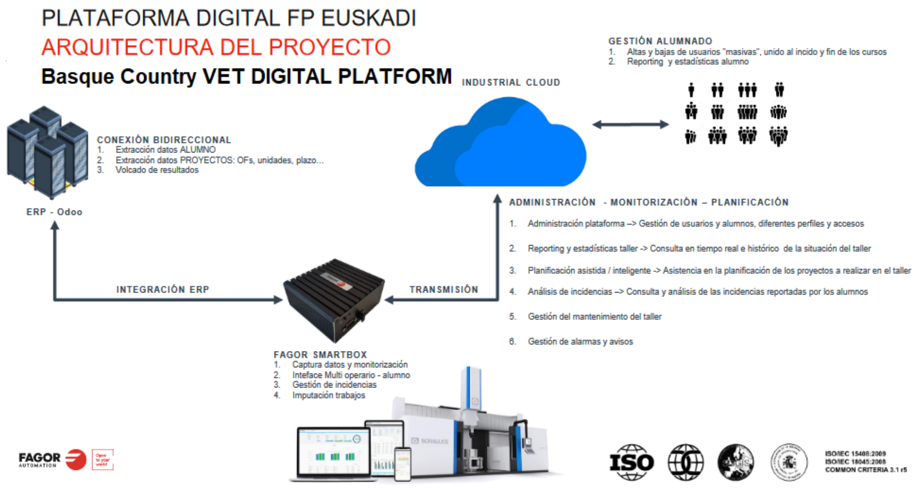


*Figure 9 Digital architecture of the platform*

6. **Integration:** Confirm compatibility with current systems, including LMS and hardware. Assess compatibility with the institution's IT systems. Configure the suite as needed to ensure it aligns with the current infrastructure and work with the supplier's team to troubleshoot any integration issues that arise during pilot testing.
7. **Virtualization evaluation:** Evaluate all aspects of implementation to promote continuous improvement, such as, virtualization capacity of the selected technology for its later integration in virtual environments.
8. **Collaboration:** Enable features supporting teamwork and remote access. Evaluate collaboration tools within the suite, such as shared virtual workspaces, group simulation projects, or feedback systems for remote learning.

## #3. Develop a Phased Implementation Plan

The Phased Implementation Plan for the Industrial BI platform in a VET setting has been streamlined as follows:

1. **Preparation and Planning**. Set up the multidisciplinary team to drive and design the implementation process together with the supplier Define goals, timelines, and scope.
2. **Configure the workshop network.** Ensure compatibility with the school's current IT and its possible extensions and updates to future developments.
3. **Connect the machines** to the platform and check the integration and connectivity of the entire system.
4. **Training of the driving team** simulation of real cases of the learning process and execution in the workshop
5. Establish a **work methodology** and set a schedule for milestone comparison and progress tracking between the driving team and the supplier's team.
6. **Design the workflow** to be developed both in the software and during the execution phase in the workshop. The focus will mainly be on two areas:
    - Workshop management: maintenance, machine availability, work order scheduling…
    - Management of the learning process vs. production

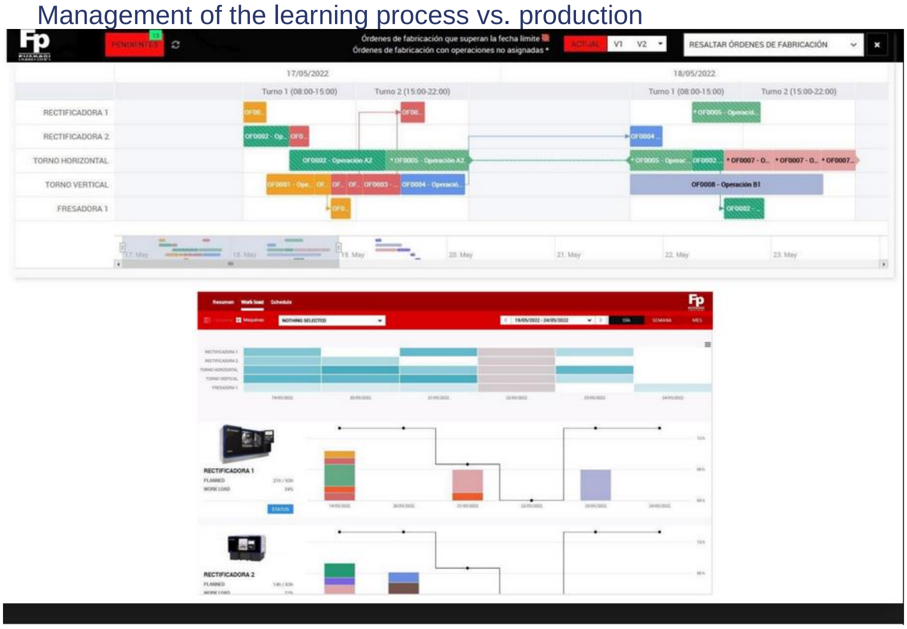


*Figure 10 workshop scheduling and machine tracking dashboard*

7. **Pilot Testing**. Deploy a small-scale test of core features, gathering feedback from teachers and students. Make necessary adjustments based on the feedback.
8. Implement all necessary **management inputs** in the software.
    - Machines
    - Users and their roles
    - Maintenance planning
    - Manufacturing order management and their allocation…
9. Interface and data visualization design. Configure screens and data reports for:
    - Machine. Overall Equipment Effectiveness (OEE), production backlog, incidents, and maintenance logs.
    - Operator/student tracking. Efficiency, training progress, and incident handling
    - Manufacturing order. PBL, order status, resource allocation, time tracking.

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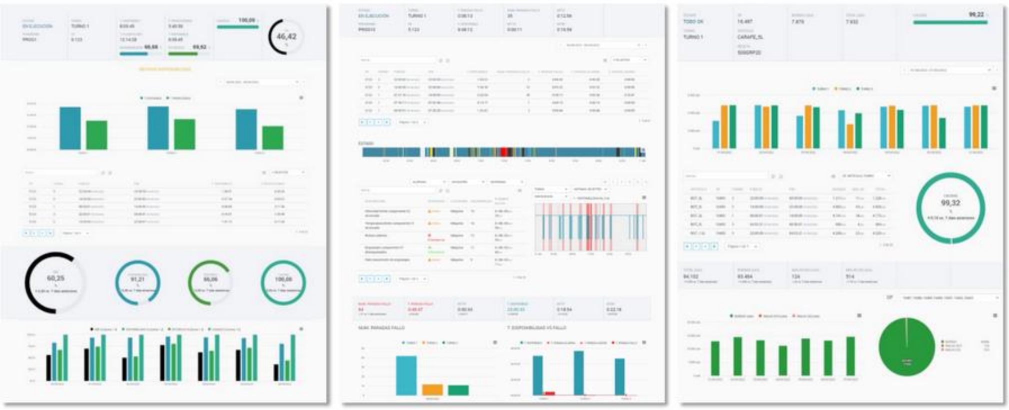
| | <br>*Figure 11 Data analysis dashboard*<br>10. **Validation and comparison** by both teachers and students, as well as the supplier team, to solve any integration problems that may arise during the pilot tests and/or their redesign.<br>11. **Staff Training and Curriculum Integration**. Provide training on core functions, focusing primarily on workflow. Develop teaching materials and create learning modules aligned with PBL standards.<br>12. **Full Deployment.** Integrate the suite across relevant modules and introduce students to real-world exercises, such as monitoring and optimizing production.<br>13. **Continuous Monitoring and Feedback**. Collect feedback from users, assess learning outcomes, and make updates to enhance usability and learning impact.<br>14. **Evaluation and Documentation.** Evaluate the overall impact, document best practices, and compile teaching materials for long-term use. |
| **#4. Training** | |
| | The developed training process has been as follows:<br>1. Initial training of the driving team in both the software and the system architecture<br>2. Initial training for the teacher pilot group by the driving group and Fagor<br>3. Periodic meetings of the driving group and supplier to develop the design and creation of the workflows for their adaptation to the teaching-learning process<br>4. Training-dissemination in the use and management of the system for the teacher pilot group<br>5. Training and instruction in the workflow both in the classroom and on the students' machines<br>6. Production of training pills for teachers and students with practical exercises on platform management |
| **#5. Integrate Technology into Curriculum and Learning Activities** | |
| | In process |
| **#6. Evaluation and Continuous Improvement** | |
| | In process |

## 4.7. USE CASE 7. CNC

| USE CASE | **CNC machines** |
|---|---|
| Author | Campus Des Metiers et Des Qualificatications D'Excellence France |
| Description | The use of CNC (Computer Numerical Control) technology in the manufacturing sector is based on the computer control of machine tools to perform precision operations such as milling, turning, drilling and cutting. These machines are programmed to perform specific movements and actions, enabling them to reproduce complex shapes and meet exact design specifications (Gavin, 2023).<br>In the CLF, CNC technology is used with:<br>**Water jet cutting**: CNC waterjet cutting uses a high-pressure water jet to cut hard materials without heat, thus avoiding deformation. It is precise, versatile and environmentally friendly, with little waste.<br>**Laser cutting**: CNC laser cutting uses a concentrated laser light to cut materials with great precision. The process provides clean edges and reduces the need for finishing, while being fast and efficient for a wide range of materials, including metals and plastics.<br>**Wire cutting**: CNC wire cutting, or wire electrical discharge machining, uses a conductive metal wire to make precise cuts in conductive materials such as metals. An electric discharge is created between the wire and the workpiece, eroding the material and cutting it along a pre-determined line.<br>**Contouring on milling machines:** Contouring on a milling machine consists of machining the external or internal contours of a part using a milling cutter, generally following a predefined line.<br><br>**And others.** |
| Location | • CMQE France<br>• Miguel Altuna LHII – Basque Country<br>• DHBW- Heidenheim- Germany<br>• Curt Nicolins Gymnasiet – Sweden |
| <br>*Figure 12 Mikron UCP 600 Vario (Machining) from CMQE If CLF equipped with the CNC technology* | |
| **#1. Identification of a need or a problem to solve,** | |

| | |
|---|---|
| Purpose (technical) | The use of CNC technology enables high precision and repeatability to be achieved in the manufacture of simple or complex parts. This reduces human error and ensures that products meet specifications.<br>The large choice of processes helps to choose the most appropriate methods for manufacturing parts. They also offer the flexibility needed to adjust parameters and choose the right tools. Different techniques can be tested to find the most efficient.<br>The purpose is to improve productivity, quality, and operational efficiency in manufacturing. (Polygenis, 2024) Some components of the CLF product are suitable to be manufactured by means of CNC machining. By incorporating CNC machining into the CLF manufacturing process, the aim is to add the benefits that this technology provides from a systems perspective, encompassing the process as a whole. |
| Purpose (didactic) | CNC technology use in the CLF enables:<br>• To master CNC programming for various processes to improve precision, quality and productivity.<br>• To be able to compare different CNC processes (cost savings, time savings, etc.).<br>• To use programming software to operate the machine.<br>• To use the digital chain, from CAD and CAM to manufacturing. |
| **#2. Technology Selection and Feasibility Study** | |
| | **CNC Technology selection**<br>**Improve precision**: Enables parts to be produced to close tolerances.<br>**Increase repeatability**: Guarantees consistent quality for every part produced.<br>**Reduce human error**: Automates processes to minimise the risk of error.<br>**Save time**: Accelerate production through fast, efficient execution.<br>**Offer manufacturing flexibility**: Enables the production of parts with varied and complex shapes.<br>**Make learning more relevant**: Aligns students' skills with current industry practices<br>**CNC Feasibility study**<br>**Needs analysis**: The CNC technology on machines meets the production requirements, offering precision and cutting complexity adapted to the different sizes of parts. It can also machine a variety of materials.<br>**Cost assessment**: Purchase, installation and maintenance costs are significant, but can be offset by the machine's durability.<br>**Performance testing**: CNC technology enables parts to be produced with great precision and uniformity, guaranteeing a quality finish for each series.<br>**Comparison of options**: CNC technology can be used with a variety of machines, giving a large choice of production processes.<br>**Impact on learning**: CNC technology enables students to familiarise themselves with programming and precision machining, skills that are directly applicable in the workplace. The integration of this machine enriches practical and technical learning.<br>Infrastructure assessment: The workspace, safety devices and electrical resources are compatible with the requirements of the machine in the CLF workshops. |
| **#3. Develop a Phased Implementation Plan** | |
| | **To ensure optimal integration of CNC technology:**<br>• Definition of objectives and requirements<br>• Identify the pedagogical and technical objectives to be achieved with the CNC machine (precision, types of parts, materials).<br>• Determine the skills to be developed by the students (programming, machining, CAD/CAM design).<br>• Draw up an overall budget, including acquisition, training and maintenance costs.<br>**To select the CNC machine:**<br>• Research and compare available machines according to defined needs (capacity, precision, material compatibility).<br>**To prepare the infrastructure:** |

<table>
<tr><td></td><td>• Adapt the workspace to accommodate the machine (ventilation, materials storage space, safety).<br>• Check that the electrical installations are appropriate for the specific requirements (power, connectivity).<br>• Install safety devices to protect users.<br>• Staff training<br>• Train teachers and technicians in the use of the machine, CNC programming and associated CAD/CAM software.<br>• Organise practical sessions to familiarise staff with basic maintenance and troubleshooting.<br>• Ensure that staff are trained in safety standards for the use of CNC equipment.<br>To integrate the technology into the training programme:<br>• Design CNC-related training modules for students, covering programming, materials handling and machine operation.<br>• Integrate the digital chain (from CAD to manufacturing) for complete and realistic learning of industrial processes.<br>Test and adjustment phase:<br>• Carry out tests to validate that the machine meets the educational and technical requirements.<br>• Adjust the cutting parameters, speed and processes to optimise the quality and precision of the parts.<br>• Gather feedback from teachers and technicians to fine-tune use and correct any bottlenecks.<br>To integrate the students:<br>• Organise practical sessions to introduce students to the use of the CNC machine and associated software.<br>• Involve students in practical projects to enable them to develop their skills in real-life conditions.<br>• Monitor progress and adjust teaching modules if necessary.</td></tr>
<tr><td colspan="2">#4. Training</td></tr>
<tr><td></td><td>Students and teachers working with the LCAMP CLF CNC technology will first receive an introduction to the LCAMP project and the concept of the CLF. This will enable them to become fully aware of the European and collaborative scope of their activities. The technology will be gradually integrated into the CLF. First, the CLF implementation team will be trained, then integration and training of teachers and finally integration and training of students.</td></tr>
<tr><td colspan="2">#5. Integrate Technology into Curriculum and Learning Activities</td></tr>
<tr><td></td><td>The students who are working with CNC technology in the CLF at CMQE If (France) are students in:<br>• Vocational Baccalaureate (EQF 4) Technician in mechanical product manufacturing and Higher Technical certificate (EQF 5) Design of product manufacturing processes. Use of CNC technology with water jet cutting machine, wire cutting machine, milling machine.<br>• Technological Baccalaureate (EQF 4) Science and Technology for Industry and Sustainable Development. Use of CNC technology with laser cutting machine.</td></tr>
<tr><td colspan="2">#6. Evaluation and Continuous Improvement</td></tr>
<tr><td colspan="2">In process</td></tr>
</table>

## 4.8. USE CASE 8: WATER JET CUTTING

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| USE CASE | **Water Jet Cutting** |
| Author | Duale Hochsulle Baden Wurttemberg – Heidenheim, Germany |
| Description | Waterjet cutting offers many technical and economic advantages:<br>**Versatility and precision:** The process can be used to cut almost any material, from metals and plastics to glass and ceramics, without thermal influence. This means there are no heat-affected zones, which is particularly advantageous for temperature-sensitive materials.<br>**Cost savings:** As no special tools are required for different materials, there is no need for tool changes and the associated costs. In addition, the narrow kerf width reduces material loss and enables efficient material utilization.<br>**Environmentally friendly:** The process produces no harmful emissions and minimizes waste, resulting in a lower environmental impact.<br>**Energy efficiency:** Energy consumption is moderate compared to other cutting processes, reducing operating costs and increasing profitability.<br>Overall, waterjet cutting is an efficient and cost-effective technology that is used in a wide range of industries due to its flexibility and precision. |
| Location | Baden-Württemberg Cooperative State University Heidenheim site |

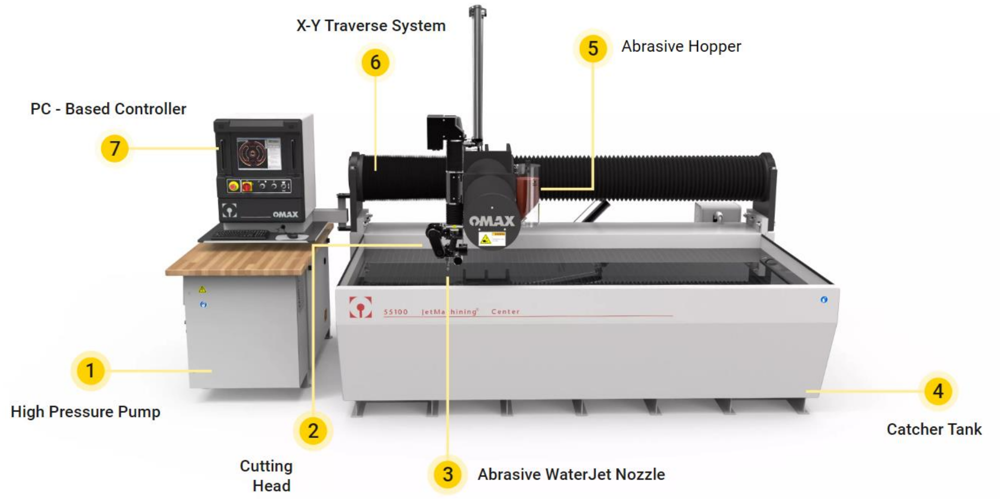


*Figure 13 - OMAX JetMachining Center. (OMAX, 2024)*


*Figure 14 - OMAX 2652 JetMachining' at the Duale Hochschule Baden-Württemberg in Heidenheim.*

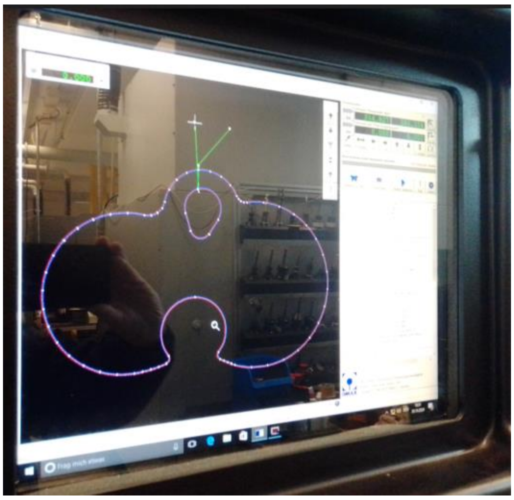

*Figure 15 - Programming of the cutting contour on the PC-based control system*

| **#1. Identification of a need or a problem to solve,** | |
|---|---|
| Purpose (technical) | In advanced manufacturing and I4.0, waterjet cutting is a highly accurate and versatile process, particularly characterized by its flexible and precise material processing. It is ideal for cutting complex and multi-layered materials without thermal effects, enabling |

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| | precise processing of metals, glass, and composites. In addition, waterjet cutting can be seamlessly integrated into automated production processes and supports real-time data integration, meeting the demands of networked and flexible smart factories. Thanks to its resource-saving approach - with low energy consumption and no toxic emissions - it contributes to sustainability in production and is ideally suited to green strategies, which are becoming increasingly important in I4.0. |
| Purpose (didactic) | In university teaching, the didactic objectives between waterjet cutting, advanced manufacturing, and I4.0 can be developed in a variety of ways. Interdisciplinary learning enables students to understand the link between traditional manufacturing techniques and modern advanced manufacturing methods, which promotes a comprehensive understanding of the requirements of I4.0. Practical applications, such as laboratory exercises in waterjet cutting, provide students with the opportunity to directly experience the principles of material processing and separation and to simulate real industrial applications.<br>The technological integration of waterjet cutting with advanced manufacturing technologies and digital systems helps students understand the connection between physical and digital systems, including the use of IoT, data analytics, and automation. Students will also develop their problem-solving skills by analysing and optimizing waterjet cutting processes, investigating process parameters, and implementing efficiency improvements and quality control.<br>Another important aspect is the discussion of the efficiency and sustainability of waterjet cutting compared to other manufacturing methods, creating an awareness of environmentally friendly practices, which is important in I4.0. Encouraging innovation through the development of new applications and improvements in waterjet cutting can strengthen students' ability to innovate, for example through research projects or competitions.<br>Finally, data analytics and data management play a central role by making students aware of the importance of data in modern manufacturing, an essential part of I4.0. By combining these approaches, universities can best prepare their students for the challenges and opportunities of modern manufacturing. |
| **#2. Technology Selection and Feasibility Study** | |
| | **SWOT analysis of the use of waterjet cutting technologies in teaching**:<br>**Strengths**<br>- **High level of precision and versatility**: The versatility of waterjet cutting makes it particularly suitable for handling diverse material categories, providing students with a comprehensive knowledge of materials. (OMAX, 2024)<br>- **Hands-on learning in advanced manufacturing**: The integration of this technology enables hands-on learning that meets the demands of I4.0 (Schneidforum: Vorteile und Nachteile des Wasserstrahlschneidens., 2024)<br>- **Sustainability and Resource Efficiency**: Through the reduction of material waste and the avoidance of toxic emissions, waterjet cutting serves as a sustainable technology, highlighting environmental consciousness within educational frameworks. (RUNSOM, 2024)<br>- **Compatibility with automation**: Waterjet cutting technologies can be integrated into automated production lines, giving students an understanding of interconnected production processes. (Aller-Weser Wasserstrahlschneidetechnik, 2024)<br>**Weaknesses**<br>- **High initial cost**: The procurement and upkeep of modern waterjet cutting equipment require substantial expenditure. (Schneidforum: Vorteile und Nachteile des Wasserstrahlschneidens., 2024)<br>- **Technical complexity for beginners**: in-depth prior knowledge required. (RUNSOM, 2024)<br>- **Time-consuming training required**: Proficiency in machine handling, routine maintenance, and adherence to safety standards is necessary. (OMAX, 2024) |

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| | - **Space and infrastructure requirements**: Waterjet cutting machines require significant space. (Aller-Weser Wasserstrahlschneidetechnik, 2024)<br>**Opportunities**<br>- **Expansion of interdisciplinary skills**: This technology facilitates cooperative efforts in the fields of engineering, science, and information technology, contributing to the cultivation of diverse skill sets. (Gruyter, 2019)<br>- **Promoting sustainable production methods**: Integrating this approach enhances recognition of eco-friendly production technologies. (RUNSOM, 2024)<br>- **Environmental**: water treatment linked (filtration/sedimentation/recycling) (Aller-Weser Wasserstrahlschneidetechnik, 2024)<br>- **Virtual learning environments**: The application of simulation software for virtual planning and process optimization helps to decrease costs while improving safety in the technology's operation. (OMAX, 2024)<br>**Threats**<br>- **Rapid technological progress**: Technology is evolving rapidly, which means that purchased machines may quickly become obsolete and require new investment. (Gruyter, 2019)<br>- **Safety risks associated with improper use**: Adherence to stringent safety protocols is essential in waterjet cutting, as operational errors may result in severe accidents. (De Gruyter).<br>- **Resource consumption**: The substantial water usage may lead to significant environmental and logistical concerns. (RUNSOM, 2024)<br>- **Limited flexibility due to infrastructure requirements**: Incorporating waterjet cutting technology into established laboratory setups commonly demands adjustments to the water and power supply systems. (Aller-Weser Wasserstrahlschneidetechnik, 2024) |
| **#3. Develop a Phased Implementation Plan** | |
| | When selecting and purchasing a waterjet cutting system for a university laboratory, it is crucial to define the specific application requirements: What materials and workpieces will be cut, and is abrasive or clean waterjet cutting required? The technical specifications, such as cutting thickness, pressure capacity, and CNC control, must match the variety of cutting tasks required and be intuitive for students to operate. Seamless automation and software integration allow direct implementation of digital designs and networking with existing CAD/CAM systems, optimizing laboratory operations and teaching methods.<br>Safety is essential: emergency stop functions, protective covers, and a user-friendly interface offer protection and ease of use. Sustainability is achieved through water treatment and recirculation systems that minimize water consumption and abrasive waste, thereby reducing running costs. The modularity of the system allows for future expansion, such as retrofitting sensors and automation components for new projects. Life cycle cost-benefit analysis and a reliable supplier with good service and support will ensure long-term operational reliability and cost-effectiveness of the system in the laboratory environment. |
| **#4. Training** | |
| | - Economic & Technical Fundamentals<br>- Energy & Environmental Management<br>- Quality Management<br>- Health and Safety Management<br>- Laboratory exercises<br>- Development towards a micro-credential in planning |
| **#5. Integrate Technology into Curriculum and Learning Activities** | |
| | In process |
| **#6. Evaluation and Continuous Improvement** | |
| | In process |

## 4.9. USE CASE 9. 3D PRINTING

<table>
<tr><td>USE CASE</td><td>3D Printing</td></tr>
<tr><td>Author</td><td>Curt Nicolin Gymnasiet, Sweden</td></tr>
<tr><td>Description</td><td>The 3D printing technology selected for the LCAMP CLF includes both Fused Deposition Modeling (FDM) and Selective Laser Sintering (SLS) printers, specifically the EOS Formiga P110. FDM printing is utilized due to its accessibility, cost-effectiveness, and the wide range of material options available. This method allows for rapid prototyping and the production of functional parts using various thermoplastics, making it ideal for diverse applications within the CLF.<br>On the other hand, the SLS printer, an advanced solution, is chosen for its ability to produce high-precision and durable parts. The EOS Formiga P110 leverages laser sintering to fuse powdered material layer by layer, resulting in intricate and accurate components that meet stringent specifications. This capability is crucial for applications requiring tight tolerances and robust components.<br>By integrating both FDM and SLS technologies, the CLF can optimize learning and production activities, ensuring that printed components are reliable, high-quality, and suitable for a wide range of uses. The combination of these technologies allows for the creation of complex geometries and functional prototypes, essential during the development and testing phases of our projects.</td></tr>
<tr><td>Location</td><td>CNG – (FDM & SLS)<br>CMQ<br>MIGUEL ALTUNA LHII<br>DHBW<br>MADE<br>GEBKIM</td></tr>
<tr><td></td><td>

Figure 16 - SLS Printer from CNG. Figure 2 FDM Printer from CNG</td></tr>
<tr><td colspan="2">#1. Identification of a need or a problem to solve,</td></tr>
<tr><td>Purpose (technical)</td><td>The aim of this system is to integrate 3D printing technologies into the LCAMP CLF to enhance production efficiency and ensure high-quality, traceable manufacturing processes. The accessibility and ease of use of 3D printing make it convenient for many to adopt and start using effectively.</td></tr>
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| | |
|---|---|
| Purpose (didactic) | Research the educational aspects of 3D printing technology and its applications. Integrate learning activities into the following programs:<br>• CAD, DfAM (Design for Additive Manufacturing), Smart manufacturing |
| **#2. Technology Selection and Feasibility Study** | |
| | The 3D printing technology selected for the LCAMP CLF is tailored to meet diverse user needs and workflows. Both FDM and SLS printers offer flexibility in terms of material choice, precision, and production speed. This adaptability ensures that the technology can be configured for various skill levels and project requirements, from rapid prototyping to the production of high-precision components.<br>Flexibility and Reconfiguration<br>The flexibility of the 3D printing system allows it to be reconfigured for different manufacturing tasks. This is crucial for the CLF, as it enables the production of a wide range of components and prototypes. The system can be used in parallel for multiple projects, enhancing its utility within the CLF and other related activities.<br>Customization for User Needs<br>In the case of the LCAMP CLF, the 3D printing system is customized to meet the specific needs of the users. This includes adjustments in the printing parameters, material selection, and post-processing techniques to ensure the highest quality output. The system's user-friendly interface and accessibility make it easy for operators to learn and use effectively.<br>Scalability<br>Once the LCAMP project is completed, the 3D printing system offers the potential to be utilized in various other projects. This includes ongoing research in digital manufacturing, process optimization, and the integration of new materials and technologies. The scalability of the 3D printing system ensures that it can continue to contribute to innovative manufacturing solutions and educational programs.<br>Why was 3D Printing chosen for the CLF in the LCAMP project?<br>3D printing was chosen for the CLF due to its accessibility and suitability for rapid prototyping. This technology is relatively user-friendly and easy to get started with, allowing for the efficient production of high-quality prototypes and components, making it ideal for diverse applications within the CLF.<br>Ensure that it is integrable into the existing infrastructure.<br>The 3D printing technology is easily integrable into the existing infrastructure, ensuring seamless adoption and minimal disruption to current workflows. Its compatibility with existing systems allows for a smooth transition and efficient implementation within the CLF.<br>Evaluate the virtualization<br>The virtualization of 3D printing technology within the LCAMP CLF allows for comprehensive simulation and optimization of manufacturing processes. By creating digital twins of the 3D printers and their operations, we can test and refine production workflows in a virtual environment before physical implementation. This approach not only enhances efficiency and reduces errors but also enables predictive maintenance and real-time monitoring. The ability to simulate different scenarios and material behaviors virtually ensures that we can achieve the highest quality outputs while minimizing resource usage and downtime. Virtualization thus plays a crucial role in integrating 3D printing seamlessly into our existing infrastructure and advancing our manufacturing capabilities.<br>Collaboration opportunities<br>Within the LCAMP consortium, the integration of 3D printing technology opens up significant collaboration opportunities among partners. The flexibility and accessibility of both FDM and SLS printers allow for seamless sharing of designs and manufacturing tasks. For instance, one partner can design a component, another can print it, and a third can handle the assembly. This distributed approach not only enhances efficiency but also leverages the unique strengths and capabilities of each partner. |

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| | The ability to share digital files and printing parameters ensures that work done in one lab can be easily replicated and adjusted in another, fostering a collaborative environment where knowledge and resources are shared. This setup enables students and researchers from different countries to work together on projects, exchanging ideas and refining processes in real-time.<br>Alternative systems might complicate such collaboration due to compatibility issues and the inability to share complete setups and configurations. The 3D printing technology we have chosen supports robust data exchange and maintains the integrity of designs across different platforms. This ensures that the collaborative efforts are not hindered by technological limitations, making the 3D printing solution an ideal choice for the LCAMP consortium. |
| **#3. Develop a Phased Implementation Plan** | |
| | **Develop a Phased Implementation Plan**<br>**To ensure optimal integration of 3D printing technology:**<br>• Definition of objectives and requirements<br>• Identify the pedagogical and technical objectives to be achieved with the 3D printers (precision, types of parts, materials).<br>• Determine the skills to be developed by the students (3D modeling, printing techniques, material science).<br>• Draw up an overall budget, including acquisition, training, and maintenance costs.<br>**To select the 3D printers**<br>• Research and compare available printers according to defined needs (capacity, precision, material compatibility).<br>• Choose both FDM and SLS printers to cover a wide range of applications.<br>**To prepare the infrastructure**<br>• Adapt the workspace to accommodate the printers (ventilation, materials storage space, safety).<br>• Check that the electrical installations are appropriate for the specific requirements (power, connectivity).<br>• Install safety devices to protect users.<br>**Staff training**<br>• Train teachers and technicians in the use of the printers, 3D modeling software, and associated technologies.<br>• Organize practical sessions to familiarize staff with basic maintenance and troubleshooting.<br>• Ensure that staff are trained in safety standards for the use of 3D printing equipment.<br>**To integrate the technology into the training .program**<br>• Design 3D printing-related training modules for students, covering 3D modeling, materials handling, and printer operation.<br>• Integrate the digital chain (from CAD to manufacturing) for complete and realistic learning of industrial processes.<br>**Test and adjustment phase**<br>• Carry out tests to validate that the printers meet the educational and technical requirements.<br>• Adjust the printing parameters, speed, and processes to optimize the quality and precision of the parts.<br>• Gather feedback from teachers and technicians to fine-tune use and correct any bottlenecks.<br>**To integrate the students**<br>• Organize practical sessions to introduce students to the use of the 3D printers and associated software.<br>• Involve students in practical projects to enable them to develop their skills in real-life conditions. |

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| | • Monitor progress and adjust teaching modules if necessary. |
| **#4. Training** | |
| | Students and teachers working with the LCAMP CLF 3D printing technology will first receive an introduction to the LCAMP project and the concept of the CLF. This will enable them to become fully aware of the European and collaborative scope of their activities.<br>The technology will be gradually integrated into the CLF. First, the CLF implementation team will be trained, followed by the integration and training of teachers, and finally the integration and training of students. |
| **#5. Integrate Technology into Curriculum and Learning Activities** | |
| | The students who are working with 3Dm Printing technology in the CLF at CNG in (Sweden) are students in:<br>• **Vocational Baccalaureate:** Production technology (EQF4), Production technology (EQF5), Design and product development (EQF4), Design and product development (EQF5)<br>• **Technological Baccalaureate:** Science technology (EQF4) |
| **#6. Evaluation and Continuous Improvement** | |
| In progress | |
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## 4.10. USE CASE 10. MANUAL ASSEMBLY LINE

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| USE CASE | **Manual Assembly Line** |
| Author | **GEBKIM VET, T**urkey |
| Description | The manual assembly line is a training environment replicating the assembly processes found in manufacturing industries. It consists of workstations where students perform assembly tasks step by step, learning how to follow standard operating procedures (SOPs), use tools, and ensure quality control. This assembly line is flexible and modular, allowing different assembly products and varying levels of complexity to be introduced.<br>The objective of this assembly line is to provide hands-on learning opportunities, bridging the gap between theoretical knowledge and practical industrial skills. The manual assembly line will simulate real-world industrial processes, offering students an immersive learning experience in line with modern manufacturing practices. |
| Location | GEBKİM VET, Turkey |

*Figure 17– Manual Assembly Line GEBKİM VET and - Computer Laboratory GEBKIM VET*

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| **#1. Identification of a need or a problem to solve,** | |
| Purpose (technical) | From a technical perspective, the manual assembly line provides a realistic simulation of industrial assembly processes. It is designed to:<br>• Teach the use of various tools and equipment commonly found in manufacturing.<br>• Develop skills in quality control, troubleshooting, and process optimization.<br>• Ensure students gain a deep understanding of workflow, time management, and productivity in assembly line environments.<br>• Familiarize students with industrial safety standards and ergonomic practices to prevent workplace injuries. |
| Purpose (didactic) | Didactically, the manual assembly line serves to:<br>• Engage students in experiential learning, where theoretical knowledge is applied in a hands-on environment.<br>• Foster problem-solving skills by simulating common challenges in production lines.<br>• Enhance teamwork and communication as students work in groups to complete assembly tasks.<br>• Build competencies in quality management, lean manufacturing techniques, and continuous improvement processes.<br>Allow for individualized learning, where students can advance at their own pace through varying levels of task complexity. |
| **#2. Technology Selection and Feasibility Study** | |
| | The selection of technology for the manual assembly line involved a careful assessment of the following factors:<br>• **Relevance:** Manual tools and assembly methods that reflect current industry practices.<br>• **Flexibility:** Modular workstation that can be adapted for different product assemblies.<br>• **Safety:** Ergonomically designed stations and the inclusion of safety protocols to mirror real-world standards.<br>• **Cost-effectiveness:** Affordable equipment that offers durability for long-term use while being accessible for educational budgets.<br>• **Maintenance:** Equipment that is easy to maintain and repair to minimize downtime during training.<br>A feasibility study was conducted to determine the following:<br>• **Technology Compatibility:** Manual assembly tools and equipment selected are compatible with future upgrades, such as automation or digital integration.<br>• **Cost-benefit Analysis:** The investment in the assembly line provides long-term value by enhancing student learning outcomes and employability. |

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| | **Threats/Disadvantages**<br>- Manual assembly lines and potential workstations require additional physical space.<br>- The technological infrastructure requirements for the development of the system require additional costs.<br>**Development Options / Potential Future Applications**<br>Potential future development options include;<br>-Predictive Maintenance: Integrate sensors and software to predict failures and plan equipment maintenance.<br>-Remote Control and Monitoring: Develop a remote interface to control and monitor the station from anywhere.<br>-Modular Expansion: Design the station to allow easy addition of new functions and equipment as needs evolve.<br>**Collaboration opportunities**<br>In the future, agreements can be made with industrial partners so that their workstations can be used by teachers and students. Thus, industrial automation systems such as robotics and CNC can be utilized without physical space and budget problems. |
| **#3. Develop a Phased Implementation Plan** | |
| | The phased implementation plan for the manual assembly line in the learning factory is as follows:<br>**Phase 1: Planning and Design**<br>• Define learning objectives aligned with industry standards.<br>• Design the layout of the manual assembly line, specifying the workstation and required equipment.<br>• Prepare safety protocols and instructional materials.<br>**Phase 2: Procurement and Setup**<br>• Purchase necessary tools, equipment, and materials.<br>• Install and configure workstation and monitoring system(computer) in the learning factory.<br>• Conduct safety checks and testing to ensure all equipment meets operational standards.<br>**Phase 3: Curriculum Development**<br>• Integrate manual assembly line training into the VET curriculum.<br>• Develop instructional guides, assessment rubrics, and supporting materials for teachers and students.<br>• Plan for various learning modules, from basic assembly tasks to advanced troubleshooting.<br>**Phase 4: Pilot Program and Evaluation**<br>• Conduct a pilot program with a selected group of students to evaluate the effectiveness of the assembly line.<br>• Gather feedback from students and instructors to refine the learning activities and processes.<br>• Make necessary adjustments to equipment, curriculum, and teaching methods.<br>**Phase 5: Full-scale Implementation**<br>• Launch the manual assembly line as a core component of the VET program.<br>• Regularly evaluate and update the assembly line setup, tools, and curriculum based on evolving industry trends and feedback. |
| **#4. Training** | |
| | A comprehensive training program within the scope of LCAMP Project will be established to ensure both instructors and students can fully utilize the manual assembly line:<br>• **Instructor Training:**<br>  ◦ Best practices for teaching in a hands-on, industrial environment. |

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| | • Guidelines for student assessment, safety management, and feedback delivery.<br>• **Student Training:**<br>• Introductory sessions covering safety protocols, tool use, and assembly procedures.<br>• Progressive skill-building exercises, starting from simple tasks and advancing to more complex assembly operations. |
| **#5. Integrate Technology into Curriculum and Learning Activities** | |
| | To fully leverage the potential of the manual assembly line, it must be tightly integrated into the curriculum:<br>• Learning Modules: Assembly line tasks will be broken down into structured learning modules focusing on specific skills such as tool use, workflow management, and quality control.<br>• Cross-disciplinary Projects: Collaboration across various subjects (such as mechanical technology and industrial design) to promote a comprehensive understanding of the manufacturing process.<br>• Case Studies: Real-world case studies will be introduced to simulate troubleshooting scenarios, improving critical thinking and problem-solving skills.<br>• Assessment and Feedback: Continuous formative assessments will track student progress, with feedback provided to support ongoing improvement. |
| **#6. Evaluation and Continuous Improvement** | |
| In progress | |

## 4.11. USE CASE 11. PLM

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| USE CASE | **Product lifecycle management (PLM)** |
| Author | Tehniški šolski center Maribor Slovenia |
| Description | Product Lifecycle Management (PLM) is an integrated, information-driven approach comprised of people, processes/practices, and technology to all aspects of a product's life, from its design through manufacture, deployment, and maintenance - culminating in the product's removal from service and final disposition. By trading product information for wasted time, energy, and material across the entire organization and into the supply chain, PLM drives the next generation of lean thinking. (Grieves, 2005)<br>LCAMP CLF is using Dassault Systèmes 3DEXPERIENCE cloud platform as primary 3D CAD modelling environment, also same platform is used as a PLM solution with Enovia Collaborative Lifecycle app, so LCAMP members can:<br>• Collaborate seamlessly no matter the location<br>• Increase creativity using virtual twin CLF<br>• Leverage a holistic and real-time view into processes. |
| Location | Tehniški šolski center Maribor, Slovenia |

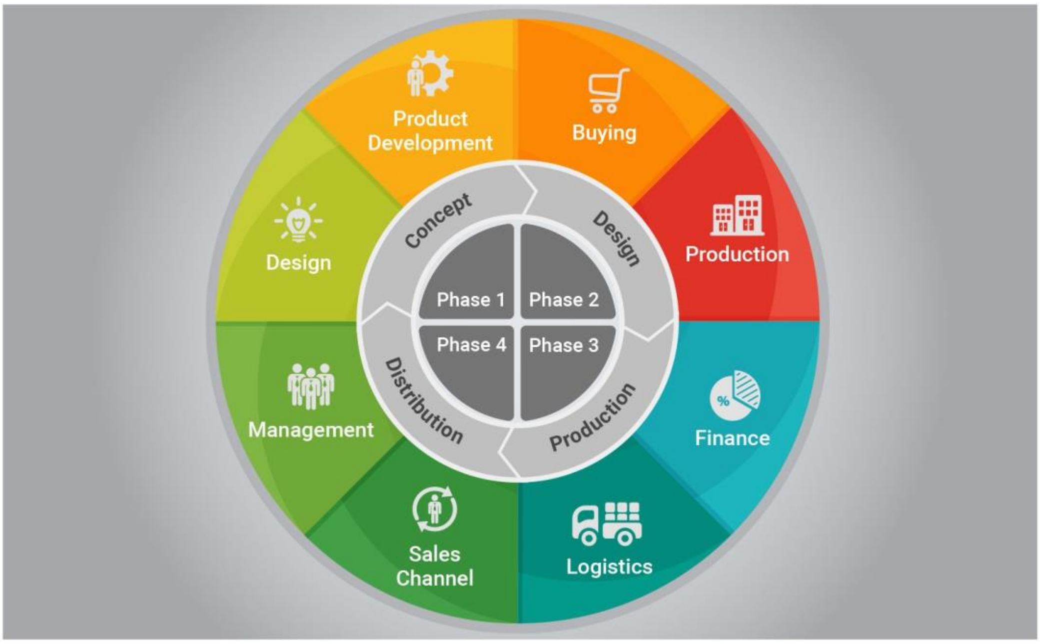


*Figure 18 Screenshot taken from https://www.surefront.com/blog/product-lifecycle-management-plm-software-6-things-you-need-to-know*

| **#1. Identification of a need or a problem to solve** | |
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| Purpose (technical) | The purpose of using 3DEXPERIENCE PLM is to enhance assembly of LCAMP robot subsystem by simulating real-world product development scenarios and managing complex data – in LCAMP case all assembly parts and documentation for robot. 3DEXPERIENCE PLM enhances collaboration between LCAMP members and in case of CLF students, mimicking industry teamwork and help optimize processes for part structure efficiency. PLM ensures compliance with industry standards and teaches the importance of regulatory adherence. It also allows students to perform lifecycle analysis, promoting sustainable practices. Idea of implementing PLM to VET is to equip students with essential technical skills for their careers. |
| Purpose (didactic) | Product Lifecycle Management (PLM) primary didactic purpose is to equip students with a comprehensive understanding of the entire product lifecycle, from conceptualization to end-of-life. By integrating PLM into engineering and manufacturing curricula, educational institutions can deliver skilled engineers, capable of driving innovation, improving product quality, and optimizing manufacturing processes.<br>Using PLM in VET enhances active, hands-on learning and helps students develop both technical and soft skills. It aligns the curriculum with current industry standards, making training more relevant. PLM supports differentiated instruction to meet diverse learning needs. It also facilitates continuous assessment and feedback for ongoing improvement. |
| **#2. Technology Selection and Feasibility Study** | |
| | Implementing a Product Lifecycle Management (PLM) system into LCAMP CLF can significantly enhance the it's capabilities by providing a centralized platform for managing product data, processes, and collaboration. PLM is designed to scale to meet the needs of VET of all sizes, from schools with few hundred student to colleges with several thousand students. It can be configured to support a wide range of workflows and processes, making it adaptable to different learning scenarios<br>The 3DEXPERIENCE platform simplifies the lifecycle of the supporting design data with the Collaborative Lifecycle app. This enables users to release, revise, branch, move and delete data directly from web browser. Users can protect completed design data by |

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| | changing its maturity state - additional states are available to make objects private when working in a shared collaborative space. Object's flag is frozen if the release is pending decisions from other stakeholders, or make the object obsolete, if it is no longer needed, or if it has been replaced by a new version. Revisions capture improvements to existing designs, users can increment the revision of an object by clicking “new revision”. This automatically creates a reference between the revisions and the app makes this visual, so users can easily understand the history of an object. In many cases you have multiple design candidates for the next revision. Users create branches for this scenario, again the references are automatically created and visualized in the app. New revisions may also be created from these branches by clicking "new revision from" and picking the desired object. To clean up the history and remove unwanted versions users can pick the objects of interest and click delete. For assemblies users can enable the "whole structure option" if they want to delete all of the child components as well. For scenarios where users want to move data to a different collaborative space or assign another user as the owner, use transfer ownership and define the desired destinations. When it comes to moving, deleting, branching, revising and releasing product design data, you can do all of this from your internet browser with one app on the 3DEXPEREIENCE platform. The 3DEXPEREIENCE platform can store documents to give them the same security as all other data stored in the platform. In addition to this, these documents can then be linked directly to other data. Documents in the platform are revision controlled and can be placed under change control, giving the same level of functionality to your documents as users CAD data. 3DEXPERIENCE uses a Unified Product Structure which brings together all elements of a design such as mechanical, electrical, PCB, Software, etc. into one ‘BOM’. This unified BOM can then be used by many other areas of the platform, for example Variants and Options can be applied to the whole BOM structure as a single BOM rather than over multiple BOM's. |
| **#3. Develop a Phased Implementation Plan** | |
| | It was important to perform an initial assessment of all possible phases of the project when using 3DEXPERIENCE implementation within LCAMP stakeholders. This involves mapping project requirements to available functionality and determining if any customizations are required.<br>The LCAMP team had to consider licensing requirements which took more time and effort as previously planned. Right from the start, the project team had to plan for a data migration step from previous project where whole robot was designed in Solidworks to perform data migration into 3DEXPERIENCE platform.<br>During the data migration, the data had to be cleaned-up to eliminate:<br>- Duplicated part numbers per file<br>- Duplicated file names<br>- Duplicated files with different names<br>- Missing or incorrect file attributes<br>- Missing or incorrect file associations or links<br>- File revision not current<br>- Non-current parts in current assemblies<br>- Non-compliance revision/versioning scheme<br>- Missing mandatory attributes in source system<br>With proper planning and testing, implementing and migrating data to 3DEXPERIENCE can go smoothly. The better prepared you are ahead of time, understanding requirements, data sets, limitations and the technology being used, the better the 3DEXPERIENCE implementation will run. It is important to set the right expectations among users, knowing that most implementation and data migration projects are accomplished in a relatively straightforward manner. |
| **#4. Training** | |
| | The training of 3DEXPERIENCE PLM solutions will be performed by TKNIKA.<br>PLM Training for Teachers in LCAMP CLF:<br>1. Assessment of user's needs: |

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| | - Identify Core Competencies: Determine the essential PLM skills teachers need to effectively guide students. This might include basic navigation, data management, workflow creation, and collaboration tools.<br>- Assess Current Knowledge: Evaluate teachers' existing knowledge of PLM and digital tools. This will help tailor the training to their specific needs.<br>- Identify Training Goals: Clearly define the objectives of the training, such as improving teaching methods, enhancing learning experiences and innovation.<br>2. Develop a Comprehensive Training Plan:<br>- Modular Approach: Break down the training into manageable modules, covering topics like:<br>▪ Introduction to PLM concepts<br>▪ Navigating the 3DEXPERIENCE interface<br>▪ Creating and managing product structures<br>▪ Working with workflows and tasks<br>▪ Collaborating with team members<br>▪ Integrating with other tools (CAD, CAM, etc.)<br>▪ Data management and security<br>- Hands-on Practice: Incorporate practical exercises and simulations to reinforce learning.<br>- LCAMP Project Integration: Use LCAMP robot assembly to demonstrate how PLM can be applied in CLF settings.<br>3. Choose Effective Training Methods:<br>- Blended Learning: Combine various delivery methods, such as:<br>• Instructor-led training: In-person sessions for interactive discussions and demonstrations.<br>• Self-paced online learning: Provide access to online tutorials, videos, and documentation for flexible learning.<br>• Hands-on workshops: Practical sessions to practice PLM skills in a collaborative environment.<br>- Mentorship and Coaching: Assign experienced PLM users as mentors to provide guidance and support.<br>- Community Building: build a community of practice among teachers to share experiences and best practices.<br>4. Provide Ongoing Support and Resources by TKNIKA:<br>- Help Desk: Establish a dedicated help desk or support team to assist teachers with technical issues and questions.<br>- Online Resources: Use 3DEXPERIENCE online resource library with tutorials, FAQs, and troubleshooting tips.<br>- Regular Training Updates: Offer refresher courses and workshops to keep teachers up-to-date with the latest PLM developments and best practices.<br>5. Evaluate the Training Program:<br>- Feedback Mechanisms: Gather feedback from teachers through surveys, interviews, and focus groups.<br>- Assessment of Learning Outcomes: Evaluate the effectiveness of the training by assessing teachers' knowledge and skills.<br>- Continuous Improvement: Use feedback and assessment results to refine the training program and address any shortcomings. |
| **#5. Integrate Technology into Curriculum and Learning Activities** | |
| | The students who are working with PLM at TSCMB (Slovenia) are students at level:<br>- EQF 4/ Mechanical engineering technician – use of PLM for project management and collaboration: learn how to manage projects efficiently, from initial design to final product disposal in collaborative environment.<br>- EQF 5/ Mechanical engineer - use of PLM for project management, collaboration, data management and digital transformation: learn how to manage projects efficiently, from initial design to final product disposal in collaborative environment, use of teamwork, learn about industry standards for data exchange and |

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| | interoperability and learn how to create digital twins of products to simulate and optimize performance. |
| **#6. Evaluation and Continuous Improvement** | |
| | In process |

## 4.12. USE CASE 12. PRODUCT CONFIGURATOR

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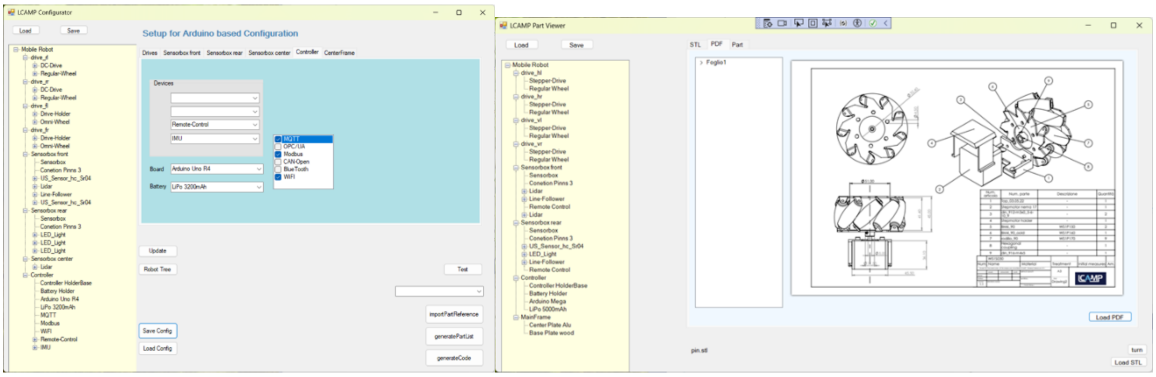
| USE CASE | **Product Configurator** |
| Author | Duale Hochsulle Baden Wurttemberg – Heidenheim, Germany |
| Description | A CLF serves to train students and professionals in realistic production environments. In this setting, it is important to be flexible, adaptable and dynamic in responding to learning needs and technical requirements.<br>**Flexibility**: Different teaching and learning modules can be dynamically configured and adapted to the needs of the learners.<br>**Efficiency**: Production resources and learning objectives are optimized and synchronized with each other.<br>**Collaboration**: Different users (teachers, students, administrators) can easily access and work with the necessary configuration in distributed educational institutions.<br>The Configuration Manager ensures the coordination and management of all relevant variants, systems, assembly equipment and associated learning content. A configuration manager for a collaborative learning factory serves as a central hub for managing processes, learning content, users, and data. It enables creating a flexible, efficient and safe learning environment to meet the needs of modern I4.0 production environments. The integration of process planning into the CLF ensures that learners can gain practical experience. |
| Location | DHBW – Heidenheim Germany |
| <br>*Figure 19 Product Configurator with Knowledge Tree* | |
| **#1. Identification of a need or a problem to solve,** | |

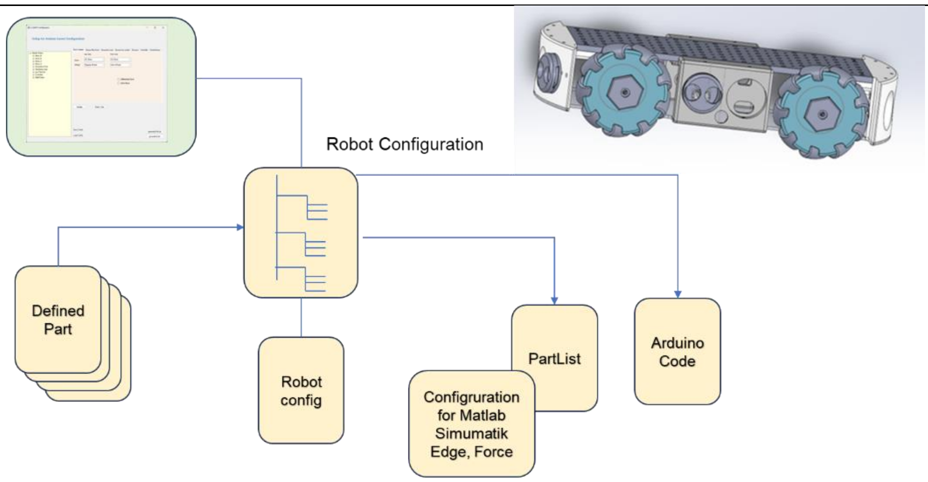
<table>
<tr><td>Purpose (technical)</td><td>


*Figure 20 Product Configurator as a connecting hub in the CLF*

The complex technical product for the CLF could not be handled by a single student group. The Robot has mechanical aspects, Electronic- and Software aspects and the interaction between Product CLF and the users. These domains could be linked together without special knowledge of an Enterprise Resource Planning (ERP) or Product Livecycle Management (PLM) System. A student group could focus on a special topic with access to all the other domains.</td></tr>
<tr><td>Purpose (didactic)</td><td>The configurator serves the different variants of a mechatronic product. It is located below the Product Lifecycle Management (PLM) at a low threshold. The configurator provides a connection between PLM and the operational levels. Real configurations can be created and the prototypes manufactured. The low-threshold approach allows processes to be implemented directly in the laboratory. The configurator is run directly on the LCAMP platform or students can use the complete source code to drive specific developments.</td></tr>
<tr><td colspan="2">#2. Technology Selection and Feasibility Study</td></tr>
<tr><td></td><td>The robot consists of subsystems that must perform the required function. A basic configuration is the omnidirectional robot, which is remotely controlled.<br>This can be produced with different technologies. Either in different 3D printing technologies, with cutting technologies or classic machining, primary forming or forming technologies. Only certain configurations that are selected by the configuration manager are useful. The data is pulled in the simple form from Json configuration files. These can be specifically adapted for each use case but can also be transferred via the cloud. The hurdle of database administration is overcome, and every student can install the system locally on his notebook.<br>In the Configurator are defined:<br>Mechanical factors: function, connection dimensions, stability ç Bill of materials including positions, 3d geometry and assembly constraint is generated.<br>Electronic factors: connectivity, function, security.  ç source code for Controller is generated.<br>Logical factors: Structural structure, traceability, quality data ç Json File is generated with the logic configuration.<br>In addition to the functional requirements, design aspects are also considered. The color combination as well as the material composition and the connection technology (screwing, riveting, gluing, …).<br>The entire robot is the result of the interaction of many individual processes that can be largely asynchronous. Parts are either procured externally (purchased parts), procured internally through the partners or manufactured in-house. The assembly is then carried out completely individually. Each robot is therefore unique. Some of these processes are accompanied by teaching materials embedded in micro-credentials<br>Circular economy in the context of training and to impart the skills of the circular economy, the aim is to ensure that the robot can be completely disassembled and merged into a new configuration. The robot thus represents a special warehouse for the configurator.</td></tr>
</table>

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| **#3. Develop a Phased Implementation Plan** | |
| | The Configurator is based on the description of the Robot. Multiple configurations are handled.<br>Integration of a 3D drawings in the Configurator.<br>Integration of new and modified parts for further development.<br>Generate the Code for Arduino or other Controllers<br>Activate the Interface to Matlab/Simscape<br>Activate the Interface to Simumatic<br>Activate the Interface to FORCAM Force/ Edge |
| **#4. Training** | |
| | The training is linked to a Micro credential to get the Skill in Configuration Management.<br>This Course is performed in the CLF for students from technical Faculty and the business department. |
| **#5. Integrate Technology into Curriculum and Learning Activities** | |
| | EQF 6/ Integrated Engineering, Mechanical Engineer, Industrial Engineer – Using the configurator for industrial process management, collaboration, data management and digital transformation as well as working with circular processes to strengthen sustainability.<br>Mechatronics Engineers, Informatics Engineers - develop in student projects new Variants and functional Modules for the configurator. |
| **#6. Evaluation and Continuous Improvement** | |
| | In process |

# 5. CONCLUSION AND OUTLOOKS

The report outlines a method for integrating advanced technologies into Learning Factories and workshops within VET and HVET institutions. It introduces a six-step framework for adopting I4.0 technologies in educational labs:

1. Identify a Need or Problem to Address
2. Select Technologies and Conduct a Feasibility Study
3. Develop a Phased Implementation Plan
4. Provide Training
5. Embed Technology into Curriculum and Learning Activities
6. Evaluate and Continuously Improve

To demonstrate the application of this guideline, the report presents nine use cases. These examples highlight the guideline's adaptability to diverse scenarios and illustrate its practical value. It is worth mentioning that not all the steps are yet reflected in the use cases, for instance the *Evaluation and Continuous Improvement* phase, as the processes are still underway. Completion of the entire guidelines anticipated by the conclusion of the LCAMP project.

From an educational perspective, a relevant step is the *Embed Technology into Curriculum and Learning Activities.* For the use cases shown, the adaptation of curriculums are very context dependant. Regional legislations set up the scope for such integrations.

Future efforts will focus on standardizing courses and learning outcomes within activities derived from technology implementation, ensuring their applicability to international counterparts. Specifically, the LCAMP CLF will incorporate the LCAMP Competence Framework into its courses. This adoption aims to ensure the courses' alignment with international standards, enhancing their usability and relevance across borders.

Finally, during LCAMP lifespan, more I4.0 technologies will be incorporated gradually. In a short term, traceability systems, smart fastening systems, dashboards for data analysis, connected wearables are planned to be incorporated.

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# 7. INDEX OF FIGURES

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