LCAMP

Learner Centric Advanced Manufacturing Platform

# D5.3 Database of I4.0 specific courses and Micro-Credentials

**WP5 Learner-Centric Training**

Authors: Stenzel, J., Korsch, M.

Contributors: KIC, TKNIKA - Basque VET Applied Research Centre, CIFP Miguel Altuna LHII DHBW - Duale Hochschule, Baden-Württemberg, Curt Nicolin High School, CMQEf, KPDoNE, Camosun College, GEBKIM VET, MADE Competence Centre Industry 4.0, TSCMB -Tehniški šolski center Maribor

Co-funded by the European Union

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Education and Culture Executive Agency (EACEA). Neither the European Union nor EACEA can be held responsible for them.

Co-funded by the European Union

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Education and Culture Executive Agency (EACEA). Neither the European Union nor EACEA can be held responsible for them.

This work is licensed by the LCAMP Partnership under a Creative Commons Attribution-NonCommercial 4.0 International License.

**LCAMP partners:**

TKNIKA – Basque VET Applied Research Centre, CIFP Miguel Altuna LHII, DHBW Heilbronn – Duale Hochschule, Baden-Württemberg, Curt Nicolin High School, AFM – Spanish Association of Machine Tool Industries, EARLALL – European Association of Regional & Local Authorities for Lifelong Learning, FORCAM, CMQE: Association campus des métiers et des qualifications industrie du future, MV: Mecanic Vallée, KIC: Knowledge Innovation Centre, MADE Competence Centre Industria 4.0; AFIL: Associazione Fabbrica Intelligente Lombardia, SIMUMATIK AB; Association HVC Association of Slovene Higher Vocational Colleges; TSCMB:Tehniški šolski center Maribor, KPDoNE: Kocaeli Directorate Of National Education: GEBKİM OIZ and CAMOSUN college.

## Document summary

| | |
|---|---|
| **Document type:** | Public Report |
| **Title** | D5.3 Database of I4.0 specific courses and Micro-Credentials |
| **Author/s** | Jan Stenzel, Moritz Korsch |
| **Reviewer** | U. Ziarsolo, Prof. Dr.-Ing. K.-D. Rupp |
| **Date** | December 15th 2024 |
| **Document status** | 0.95 |
| **Document-level** | Confidential until its publication |
| **Document description** | This document describes the main features and the development of the LCAMP Database for I4.0-specific courses and micro-credentials (D5.3) |
| **Cite this deliverable as:** | Stenzel, J., Korsch, M. et al. (2025). Database of I4.0 specific courses and Micro-Credentials (LCAMP4.0 Deliverable D5.3) |
| **Document level** | Public |

# GLOSSARY AND/OR ACRONYMS

**CF** - Competence Framework
**CLF** - Collaborative Learning Factory (LCAMP Work Package 6)
**CoVE** - Centres of Vocational Excellence
**CBE** - Competency-Based Education
**EXAM 4.0 -** Excellence Advanced Manufacturing 4.0
**EDC(I)** - European Digital Credential (Infrastructure) (refers to ELM metadata)
**ECTS** - European Credit Transfer and Accumulation System
**ELM** - European Learning Model
**EQF** - European Qualifications Framework
**ESCO** - European Skills Competencies and Occupations
**EQAR** - The European Quality Assurance Register for Higher Education
**Future Skill (Framework) –** According to U.-D. Ehlers et al. (2021) here as the scientific educational concept behind a machine-readable LCAMP Nano-Credential
**HEI** - Higher Education Institution
**HRK** - HEI Rectors Conference on recognition and validation principles in Germany
**HVET** - Higher Vocational Education and Training
**LCT** - Learner Centric Training (LCAMP Work Package, WP5)
**LO** - Learning Outcome
**LCAMP Comp.** - LCAMP Competence Framework (see D5.2)
**LLL** - Lifelong Learner / Learning
**LLM** - Large Language Model (Generative AI)
**MC** - Micro-Credential: Here understood as a bundle of Nano-Credentials/
**NC** - LCAMP Nano-Credential: Harmonized & Digitalized curricular LO aggregated with ESCO Skills Bundles, ELM and LCAMP Framework metadata
**OECD** - Organization for Economic Co-operation and Development
**OER** – Open Educational Resources
**PoC** - Proof of Concept
**QA** - Quality Assurance
**RPL** - recognition of prior learning
**S3** - Smart Specialization Strategy
**WoW** - World of Work
**WP3** - LCAMP Observatory

# CONTENT TABLE


EXECUTIVE SUMMARY ..... 6
1. INTRODUCTION ..... 8
1.1.1. The LCAMP Ecosystem ..... 9
1.1.2. Definition of a Micro-credential (EDCI-MC) ..... 9
1.1.3. The scope of Deliverable D5.3 ..... 10
2. EDUCATIONAL FOUNDATIONS OF H-VET NANO-CREDENTIALS ..... 11
2.1. Competency Concepts & ESCO ..... 12
2.1.1. LCAMP Maturity Matrix for levelled Competence Alignment ..... 14
3. R&D METHODOLOGY ..... 18
3.1. Educational Design Approach ..... 18
3.1.1. I4.0 Course Identification and Curation ..... 18
3.1.2. Defining Learning Outcomes and Competencies ..... 19
3.1.3. Nano-Credential Structuring within a Clearing House (PoC) ..... 20
3.1.4. Technical/Digital Implementation: Tagging Workflow and Platform Integration 24
4. RESULTS & KPI ..... 28
4.1. Scale of the Database ..... 28
5. DISCUSSION ..... 31
Institutional InsightS — HRK-Modus Findings and DHBW Experience ..... 33
5.1.1. Ad-Hoc Recognition and Policy Environment ..... 35
5.1.2. From the employer perspective: ..... 37
6. CONCLUSION AND OUTLOOK ..... 38
6.1.1. Maintain and expand the I4.0 Credential Database ..... 40
7. REFERENCES ..... 43
8. INDEX OF IMAGES ..... 45
9. INDEX OF TABLES ..... 45
10. ANNEXES ..... ¡ERROR! MARCADOR NO DEFINIDO.
10.1. Annex 1 ..... **¡Error! Marcador no definido.**
10.2. Annex 1 ..... **¡Error! Marcador no definido.**

# EXECUTIVE SUMMARY

This report provides a comprehensive overview of the educational frameworks fostering micro-credentialing in European Vocational Education and Training (VET) alongside the development of the LCAMP Database of I4.0-Specific Courses and Micro-Credentials. Authored by the Learner-Centric Training working group (LCT), the D5.3 deliverable examines critical intersections between Industry 4.0 (I4.0) innovations and the digital transformation in VET systems across Europe and beyond. Emphasis is placed on identifying and benchmarking key conditions and standards essential for designing tailored micro-credentials for enhanced interoperability, leveraging European Digital Credential metadata. This approach aims to facilitate flexible, responsive, and future-oriented learning pathways, supporting sector-specific lifelong learning strategies throughout Europe and beyond.

This report presents the development of a comprehensive database of Industry 4.0-specific courses and micro-credentials (here referred to as “nano-credentials”) as part of the LCAMP project. The LCAMP LCT working group aims to support advanced manufacturing education through innovative, learner-centric approaches. One key outcome is a curated catalog of training courses and micro-credentials in Industry 4.0, aligned with European competency frameworks and EDC quality standards. This report first outlines the educational context for Industry 4.0 (I4.0) and the need for upskilling and reskilling in advanced manufacturing. We then detail how micro-credentials – short, competency-based certifications – are being leveraged to address these needs in vocational and higher vocational education (H-VET). The Introduction provides the necessary research background on the LCAMP project’s scope and how it fits into the broader micro-credentialing ecosystem, referencing recent European policy developments (e.g., the Council Recommendation on micro-credentials (EC, 2022)) and the OECD’s interest in micro-credentials for lifelong learning.

Chapter 1 introduces the LCAMP Ecosystem, and the approach taken in D5.3.

Chapter 2 lays the educational foundations for competency-based nano-credentialing in H-VET. It introduces the OECD competence braid concept – viewing competences as an intertwining of knowledge, skills, and attitudes, fostered by work-based training – and how this informs our approach. It also discusses the European ESCO framework as a taxonomy of common skills and defines four maturity levels (L1–L4) of competency development to classify learning outcomes from basic to expert. Key educational theories underpinning our approach are analyzed to foster informed decision-making. The theories guide the R&D approach on how to transform traditional competency-based (CBE) micro learnings as outlined by Zhang, J., and Richard E. West. (2020) into agile future Skills (Ehlers, 2021) for the world of work in advanced manufacturing, presented with clear visuals for ease of understanding.

Chapter 3 describes the R&D methodology for building the database, distinguishing between the educational design process and the technical/digital implementation. The authors explain further how the LCAMP team identified relevant courses, defined learning outcomes, and

“tagged” each granulized course/micro-credential with standardized ESCO skill tags and other relevant metadata in an iterative semi-automated workflow. We also show how the micro-credential structure was defined (ensuring each nano-credential includes standard elements like title, description, learning outcomes, workload, EQF level, assessment method, etc., per EU recommendation and integrated into the LCAMP digital platform. We illustrate the tagging workflow and the architecture of the nano-credential system, including integration with tools provided by the Knowledge Innovation Centre (KIC), the project’s technical partner.

Chapter 4 presents the results and KPIs. The final database includes 230+ nano-credentials covering a wide array of Industry 4.0 topics (robotics, additive manufacturing, AI, etc.), aggregated from dozens of consortium courses and training programs contributed by LCAMP partners. We provide tables and graphics summarizing the number of courses and micro-credentials by partner institution and highlight that all nano-credentials have undergone internal national/institutional validation process, where they are issued under the legislation of the national authorities. The ESCO tagging and the multi-faceted references to relevant EU framework meta-data, aggregated in our Clearing House Concept, prepares the LCAMP Learning Ecosystem for advanced educational scalability and international interoperability. Additionally, each credential’s metadata adheres to European standards (following the Council’s “mandatory elements” for micro-credential description (see Camilleri, ETF, 2022) to maximize transparency and interoperability. The key performance indicators (KPIs) include the constantly growing total count of credentialed courses, the coverage of LCAMP frameworks competence areas, and the extent of cross-institutional uptake. These results demonstrate a successful collaboration, yielding a rich repository of Industry 4.0 training opportunities.

In Chapter 5, we engage in a discussion of challenges, pitfalls, and stakeholder perspectives. Despite the achievements, implementing HVET-nano-credentials in formal education still comes with enormous challenges. We reference prominent findings that caution against the fragmentation of learning and the potential “weakening of established qualifications” when introducing micro-credentials. Institutional barriers are discussed, such as the need for internal quality assurance, faculty buy-in, and integration of micro-credentials into existing curricula. We note that recognition of micro-credentials is not yet automatic; often, it is handled via ad-hoc agreements between institutions, requiring case-by-case evaluation. (See ETF, 2022: p.36-48). Camilleri’s (2022) observation further states that without systemic frameworks, micro-credentials rely on “bespoke” recognition processes, which increase administrative overhead and uncertainty. We also discuss lessons learned about ensuring quality and consistency, drawing on examples of pitfalls and how we mitigated them. On the positive side, we outline the strategic advantages of nano-credentials for H-VET. These include greater flexibility for learners, high responsiveness to industry skill needs, and the ability to foster continuous upskilling, collaborating with local employers, and corporate academies. We incorporate stakeholder perspectives: for instance, the OECD has highlighted, that micro-credentials can promote lifelong learning and quick workforce reorientation in times of change (OECD, 2023) but also warns of the need for common standards to ensure they are widely understood and valued. Employers, crucial stakeholders, are, as experienced in our LCAMP surveys, increasingly aware of micro-credentials but remain hesitant since they often lack incentives and the capacity to collaborate in developing and recognizing these new credentials. This chapter synthesizes these insights, providing a balanced view of the promise of micro-credentials and the work still needed for their broader acceptance and roll out (e.g. developing robust quality assurance, credit recognition frameworks, and raising awareness among employers and learners).

Chapter 6 concludes the report and offers an outlook. We summarize the key outcomes: the establishment of a micro-credential database and clearinghouse ecosystem for Industry 4.0 training, and the successful alignment of nano-credentials with European frameworks (ESCO, EQF, EDCI). We then present recommendations for policy and institutional practice. These recommendations include: adopting the European approach to micro-credentials at national and institutional levels (implementing the standard descriptors and ensuring micro-credentials are quality-assured and portable); investing in capacity-building for educators to design and deliver competency-based micro-credentials; and creating formal pathways for recognition and stackability (so that clusters of micro-credentials can potentially lead to larger credentials or be recognized for credit in formal programs). We also emphasize the importance of transnational cooperation – as exemplified by LCAMP – in developing a common approach. The LCAMP experience suggests that networks of institutions (such as Centers of Vocational Excellence across different countries) are invaluable for sharing best practices and even mutually recognizing each other's micro-credentials among a micro-credentialing ecosystem, laying the groundwork for "recognition networks" beyond ad-hoc bilateral agreements (ETF, 2022). By continuing to work together and align with initiatives like the European Universities alliances (DHBW, EU4Dual) and Erasmus+ mobility frameworks, LCAMP can move toward a future where micro-credentials are seamlessly integrated into lifelong learning and labor market ecosystems.

Overall, this deliverable shows that a thoughtfully designed, competency-based nano-credential system is not only possible but highly beneficial for advancing Industry 4.0 skills development. While challenges remain, the project provides a solid foundation and practical tools for ongoing innovation in learner-centric training. The LCAMP micro-credential database will be hosted on the upcoming LCAMP platform, serving as a lasting resource for learners, educators, and employers seeking targeted I4.0 upskilling opportunities, when continuously updated by the national issuing body. In closing, we stress that policy support and stakeholder engagement are crucial to scale these efforts, and we call on education providers, industry partners, and policymakers to leverage the insights from LCAMP to foster a vibrant, quality-assured micro-credentials ecosystem in advanced manufacturing.

# 1. INTRODUCTION

The term Industry 4.0 (I4.0) refers to the fourth industrial revolution characterized by smart automation, cyber-physical systems, IoT, AI, and data-driven processes in manufacturing. As the manufacturing sector undergoes this digital green and technological transformation, there is a critical need for the workforce to acquire new skills and competencies (cedefop, 2024 & 2025). Traditional training and degree programs often struggle to keep pace with rapid technological advances and our common European endeavour to transform both manufacturing technology and the human mindset into a viable future global economy that truly values the visionary perspectives of the "Cradle to Cradle" product lifecycle. (Braungart & McDonough, 2014).

This all has led to an upskilling and reskilling imperative worldwide, particularly for technicians, engineers, and skilled workers (EQF3-4) in advanced manufacturing. Education and training must become more agile and continuous, enabling learners to update their skill sets in shorter and more agile cycles. Here is where micro-credentials enter the picture as a promising solution

within a typical micro-credentialing ecosystem while relying on the collaboration and strategic commitment of its “key stakeholders”. (OECD, 2023, p.10).




*Figure 1: Key Stakeholders of a Micro-Credentialing Ecosystem, OECD, 2023, p.10*

### 1.1.1.THE LCAMP ECOSYSTEM

Against this background, the LCAMP (Learner-Centric Advanced Manufacturing Platform Centres of Vocational Excellence (CoVE) project was launched under Erasmus+ to strengthen advanced manufacturing education across Europe. LCAMP brings together over 20 partners – including vocational education and training (VET) providers, higher VET (or applied science universities), companies, industry associations, and regional authorities – from countries in Europe (and even Canada and Türkiye).

The goal is to create a micro-credentialing ecosystem across the LCAMP Consortium and other Centres of Vocational Excellence (CoVEs) in advanced manufacturing that collaborate on innovative training methods, curricula, and support future upskilling services for H-VET. Key objectives of LCAMP include developing Advanced Manufacturing competency frameworks, setting up collaborative learning factories (CLF, WP6), setting up an observatory for skills needs, and crucially, developing micro-credentials and training for Industry 4.0.

The LCAMP project aims to enable regional VET centers to become more resilient, innovative, and better equipped to train learners (both young and adult) with the skills needed for the digital and green transitions in industry 4.0.

### 1.1.2. DEFINITION OF A MICRO-CREDENTIAL (EDCI-MC)

Micro and Nano-credentials, as fine-grained and scalable educational units, are succinct, certified microlearnings that verify a person’s assessed mastery of a specific Learning Outcome (LO); in light of the interwoven nature of knowledge, skills, and attitudes adding up to what is broadly accepted to constitute a Competency (OECD Competency Model 2030, see Figure 2).

Micro or Nano-credentials are typically smaller and therefore more scalable than full degree programs or diplomas – for example, a micro-credential might cover one specific topic or competency that could be learned in a few weeks or months, or even less. According to the European Council's definition, a micro-credential is "a record of the learning outcomes that a learner has acquired following a small volume of learning," which has been assessed and is subject to quality assurance. (EC, 2022)

Micro-credentials can stand alone or be aggregated into larger qualifications. The flexibility and targeted nature of micro-credentials make them especially suited for lifelong learning and fast-paced fields like I4.0. Policymakers and institutions are increasingly exploring micro-credentials to help individuals quickly gain relevant skills and to support employment transitions.

### 1.1.3. THE SCOPE OF DELIVERABLE D5.3

This report corresponds to deliverable D5.3, produced by the Learner-Centric Training working group in collaboration and interdependency with co-developments in the work packages 3, 6, and 8 (Observatory, Collaborative Learning Factory, and platform development, respectively) within LCAMP. The deliverable's title is *"Database of I4.0 Specific Courses and Micro-Credentials,"* which reflects, as is typical for WP5 deliverables, **a dual focus**: (1) identifying and cataloguing existing courses related to Industry 4.0 skills, and (2) developing new micro/nano-credentials system and clearing house that enable future cross-border certification of specific I4.0 competencies in advanced manufacturing offered by the consortium stakeholders. To achieve this, the WP5 working group populated a database or micro-credential catalogue that will feed into the LCAMP digital platform, functioning as a "clearing house" of advanced manufacturing training opportunities.

D5.3 Database of I4.0 specific Courses and Micro-credentials (PoC), delivered on October 15th 2024 by the Learner-Centric-Training (WP5), is sector-specific (focused on advanced manufacturing/I4.0) and is designed to support multiple and agile educational pathways within that sector. For each training course or module offered within this catalogue, the working group documented its core (mandatory European Digital Credential metadata) information and tagged it with interoperable educational framework data so that the credentialed courses can be searched, compared, and potentially linked to a variety of micro-credentials concepts, and supporting inter-institutional and international learners mobility. Since micro-credentials are a relatively new concept in the context of education systems, especially in Vocational Education and Training (VET) and its traditional qualification offers, part of the work executed in D5.3 was ensuring alignment with emerging standards and frameworks compatible with canonical education systems and its principles. In June 2022, the Council of the European Union adopted a Recommendation on micro-credentials for lifelong learning and employability, which provided a common definition and a list of standard elements that describes a smaller, more versatile approach to learning, the micro-credential (such as title, awarding body, approximate workload, learning outcomes, etc.). Our project utilizes this European approach and its follow-up initiatives (ELM) as a guiding framework to ensure that the nano-credentials concept developed meets quality and transparency criteria. We also align with the ESCO framework – the European Skills, Competences, Qualifications and Occupations classification – so that the competencies addressed by each micro-learning use a common digitized skills language that can establish a connection with future (automated) job profilers across Europe.

ESCO serves as a multilingual taxonomy; enabling course tagging for e.g. “industrial robotics programming” with standardized skill descriptors that employers and other educators can recognize. Another important aspect is ensuring the interoperability of the credentials. This involves structuring the data in a way that could be used in digital credential platforms (such as the Europass Digital Credentials Infrastructure). The leading involvement of DHBW helps here to link our work to previous European projects on digital credentials MicroHE, MicroCredX, EU4Dual etc.). The LCAMP platform hosts the MC Course Catalogue and allows learners to discover a set of over 230 EDC nano-credentials that are available as competency-based I4.0 future skills (Ehlers, 2021), paving the way for agile up- and reskilling opportunities across H-VET institutions.

Following this introduction, the report is organized into five chapters:

Chapter 2 covers the theoretical underpinnings of competency-based nano-credentialing in H-VET (Higher Vocational Education and Training) (Stenzel & Korsch, 2025), introducing key concepts and frameworks that guided our approach.

Chapter 3 details the R&D methodology, distinguishing the pedagogical design aspects from the technical implementation. It describes how the courses were collected and annotated (tagged), and how the nano-credential framework was constructed.

Chapter 4 presents the results, including the composition of the database and key metrics (number of courses, number of micro-credentials, etc.), along with examples of the content.

Chapter 5 provides a discussion, reflecting on challenges encountered and discusses the benefits and perspectives of various key stakeholders of a micro-credentialing ecosystem such as learners, institutions, employers, and policymakers (Kato et al. 2023, OECD).

Chapter 6 concludes with an outlook and recommendations, including how such an initiative can be sustained and scaled through policy support and international cooperation.

By combining a sound theoretical foundation with a practical methodology and real-world results, the report aims to serve as both a documentation of LCAMP’s achievements and a blueprint for others looking to implement micro-credentials in vocational and technical fields. We hope this deliverable will inform educators, administrators, and decision-makers interested in leveraging micro-credentials to enhance advanced manufacturing education and beyond.

# 2. EDUCATIONAL FOUNDATIONS OF H-VET NANO-CREDENTIALS

To effectively develop a database of Industry 4.0 courses and micro-credentials, our approach needed to be grounded in robust theoretical foundations. In this chapter, we outline the key concepts and frameworks that informed the design of the newly developed credentialing concept and the harmonization approach from competency-based VET curricula towards a future skills-based output that meets the requirements of the world of work (WoW). We leveraged: (1) the latest European competency frameworks (in particular, the OECD’s competency model (see

Figure 1), the LCAMP learner centric-sustainability framework, LCAMPComp, delivered in D5.3 (2) Future Skills Framework (Ehlers et al. 2021) , (3) the European Qualification Framework (EQF) and (4) the European ESCO database and (5) a newly created maturity model (L1-L4) for consistent description of competency development; and (6) utilized Bloom's taxonomy for their grounding it on widely recognized educational descriptors for learning outcomes in Europe and beyond. (7) Leveraging further EDC meta-data standards, we ensure that our newly developed fine-grained nano-credentials is not a just ad-hoc badges, but quality assure certifications of learning that reflect both educational best practices and labor-market relevance in line with European digital credential infrastructure for lifelong learning (EDCI).

## 2.1. COMPETENCY CONCEPTS & ESCO

A cornerstone of competency-based education approach (CBE) requires and sets a clear understanding of what "competency" entails. The development of the LCAMP competency-based micro-credential ecosystem followed a rigorous methodological approach, ensuring alignment with European frameworks and stakeholder needs. The LCT adopted a learner-centric and employer-informed design, combining top-down framework alignment with bottom-up curriculum analysis.

The LCT team established a common competency framework for advanced manufacturing in Higher Vocational Education and Training for European H-VET institution, D5.2 and further optimised the approach in D5.3, drawing on European Digital Credential (EDC) standards like the European Qualifications Framework (EQF) and ESCO skills taxonomy. This ensured each micro-credential ("nano-credential") would be defined in terms of learning outcomes and competencies recognizable across Europe. The OECD's broad definition of competency – the mobilization of knowledge, skills, attitudes, and values to meet complex demands – underpinned our approach, reinforcing that each credential should reflect holistic capability, not just isolated skills. The OECD has conceptualized competencies as a multifaceted braid or weave of different strands: knowledge, skills, and attitudes/values. In its education framework (OECD Learning Compass 2030, 2019) the OECD emphasizes that learners need not only knowledge and skills, but also attitudes and values to apply them, all intertwined like a braided rope to produce strong competence. In other words, effective performance in "highly emergent" (Ehlers, 2021) real-world tasks arises from the integration of what one knows (knowledge), what one can do (skills), and how one approaches situations (attitudes/behaviors). This "competence braid" concept is illustrated by OECD as three strands (K, S, A) woven together. It implies that our nano- and micro-credential PoC should ideally capture learning outcomes (LO) across these dimensions. For example, a nano-credential in Collaborative Robotics might certify specific technical knowledge (e.g. safety standards), practical skills (programming a robot arm), and certain attitudes (e.g. adherence to safety protocols or teamwork). Recognizing competence as a blend of these components ensures our credentials are holistic and meaningful for all key stakeholders of the Micro-Credential Ecosystem (Kato et al. 2023). As one commentary on the OECD framework notes, the model weaves knowledge, skills, attitudes, and values to produce competencies, reinforcing the idea that competencies are not one-dimensional.

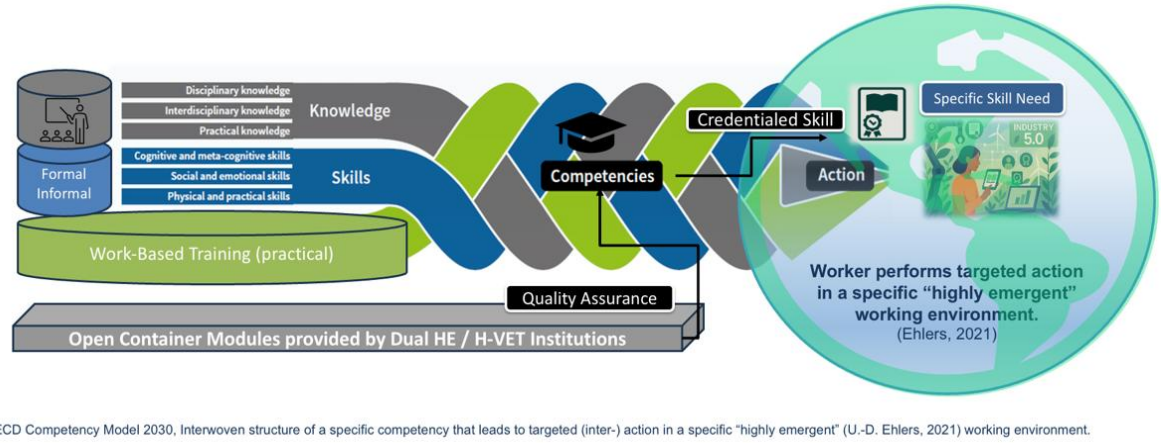



*Figure 2: Modified after OECD Competency Model 2030 (OECD, 2019)*

Our adaption of OECD Competency Model 2030 (2019) outlines the process how nationally validated and recognized CBE learning outcomes & Work-Based Training Offers of LCAMP course catalogue were leveraged and unbundled to prepare for curricula harmonization and digital transformation processes, via matching with the ESCO and other European educational framework metadata. The technical methodology utilized to aggregate LCAMP future-proof I4.0 learning outcomes stored in our clearing house MC- course database is described in detail in chapter 3.

ESCO (European Skills, Competences, Qualifications and Occupations) is a multilingual classification developed with European Commission and was utilized to establish a linkage between LCAMP partners' competency-based LOs at regional level and a machine-readable skill-based international reference language between public H-VET and labour market needs (e.g. LinkedIn). ESCO provides standardized entries (URIs) for thousands of skills and competences, and links them to occupations. For instance, ESCO can tell us that "CNC programming" is a skill related to the occupation "Industrial Machinery Mechanic." By aligning our content with ESCO, we ensure that each credentialed learning outcome explicitly references skills that are recognized at the European level. This makes the credentials more transparent and transferable between WoW and education providers across countries. It also facilitates searchability: a learner or company can search the LCAMP catalogue by specific skill keywords (which are ESCO-indexed) that require a specific role. In practice, for every course or nano-credential, we identified relevant ESCO skills/competence terms. If a course covered "additive manufacturing design," we might tag it with ESCO skills like "operate 3D printers" or "additive manufacturing design software proficiency." Using ESCO as a backbone thus provides interoperability and cross-context understanding of the competencies our micro-credentials certify. However, the ESCO entries still show some inaccuracies, since the entries are not updated regularly, and as we identified, they lack a clearly aligned educational concept and terminology to organize the structuring methodology of the latest database concept (v3). This nowadays, can still lead to mismatches and inaccuracies when education providers leverage the entries to harmonize and digitalize their curricula, though ESCO still provides a net benefit for its large database and higher quality is achievable on this basis.

### 2.1.1. LCAMP MATURITY MATRIX FOR LEVELLED COMPETENCE ALIGNMENT

In our framework approach (D5.2), we defined four levels of competence maturity (L1 through L4) to classify learning outcomes and credential "depth." This scheme draws from common educational levelling (in spirit to Bloom's taxonomy (1956) and was adapted to the context of vocational skill acquisition. The levels can be summarized as follows:

L1 – Introductory / Basic Awareness: The learner has basic knowledge of the subject and can understand or explain fundamental concepts. At this level, competencies might involve remembering and recognizing terminology or simple procedures. For example, an L1 outcome for an IoT course could be *"Describe the main components of an IoT system."*

L2 – Intermediate / Assisted Application: The learner can apply knowledge in structured contexts and perform tasks with guidance. This equates to a working understanding where one can follow instructions to achieve results. An L2 outcome might be: "*Assemble and configure a simple sensor network given a step-by-step protocol."*

L3 – Independent Competence: The learner can perform tasks and solve problems independently in familiar contexts. They demonstrate solid skills and can adapt knowledge to practical scenarios without direct supervision. For instance, "*Troubleshoot common issues in a PLC-controlled manufacturing line*" could be an L3 skill – it implies autonomy and problem-solving.

L4 – Advanced / Expert Application: The learner shows a high level of proficiency, can handle complex and unexpected situations, and might guide others. This is akin to an expert or specialist level within the scope of the micro-credential. An example outcome: *"Design and implement a robotic workcell integration from specifications, optimizing for cycle time and safety."* Achieving L4 signals a high likelihood the individual is able to innovate or lead in that competency area - though this might require additional (soft) skills and this innovation/leadership competency might not be limited to the L4 maturity.

These maturity levels help in structuring and relating LCAMP nano-credentials. They ensure that we indicate the depth or proficiency a credential represents. Notably, and this was intended, the levels L1–L4 here do not directly correspond to formal qualification levels like EQF (European Qualifications Framework) levels, but there may be some loose alignment (for example, an L4 micro-credential might be more suitable for someone at EQF level 6 or higher, whereas L1 could be EQF 3–4). By labelling nano-credentials with a maturity level, the database can convey whether a given credential is beginner-friendly or intended for advanced practitioners. This also aids in stacking the credentials – learners might start with L1/L2 badges and progress to L3/L4 as they deepen their expertise, as will be demonstrated within D5.4.

These proficiency levels we leveraged already in our previous R&D concept (D5.2) where the ESCO data have been associated with harmonized curricula data and basic, intermediate, and advanced, and expert maturity levels to build a SAT for advanced manufacturing skills. Ultimately, our learning and skills-profiling approach aims to communicate what a holder of a nano-credential can do, whether they have just a foundational awareness (beginner) or can perform complex (expert) tasks. This clarity is critical for employer acceptance, as employers seek to know the exact competencies a micro-credential signals. Furthermore, the maturity level approach ties into a future curriculum redesign at the local/national level, incorporating official

taxonomies and descriptors in a more unified and machine-readable educational language. When creating or reviewing partners' courses for micro-credentials, we used these principles and maturity levels to classify and short-circuit both curricula learning outcomes (LO) and our self-assessment methodology (see D5.2). This encourages a focus on competence demonstration (what the learner is currently able to do, and what the learner will be able to do after the successful completion of the learning, ensured by accredited assessment principles at national level) at the appropriate level of complexity. This aligns well with competency-based education principles anchored in both secondary and tertiary education.

We also glean that our CBE LCAMP micro- and nano-credentials should not be seen as just "online courses" or "modules" in isolation. Instead, they can encapsulate outcomes from on-the-job learning and mentoring as well, as exemplified by DHBW's **modified dual competency model** of OECD that references explicitly the non-formal and informal aspects of *Situated Learning* scenarios provided during work-based trainings.

Finally, *Situated Learning* (Lave & Wenger, 1991) provides a perspective that learning is most powerful when it is embedded in the authentic context of practice. They introduced the idea of "legitimate peripheral participation" – newcomers become part of a community of practice and gradually move from peripheral simple tasks to full participation as they gain skills in the real world of work. In situated learning, knowledge is not abstract and decontextualised; rather, it is inherently tied (as exemplified above) to the activity, culture, and context in which it is used developed and credentialed within the credentialed work-based training approach of H-VET-Institutions. This has huge implications for how we urge to implement micro-credentials in H-VET. It suggests that the learning experiences leading to a credential should simulate or actually take place in real work settings whenever possible.

For instance, learning CNC machine operation in a classroom versus on a shop floor are very different – the situated learning approach privileges the latter. In LCAMP, the concept of Collaborative Learning Factories (CLF, co-led by DHBW, which simulate I4.0 factory-like educational environments) is a key innovation, empowered by the learner-centric training concepts in WP5. These provide realistic settings for students to engage in production-oriented and task-based credentialed microlearnings (T6.3, GA, p. 71), in line with our dual credentialing approach for H-VET. We incorporate these in our innovative LCAMP learning framework: many courses in the database therefore will be tied to learning factory sessions or industry-based projects in collaboration with WP4&7. These situated learning involve besides new knowledge in STEM, mostly cooperative activities and authentic contexts, where students construct their knowledge through real-life tasks (Skills) and social interaction (behaviours, attitudes). We see this as crucial asset in our approach – students might work in intercultural teams (T6.3) to solve a problem on an actual machine, thereby learning not only the technical skill but also how it's applied in practice (and even developing soft skills like teamwork and intercultural communication with peers of partner institutions).

Following the "dual" VET approach within situated learning theories further, the community of practice is crucial. Learners aren't just ingesting content; they are becoming practitioners of a craft by engaging with experts (mentors and supervisors) and peers (Lave & Wenger, 1991) This perspective influenced how we plan the recognition of micro-credentials. A "***dual***" nano-credential could represent that the learner is no longer just an outsider to the field but has

achieved a certain legitimacy in the professional community (albeit at a smaller scale than a full apprenticeship or qualification). We encourage involving industry professionals in both delivering training and assessing LO, effectively bridging the gap between learning and practice of tomorrows WoW. One practical example: for a nano-credential in laser-cutting Quality Inspection, we foresee to engage an experienced welding inspector from DHBW dual industry partner, acting as mentor to the LCAMP LLL participants, also co-validating their final assessment. This mirrors the dual heart of our LCT community appreciating and accrediting the Companies perspective holistically within our situated learning approaches with the Industry in Germany.

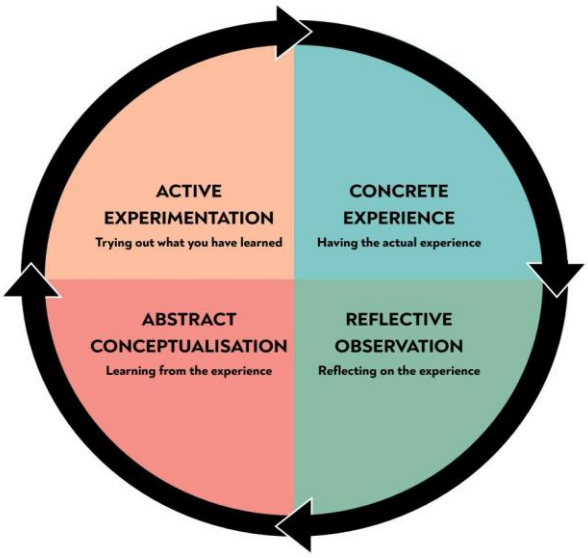



*Figure 3: The Experiential Learning Cycle and Basic Learning Style (Kolb, 1984, 2015), p.141, modified after SIMPLYPSYCHOLOGY*

Moreover, situated learning reminds us that all contexts matter. If a micro-credential is too generic and taught out of context, it might not *yield truly transferable dual H-VET future skills (Ehlers, 2021).* Therefore, whenever possible, we contextualised learning scenarios (e.g., troubleshooting this specific model of LCAMP robot in that specific workflow along the CLF). According to the core principles of VET, learners can then abstract to other contexts, but starting situated provides concrete experience (tying back to Kolb's cycle as well). It also fosters the formation of transnational peer networks – international learners who trained together form their own micro LCAMP community of practice" and can continue to exchange knowledge beyond the course.

In summary, these theoretical foundations emphasize and integrate experiential and social learning over just formal content; and ensures authenticity and contextual relevance, connecting learners to real practices and communities. Together, they underpin a learner-centric model – rather than being teacher or content-centric – which is key for LCAMP's philosophy. The newly created micro-credentials alongside the CLF within T6.3 are thus not just EDC mini-courses; they are carefully constructed learning and assessment experiences grounded in (each partners national education legislation) on how people actually learn and perform skills in the given real WoW experience (following modified OECD Comp. Model 2030, 2019). This theoretical grounding increases the likelihood that our micro-credentials have real value: that someone who earns one can indeed perform that skill in an industrial setting in that very regional specific working environment, and that they acquired it through a robust (national accredited) learning process.

This work-related educational aspect, for example is already an accredited learning outcome provided by dual H-VET institutions. For example, one can imagine, such "dual" nano-credential,

that is earned after a workplace assignment (with a mentor verifying the competency) – the formal training might just be a small part of it. Our H-VET Nano-credential database includes some credentials that are project-based, where the evidence of learning comes from a project done perhaps at the learner's workplace with periodic check-ins. This concept of learning distribution aligns with core principles of VET. But we use it conceptually to ensure we're not skewing too much towards passive and classroom-based learning to incorporate the new credential courses co-developed along the collaborative learning factory (CLF, WP6) which reinforces the design principle of learning-by-doing and learning-by-interacting, which is at the heart of higher vocational education.

To operationalise these theoretical foundations to create a machine-readable credential existing HVET curricula were analysed and broken down into specific learning outcomes (LOs) and competencies. Traditional courses and modules were deconstructed to identify the granular skills and knowledge units that are relevant for advanced manufacturing. Each LO was explicitly mapped to one or more ESCO skill descriptors, using a semi-automated (KIC-powered) tagging methodology. This tagging was facilitated by an AI-driven tool (developed with the Knowledge Innovation Centre, KIC) that automatically suggested relevant ESCO skills for each learning outcome, followed by expert validation. This step ensured a tight linkage between educational content and labor market terminology, bridging the gap between VET and industry needs.

**Nano-Credential Definition:**

Based on the granular mapping of European framework metadata, we **defined nano-credentials as the smallest certified units of the learning in our LCAMP ecosystem.** Each nano-credential is constituted by a clearly defined learning outcome, linked to at least 2 ESCO skills, aligned to the LCAMP competency framework top-level domains, ensuring sustainability and i4.0 relevance, maturity levels (L1-4) and EQF level, and connected to an identified skill gap from the WP3 Observatory analysis or cedefop skills intelligence (https://www.cedefop.europa.eu/en/tools/skills-intelligence).

***LCAMP nano-credential*** *= LCAMP Framework[1] + LO[2] + ESCO skill tagging[3] + maturity level[4] + EQF + skill gap[5] + assessment*

This refined definition emphasises that a nano-credential encapsulates not just an outcome, but also its relevance (skill gap), educational level, assessed within a national VET curriculum.

[1] LCAMP Framework = top domains for sustainability and resilience in advanced manufacturing
[2] LO = official Vocational Education and Training Learning Outcome
[3] ESCO skills = (a bundle of) ESCO data items
[4] Maturity level = LCAMP proficiency level (see Chapter 2.1.1)
[5] skill gap = skills gaps that have been identified via WP3 and CEDEFOP intelligence

# 3. R&D METHODOLOGY

This chapter describes the research and development (R&D) methodology followed to create the I4.0 courses and micro-credentials database. The process integrated a systemic analysis and refers to two parallel strategic tracks: an *educational design* track and a *technical implementation* track. The educational design track focused on identifying and curating content, defining learning outcomes, and developing the structure of nano-credentials (drawing on the theories and concepts from Chapter 2). The technical track dealt with building the database infrastructure, implementing the tagging system, and integrating our outputs into the LCAMP digital platform (with support from KIC's technical expertise). We also illustrate key workflows with diagrams to make the process clear. By dividing the methodology into these two facets, we ensure that both pedagogical integrity and technological robustness were achieved.

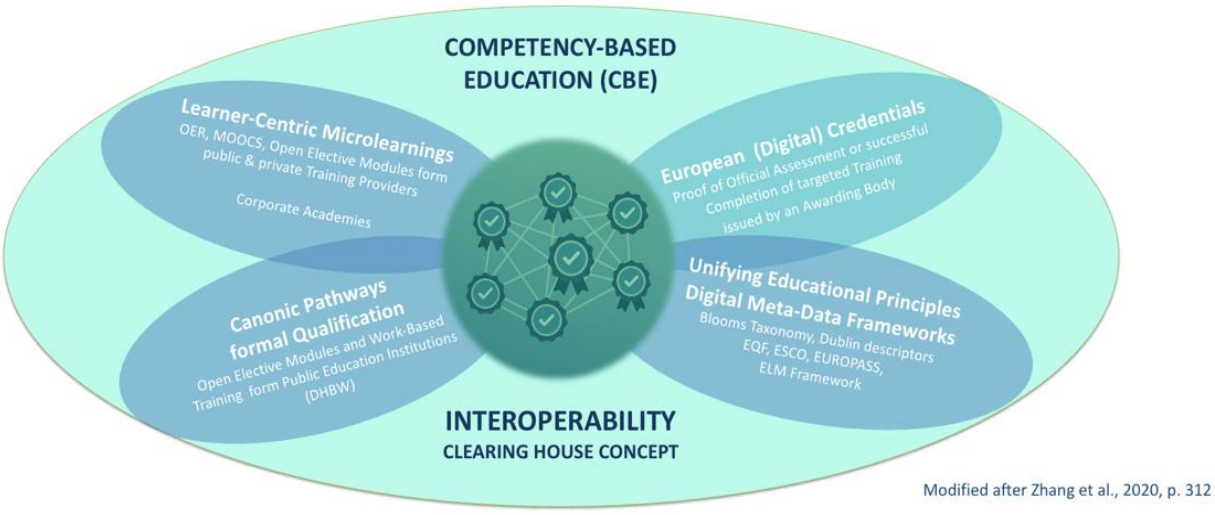



*Figure 4: Strategic Harmonization & Digitalization Frameworks for Nano-Credentialing in HVET*

## 3.1. EDUCATIONAL DESIGN

### 3.1.1. I4.0 COURSE IDENTIFICATION AND CURATION

The first step was to gather a wide range of existing Industry 4.0-related courses and training modules from the LCAMP partners. The consortium includes national VET authorities, universities of applied sciences, higher vocational colleges, and training centres specializing in advanced manufacturing across Europe, and also Canada and Türkiye. Each partner was asked to contribute information on courses they or their associated industry clusters offer (or plan to offer) that relate to Industry 4.0 future skills – for example, courses on robotics, industrial IoT, additive manufacturing, digital factory simulation, cybersecurity in manufacturing, etc. We also looked at online courses and modules (e.g., MOOCs or proprietary training programs) that could be relevant, and which were scraped (with the support of KIC), curated and stored separately

within the LCAMP Course catalogue. This resulted in a raw pool of data comprised of thousands of I4.0 specific (non-credentialled) digital micro learnings from platforms across the globe (KPI > 5000). The LCAMP-Platform-Users can navigate the search interface here to find suitable learning offers, mostly provided in English. WP5 then started curating this pool of course data, and additionally leveraged partners newly developed I4.0 relevant courses, developed in line with the strategic objectives of the LCAMP Competence Framework's strategic Top-Level Domains (for ex.: AI, Sustainability, Resilience, covered by the MC Course "Future Management & Technology (EQF6) Forecasting" officially accredited and issued to enrolled learners by DHBW Heidenheim, 2024) complemented by more specialization courses and learning offers in the field of I4.0, researched and identified in D5.1. Regarding the further development of new micro-credentials provided by nationally accredited courses, the focus was to be modular and competency-focused enough to be considered for unbundling and harmonization strategy in the context of heterogeneous educational H-VET systems. For instance, a full degree program (traditional qualification offer) in Mechatronics would be equally eligible as a specific 2-week module on "Introduction to PLC Programming" to be a good nano-credentialing candidate.

Ultimately, WP5 team curated and created datasets **of around 230 micro-credentials courses/modules** which formed the basis of over 230 nano-credentials (in many cases, one course/module corresponds to a set of nano-credentials, though sometimes a course was split into two credentials, etc.). Each entry in the database includes metadata such as course title, provider, duration, mode (online/blended/in-person), and crucially, the learning outcomes/competencies targeted.

### 3.1.2. DEFINING LEARNING OUTCOMES AND COMPETENCIES

For each course, we reviewed its syllabus or description to extract or formulate clear learning outcomes (LOs). In some cases, the courses already had listed streamlined LOs; in others (for ex. MADE as non-institutional training provider), we interviewed instructors or used course materials to derive them. Consistent with competency-based education, we phrased learning outcomes in terms of what the learner will be able to do before and after completing the credentialed course or learning unit. For example: "The learner can configure and operate a collaborative robot for a pick-and-place task safely." We then matched these outcomes against the ESCO skills framework's entries. This step was essential to tag each course with standardized machine-readable Skills Data. Using ESCO's online portal and documentation, we searched for relevant skill entries utilizing web service provided by KIC, leveraging an integrated SkillFinder tool for enhanced mapping. In some cases, multiple ESCO skills matched one outcome; we included all items that applied according to our transnational team of educational experts and levelled them according to Bloom's taxonomy and the ***LCAMP Maturity Matrix (see p.).*** If an exact match wasn't found, we chose the closest broader skill. Additionally, we tagged the EQF level (European Qualification Framework level, if applicable or known) of the course to gauge its complexity according to Bloom (1956). Many courses from VET would be around EQF 4-5, and from applied universities EQF 6-7, etc., which helps in the classification and open alignment challenge.

### 3.1.3. NANO-CREDENTIAL STRUCTURING WITHIN A CLEARING HOUSE (POC)

With learning outcomes and competences in hand, we proceeded to structure what a "nano-credential" would look like for each. We adopted the EU's meta-data standard elements for micro-credential description (Camilleri, 2022, ETF) our clearing house template. Each nano-credential entry in the database includes at least all mandatory fields such as:

- **Title** – a concise name of the micro-credential (often matching the course/module name, e.g. "Industrial Robotics Safety Credential").
- **Description** – a short description of what competency & set of future skills the credential certifies.
- **Learning Outcomes** – the list of specific outcomes the learner has achieved (as discussed, phrased as action statements in the native language for ease of the VET learner
- **Workload** – the approximate effort required (in hours or using ECTS credits if applicable). For instance, "40 hours (equivalent to 1.5 ECTS)" might be noted.
- **Level** – the level of difficulty/complexity, which we indicated through our L1–L4 maturity level and/or an EQF level if appropriate.
- **Assessment Type** – a brief note on how the competency is assessed (e.g., "Practical lab assignment + oral test" or "Online quiz and project submission").
- **Provider** – which institution or organization awards the credential.
- **Quality Assurance** – any QA mechanisms (for example, if it's part of an accredited program, or if an exam is proctored, etc.). This is in line with requiring transparency about how the credential is trustworthy.
- **Validity/Expiry** (if applicable) – for some industry certificates, a skill must be renewed (for example, a credential in a software might only be relevant for a certain version).
- **Mode of learning** – online, face-to-face, blended, etc., just for information.
- **Skills Gap Reference** according to cedefop Skills Intelligence and LCAMP Observatory reports,
- **LCAMP Maturity Matrix** for levelling Maturity of each LO
- **LCAMP Competence I4.0 & Sustainability Framework metadata**
- **ESCO** Skills data Bundles
- **EQF** Framework metadata
- **Bloom's Taxonomy** & adapted learner-centred LO-descriptors
- **National Curriculum Data** & Curation of Content Description




*Figure 5: Left: Clearning House Template/Prototype; right: Final Course Catalogue entry*

By populating these fields, we essentially created a nano-credential clearing house standard in line with our educational PoC for any (future) training opportunity provided by (future) member of the LCAMP CoVE Alliance. Notably, this structure aligns to the European Metadata standard for micro-credentials (as per the Council Recommendation (2022), which we followed diligently). Our goal was that any entry in this database could be easily converted to, say, a Europass Digital Credential Infrastructure (EDCI) or an open badge if needed, since we have all the mandatory key metadata tagged within our harmonization approach.

One challenge was ensuring consistency across different contributions. Different partners had different, sometimes inconsistent ways of describing and tagging their courses learning outcomes. Sometimes the Webservice didn't register the tagged framework data, leading to drawbacks and iterations of the same tagging process. To address this challenge, we integrated an instruction guide, within DHBW Clearing House template (Annex 1) for streamlined presentation and accurate tagging of learning outcomes (using Bloom's taxonomy action verbs, one action per outcome, etc.) and for how to accurately choose ESCO skills and tag CEDEFOP and/or WP3 Skills Gap Intelligence to the newly created nano-credentials. Since this tasks comprising a holistic curriculum redesign initiative for CBE, constitutes an exhaustive endeavour far exceeding our project's scope and funding, so that we, in LCAMP WP5 are motivated and committed to enlarge our national curriculum rewriting approach with the support of more advanced and automated, LLM powered ICT tools to fully roll out learner-centric competency descriptor within an ELM driven European learning ecosystem in the near future.

Moreover, we held several calibration workshops, where WP5 team members reviewed samples of credential entries coached by DHBWs WP5 team members on best practices. This improved inter-rater reliability in tagging but ultimately wasn't enough to fully meet the desired high

standards of WP5 lead that urges for further refinements and funded maintenance strategy for the future of LCAMP credentialing approach. The tagging approach was supported by an instructive coaching video, compiled and provided by the platform's developers at KIC that supported WP5 partners to meticulously map their institutional framework data with the broader European framework meta-data. Additionally, the WP5 Lead (DHBW) classified the nano-credentials into thematic clusters to prepare for flexible learning pathways, D5.4 deliverables. For example, we grouped existing credentials related to Course of Study „Computer Science", offered at DHBW Heidenheim. Elective Credentialing Modules were piloted for preparing agile Learning Pathways to be rolled out across the LCAMP consortium (due M48).

The nano- and micro-credentials in our D5.3 database, exemplified in the table below, serve as the building blocks of the CBE-HVET credentialing ecosystem. Each represents a certified sub-modular micro-learning, focusing on one assessed I4.0 future skill or a cluster of related competencies (Future Skills Bundles). They are designed to be modular and stackable – multiple nano-credentials can be combined to form larger credential containers or even academic qualifications (Rupp, 2025), reflecting the principle that micro-credentials may be stacked individually to create larger (learner centric) credentials. For example, a set of nano-credentials in digital manufacturing: The figure shows how smaller (nano) credentials at DHBW are stackable within larger educational container modules. The consistent CBE regrouping of the nano- and micro-credentials is consequently a learner-centric micro-degree. Ideally this recombination of assessed LOs leads towards a formal HVET diploma within an accreted upskilling pathway.

**Elective Modules (60 ECTS) Micro-Credential-Modules (60 ECTS) DHBW Heidenheim**

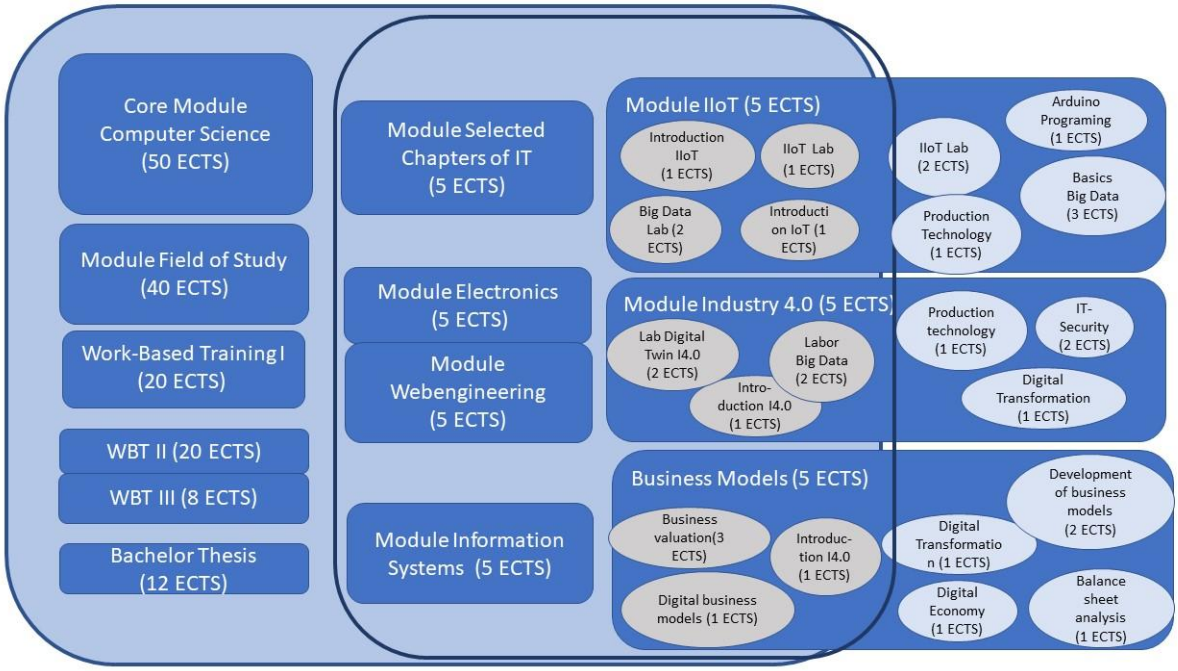



*Figure 6: Course of Study Computer Science at DHBW and established Container Modules for Micro-Credentialing and Nano-Credential perspective (PoC), with consistent CBE-EDC granularity parametric*

**Validation of Content:**

As a final step within this extensive educational curriculum re-design approach, we performed iterative cycles for validation of each nano-credential entry with LCAMP partners. This involved a small peer-review process where WP5 Lead (DHBW) acted as a coaching leader, providing extensive mentoring and bilateral peer-review meetings with each partner (sometimes not the original author of the entry) who would review the learning outcomes and tags for accuracy and completeness. In some cases, we also consulted industry partners (ensured by DHBW's internal processes for Cooperative Curriculum Design in partnership with the local industry) to verify that the stated outcomes align with real job needs. For example, a German company expert might confirm that the outcomes listed within the accredited Curriculum for a Course of Study "Computer Science" (B.A. Ing., EQF6) credential course indeed formally cover what the associated Industry H-VET-Partner would expect from someone competent in that area, holding an engineering degree on EQF6. This validation step is a form of (hidden) quality assurance performed within each of LCAMP's H-VET institutions, ensuring tamper-proof quality of our credential database's credibility. Similar validation and national recognition procedures, as exemplified by DHBW, have been performed by partners via local curriculum design principles. (Indicator 32 (I32), p.67, LCAMP grant agreement)

### 3.1.4. TECHNICAL/DIGITAL IMPLEMENTATION: TAGGING WORKFLOW AND PLATFORM INTEGRATION

In parallel with content development, KIC (WP8) built the technical infrastructure to host and manage the database of courses and micro-credentials. A user-friendly, searchable database is crucial for the LCAMP platform to effectively serve as a "catalogue" and "clearing house" of training opportunities at lcamp.eu. The technical implementation had a few main components: designing the data schema, implementing the tagging and search functionalities, and integrating the database into the broader LCAMP platform (and potentially linking with external systems).

**Data Schema and Tooling:**

We defined a data schema (essentially a database model) for courses and their nano-credentials, corresponding to the fields described above. Because of the need to align with Europass and other standards, we chose to use a structure that could be mapped to JSON-LD (Linked Data) for credentials, similar to the emerging *European Digital Credentials* standard format and in accordance with the EDC MC Guidelines (Camilleri, 2022). Each record has identifiable fields for title, description, etc., and some fields (like ESCO skills or occupations) are stored as references (URI or codes) to the official ESCO dataset. We leveraged the public ESCO API to retrieve standardized labels and codes for the skills we tagged. For the platform, a web-based application was set up, as part of the LCAMP website portal, on which the Knowledge Innovation Centre (KIC) provided support.

**Tagging Workflow:**

The tagging workflow refers to the process of annotating each course/credential with the relevant metadata (especially ESCO skills, but also other tags like thematic category). We systematised this process to ensure it was efficient and consistent. The data entry process works like this:

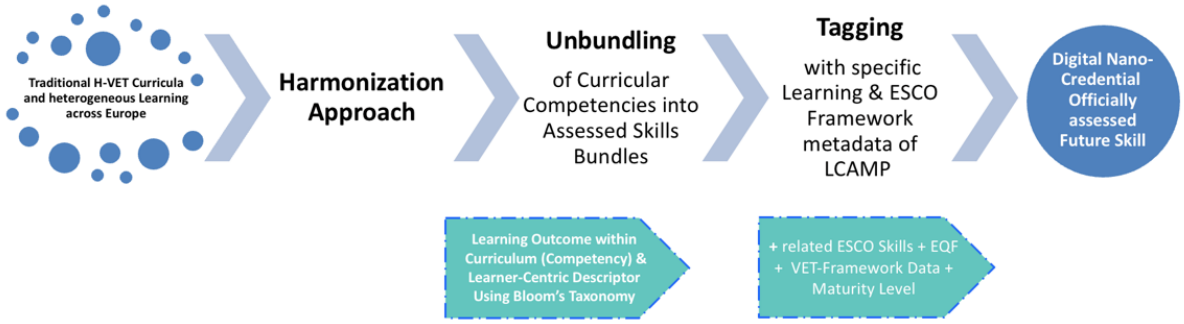



*Figure 7: Granularization & Harmonization Workflow in LCT (WP5)*

*Tagging Workflow (Figure 7) – from course identification to publishing the nano-credential in the LCAMP platform. The process ensures each course is defined, outcomes tagged with ESCO competencies, packaged with metadata, and then made available on the platform. A course is entered into the system by a content editor → the system suggests possible ESCO skills based on keywords in the description (we had a semi-automated suggestion mechanism using the ESCO API and keyword matching) → the editor selects/adjusts the suggested tags → the entry is saved and becomes searchable.*

As shown in the **diagram above**, the workflow consists of sequential steps:

1. **Course/Training Content Identified & Analyzed** – We gather information on a training module.
2. **Define Learning Outcomes** – Clear competencies are articulated for that module.
3. **Tag Outcomes with ESCO Skills** – Each learning outcome or the course as a whole is linked to entries in the ESCO database (skills/competence concepts).
4. **Package for tagging as Nano-Credential (+ metadata)** – All the information (including tags, provider info, etc.) is compiled into the standardized credential format.
5. **Publish to LCAMP Platform** – The credential is uploaded to the platform database, making it accessible to users via the KIC webservice. Partners were motivated to work in the platform backend.

This process was managed using a custom WP5 user interface provided by KIC (WP8) that allowed institutional editors to input and edit entries. Because the database could eventually contain hundreds of entries, filtering and batch editing tools (for example, to assign all credentials from a certain provider under a certain category, etc.) are necessary within the

platform and have been implemented by KIC to create the webservice for data gathering and streamlining.

**Integration with LCAMP Platform and KIC Tools:**

The LCAMP platform (in development) is envisioned as a one-stop digital environment offering various services (observatory, learning factory resources, etc.). The micro-credentials database is one module of that platform. KIC's integration role possibly included ensuring that the credentials database can interface with other systems. For example, if LCAMP platform users have profiles, we might integrate so that when a user completes a course, a credential entry is linked to their profile. Or integration with the Europass standard – KIC might implement an Open Badges issuance system so that when a course is marked as completed, a digital badge (with the metadata) is issued to the learner.

We made sure to incorporate outcomes from the MicroCredX and QualityLink projects, such as ensuring interoperability and adopting best practices in credential design (many of which we've covered: standard metadata, clear outcomes, QA, etc. and our learning in the field of ad-hoc recognition agreements, we already provided as blueprint to the LCAMP Coordinator.

On a practical level, we deployed the database on a KIC server where it can be accessed via the LCAMP website (https://www.lcamp.eu). We also prepared the data to be exportable (for instance, as a CSV or JSON) to share with other EU platforms or for research purposes. The front-end interface allows users to search by keyword, filter by topic, filter by training provider, etc. For example, an engineer looking to upskill in "cybersecurity" could search and find all nano-credentials related to cybersecurity in manufacturing provided by the Basque VET School Miguel Altuna, and see which other institutions offer similar or skill-related credentials, whether they are online, and what exact ESCO-based future skills they cover. This is aligned to facilitate a catalogue of these training courses through the LCAMP platform.

Quality Control and Updates:

Technically, we implemented version control for entries. The field of I4.0 evolves quickly, so the database is designed to be dynamic. If a course changes or a new technology emerges, we can update or add entries via the WP5 Backend. Each credential entry has a creation date and a last-updated date. We also plan to include a mechanism for user feedback – for instance, on ESCO Data or if an employer or learner notices something outdated or wishes to comment on the utility of a credential, that feedback can be recorded, and editors can act on it, for now still manually.

Translations:

One technical consideration was how to cope with multilingualism, anchored as indicator in the LCAMP grant agreement. Since LCAMP is a European project with partners and future platform-users in many countries, we translated key parts of entries (at least the title and the course description is available both in its original language and in English). English is the primary one in the database. ESCO skills are already available in many EU languages, so using ESCO codes allows automatic display in a user's language. For now, the working language of the database is English (for consistency and because it's the common project language), but the platform design allows future output in any language.

Ensuring Interoperability:

We aimed for compliance with emerging standards, like the Europass Learning Model, for describing credentials to be machine-readable. This means our technical schema could be mapped to any XML/JSON format (e.g. Europass) in the future. For integration with the European Digital Credentials Infrastructure (EDCI) – which includes a system for issuing verifiable credentials – we considered how our nano-credentials could best be issued as verifiable credentials not only on a national level, where they already are accredited by national education legislation (S3). KIC's team, being experienced in digital credentialing (Camilleri et al., 2019) likely advised on further metadata such as using unique identifiers (e.g., URI for each credential) and ensuring data.

In summary, the methodology combined educational expertise with technical rigor. We created a scalable workflow for tagging and entering credentials, and WP8 lead KIC built the digital infrastructure to host them. The outcome is a functional database integrated into the LCAMP platform, following best practices of open EDCI interoperability. The figure above captures the linear workflow, but in practice, some steps were iterative (e.g., sometimes after publishing, we got feedback and went back to adjust the learning outcomes or tags). This iterative development was part of our agile approach, and it allowed the database to improve in quality over time. With this methodology, by the end of the project, we have a solid backbone to continue growing and maintaining the I4.0 course and micro-credential repository.

# 4. RESULTS & KPI

In this chapter, we present the results of our work – essentially, the contents and metrics of the developed database of I4.0 courses and nano-credentials. We provide an overview of the scale and composition of the database, including the number of courses collected, the number of nano-credentials defined, the distribution across topics and partners, and other relevant statistics (KPIs) are, for the ease of the reader, provided on the platform. We highlight examples of entries to illustrate the richness of the data gathered. Furthermore, we discuss how the results align with project objectives, specifically noting achievements like validation of credentials, alignment with ESCO and EU standards, and the establishment of metadata conventions.

## 4.1. SCALE OF THE DATABASE

As of the completion of D5.3 (October 15th, 2024), the database includes **230+ nano-credentials** (meeting both I35, target 30 & I34, target 60) derived from partners' newly developed training courses relevant to Industry 4.0. These credentials were collected from **7** contributing LCAMP partner institutions (out of 21 partners, with some being non-educational partners who did not contribute courses but assisted in validation). The total number of underlying courses/modules catalogued in LCAMP is on the order of >5000 MOOCS (meeting I33 & I32) whereas >230 nano-credentials were newly created by splitting or augmenting accredited I4.0 H-VET credential-courses (unbundled, harmonized and aggregated framework-metadata), which is why the count of credentials exceeds by far the count of original courses (58) – in a few cases, we created multiple nano-credentials from one course, addressing different competencies. This surpasses our initial target (which was around 100 micro-credentials, I32), reflecting both the high interest and the extensive offerings of the consortium.

| Partner (Country) | Credential Courses Contributed | Nano-Credentials |
|---|---|---|
| **TKNIKA / Miguel Altuna (BC/Spain)** | 12 | 48 |
| **DHBW (Duale Hochschule Baden-Württemberg, Germany)** | 16 | 70 |
| **MADE Competence Center I4.0 (Italy)** | 8 | 17 |
| **Maribor VET /Skupnost VSS (Slovenia)** | 3 | 6 |
| **Mécanic Vallée / CMQEf (France)** | 4 | 11 |
| **Curt Nicolin Gymnasiet (Sweden)** | 6 | 42 |
| **GEBKIM VET / OIZ / KPDoNE** | 9 | 39 |

| | | |
|---|---|---|
| **(Türkiye)** | | |
| **TOTAL** | **58** | **230+** |

*Table 1: Contributions by partner (indicative figures). Breakdown by thematic area (category) and number of nano-credentials available per LCAMP partner.*

Most partners were able to provide content. Some partners with larger training catalogues (like TKNIKA, DHBW) have significant contributions, while smaller institutions couldn't provide as many credentialing courses. The numbers also show that, in general, the number of nano-credentials is larger than the number of courses (as expected by our theoretical approach outlined above). Moreover, the number of nano-credentials provided also depended on the partners' original curriculum design and whether this allowed for a more or less granular matching between curricular competencies and standardized, machine-readable Learning Outcomes (LOs) with corresponding metadata, defining the final credential count on the platform. WP5 & WP8 are motivated to optimize the digitalization workflow via refined ICT systems for the upcoming deliverable.

*Validation and Quality Alignment:*

Among the results, an important aspect is that *all 230+ nano-credentials have undergone a national validation process.* International validation processes will be established via the LCAMP recognition agreement as detailed in next chapter (5. Discussion). This means each credential's content was either validated internally by a second educator or externally through an expert. By doing so, we ensured that the learning outcomes are goal orientated, and the assessment methods actually confirm the LO's competencies on the national level, guaranteed by the local issuing body (LCAMP H-VET institution or national governmental body). We can report that 100% of credentials were mapped to at least two ESCO skills (most have between 3 and 8 ESCO tags), achieving alignment with European competence taxonomy – a key quality indicator since it means the credentials use the same language of employability skills. Additionally, the credentials include at least the standard "mandatory" metadata fields recommended by the EU MC Guidelines (Camillieri, 2022, p.17). Currently, some pilot entries may still exist that have one or two non-mandatory fields missing because of simultaneous development or mapping mistakes, which will be completed as data is refined within the new system (M48, D5.4).

We also achieved a **learner-centric, neutral, and inclusive phrasing** of learning outcomes, an aspect further considered during review. And in terms of **transparency**, 90% of credential entries include a note on the assessment method, if available, and quality assurance approach (for example, stating if the exam is supervised, if a national body, etc. accredit the course), which is in line with European principles for micro-credentials to ensure trustworthiness (see also hrk-modus.de.)

*KPIs against Project Objectives*

One objective was to “provide a sector-specific dataset of trainings, courses and micro-credentials for different career pathways” (GA, p.67). The result of 230+ credentials covering at least 8 major thematic areas of advanced manufacturing fulfils this objective; we have indeed created a rich sector-specific dataset. (I32-I35) Another objective was to “establish [a] clearing house for micro-credentials and trainings based on Micro-Credential EU Standards”(GA, MS12, p.67) - our alignment with the EU standards (common definition and elements) and the deployment of the online catalogue meet this KPI. The database essentially functions as a clearing house, as it aggregates offerings from various providers in one place with common descriptors.

One Indicator is still open (I36) and will be tackled using a refined KIC system in line with the Skills Profiler tool and Job Call Builder (D5.4). It is not possible to fulfil the target before that step of the development, which will be done by M48. When this is realized, WP5 will be able to look at **engagement metrics**. During development, we exposed a beta version of the database to targeted users (like some students and industry representatives). The feedback was positive, with users finding the search functionality useful but wished for skill-based searching, in particular. As the platform gets officially launched and disseminated, we expect usability to grow significantly.

We also consider how many of these credentials might be adopted or recognized by other institutions (a forward-looking KPI, ensured by the upcoming LCAMP recognition agreement). Already, a few credentials developed by one partner are being considered for use by another partner institution (The full potential will unfold within T6.3 (Lead DHBW) when tailored LCAMP microlearning is didactically and systemically co-created alongside the advanced digitally interconnected CLFs located at some LCAMP partner institutions). This indicates a good level of transferability and offers great potential for impact beyond the consortium, reinforcing trust and LCAMP credentials transferability when adhering to the EDC standard description and framework alignment.

In terms of **metadata standards**, one result is that, in the future, our database can be exported in a **Europass-compliant format** (we created a script to output all credentials as ELM JSON and as JSON). This technical result is significant as it means the dataset could be ingested by other platforms like CEDEFOP’s repositories or integrated into credential transparency databases.

To ensure sustainability, we have set up an update mechanism: the working group will maintain the database for the project duration, after which the LCAMP Alliance (once formalized) is expected to take ownership. This is noted as a deliverable outcome in WP10: a maintained database that will live on as part of the LCAMP platform services. It will continue to grow as new courses are developed. By the end of the project, we anticipate adding credentials for emerging topics (e.g. AI ethics in manufacturing, hydrogen and battery assembling technologies), reflecting the evolving landscape of Industry 4.0 & 5.0 trends and new economical and geopolitical challenges arising in Europe and beyond.

In summary, the results demonstrate a successful creation of the I4.0 course and micro-credential database, with quantity and quality exceeding expectations. We have a wide

coverage of relevant skill areas, standardized descriptions that ensure clarity and recognition, and an operational platform to disseminate this information to our target audience. These results set the stage for the next chapter, discussing the implication of these results – the challenges we encountered, how micro-credentials might be used by stakeholders, and what remains to be addressed moving forward.

# 5. DISCUSSION

While the development of the micro-credentials database has been successful, it has also brought to light various challenges, considerations, and broader implications. In this chapter, we reflect on the **pitfalls and barriers** encountered (and how we addressed them), situate our experience in the context of wider findings such as the HRK-Modus project's insights on micro-credentials, and discuss the perspectives of different stakeholders. We also highlight the **strategic advantages** that micro-credentials can offer to institutions, learners, and employers – and whether stakeholders are ready to embrace them. This discussion is crucial for formulating recommendations and next steps.

### *Challenges and Pitfalls in Implementing Micro-Credentials*

**Fragmentation vs Integration:** A commonly cited concern (also noted in HRK's analysis) is that introducing micro-credentials could lead to a fragmentation of learning and a *weakening of traditional qualifications* (hrk-modus.de). We indeed grappled with this: On one hand, modular nano-credentials allow flexibility; on the other hand, universities or VET schools worry that these will replace parts of degrees or that having many small certificates devalues larger cohesive education. In our project, we addressed these issues by positioning both nano- and micro-credentials as complementary to, not in competition with, traditional programs. Many of our credentials can be used for **recognition of prior learning (RPL)** or as add-ons for degree students (e.g. an engineering student can earn an extra certificate in *AI in Manufacturing* alongside their degree). However, we did encounter institutional resistance – for example, some faculty were hesitant to formally issue a micro-credential for a subset of a course's outcomes, as they felt it might confuse the qualification framework. This reflects a broader pitfall: lack of a common understanding and buy-in internally (hrk-modus.de). To mitigate this, we held internal workshops at institutions explaining how micro-credentials align with their mission (lifelong learning, outreach to industry learners, etc.). Slowly, perception shifted from seeing micro-credentials as a threat to seeing them as an innovation and opportunity, though this change has to take effect at the policy level, still. We believe there is much power in bottom-up projects like LCAMP to nudge policymakers into seeing the benefits of micro-credentialling.

*Quality Assurance Concerns*

Another challenge is ensuring all micro-credentials meet rigorous quality criteria (see QualityLink project). Unlike full programs which undergo accreditation, micro-credentials may fall through cracks of oversight. HRK (2023) notes the need for agreed standards and QA when recognizing micro-credentials (hrk-modus.de). In our project, we instituted a peer-review for content, but questions remain about external validation. We leveraged existing QA, but for brand-new micro-credentials, we essentially rely on expert peer review rather than formal accreditation. Going forward, one pitfall is that without recognized accreditation processes, micro-credentials might have variable trust. One idea discussed is using frameworks like the **European Approach for Quality Assurance of Micro-Credentials** being developed by organizations like EQAR. Also, the **issuer's reputation** is key – a credential from a known institution carries weight; from an unknown provider, less so – though this is a systemic issue not new to this discourse. Thus, consortium-based credentials, like ours, benefit from the each partner's reputation.

*Recognition and Credit Transfer:*

The issue of recognition by other institutions (for credit or hiring) is perhaps the hardest to solve. As Camilleri (2022, p.36) points out, much recognition of micro-credentials is currently handled *ad-hoc*, bilateral agreements, or individual assessments. This procedure is labour-intensive and not scalable. For example, if a learner is interested in a nano-credential offer from our database and wants it accredited at a university elsewhere, it might require a manual review of content and a case-by-case decision. Without a recognition agreement, this is the process through which the LCAMP partners will exchange their credit. The **HRK-Modus project** emphasized clarifying whether micro-credentials are accepted for credit and under what conditions (Dörr & Ernst et al. 2023). In practice, within our consortium, we will experiment with mutual recognition: two institutions agreeing to recognize each other's micro-credentials across elective module (see Figure 6). This will eventually be done through a Memorandum of Understanding – essentially an ad-hoc agreement. This aligns with what Camilleri et al. describe: using inter-institutional learning agreements for bespoke recognition (p.40-46). While it could work for us, scaling it to many institutions is cumbersome – a challenge moving forward is establishing broader "recognition networks" or integration into frameworks like ECTS, which will be another challenge for VET schools.

Another pitfall is if micro-credentials are not properly recognized, learners might not see value in them. We need to avoid the scenario where a learner has a stack of 10 micro-credentials that no one (university or employer) knows how to interpret. This is why the European effort to define standard elements and issue credentials in digital form is important – to enable automatic paradigmatic recognition, eventually. One promising development is the idea of an *EU Micro-Credentials Passport* or the Europass digital wallet where individuals can own and collect credentials. For that to become common practice, recognition has to improve. For now, our way of mitigation is (1.) extensive and thorough documentation far beyond mandatory info, so receiving institutions have enough info to assess equivalence, and (2.) advocacy, by sharing the LCAMP framework with other CoVEs and universities to encourage them to accept these credentials.

*Institutional Barriers*

Internally, beyond academic concerns, some practical barriers include but are not limited to platform adoption (some teachers find it extra work to input data for micro-credentials) and administrative processes (issuing a certificate or badge outside the usual student information system can be bureaucratic). We found that integrating micro-credentials into existing systems (like getting them listed in course catalogues, or having the registrar issue a certificate) can be challenging. Our partners often resorted to manual issuance (like printing a certificate or using a badge platform). This is an area needing streamlining. The **HRK** MODUS project in Germany is exploring how to update recognition procedures and information systems to handle micro-credentials, which will be valuable.

Another barrier is a cultural one: persuading learners of the value. Interestingly, younger professionals and students were quite enthusiastic (they like the idea of accumulating specific skills and the immediacy of proof), but some older professionals or academic purists were sceptical, viewing micro-credentials as possibly "shallow". Overcoming that required only a well explained model of micro-credentialling or showcasing success stories (e.g., a technician got a job interview partly because of a micro-credential on their CV), showing these issues are not deeply rooted and most of them can be overcome by proper discussion.

**Resource and Financial Considerations**

Developing and maintaining micro-credentials isn't without cost. We were fortunate to have EU funding, but institutions might think about the return on investment or how to sustain the effort, if micro-credentials are offered for free or as open educational resources. Some institutions consider charging for the credential assessment or for badge issuance as a revenue model for continuing education. None of our current LCAMP credentials (PoC) are provided to the learner for a fee, yet (most are either embedded in existing programs or offered as free pilot courses), but LCAMP will have to cover the cost of learning offers/assessment. Therefore, a business model for WP10 in LCAMP will need to set the cornerstones regarding a future rollout of the nano-credentialing PoC. On the other hand, a pitfall could occur if micro-credentials become too commercialized, leading to inequality (only those who pay get certified). This touches on the inclusion point discussed by OECD – micro-credentials should not exacerbate inequalities by being accessible mainly to those already educated or with resources (OECD, 2021). LCAMP will try to ensure offerings that are accessible, but the issue of financing and business model is still open.

## INSTITUTIONAL INSIGHTS — HRK-MODUS FINDINGS AND DHBW EXPERIENCE

The **HRK-Modus Expert Group Initiative** (by the German Rectors' Conference) has been examining recognition across educational boundaries, including micro-credentials. They published in 2023 a paper highlighting strategic questions around micro-credentials in HEIs (hrk-modus.de). A few relevant findings we relate to:

HRK stresses the importance of a *common definition* and understanding of micro-credentials in the institution's strategy (hrk-modus.de). We found that once our institutions incorporated micro-

credentials into their strategic plans (some doing it as part of their life-long learning strategy (e.g. DHBW Centre of Advanced Studies), implementation gets easier. For instance, DHBW formally included micro-credentials in its 2024 strategic goals for outreach, giving our work institutional backing. The HRK sees a distinction between micro-credentials used in *degree* context vs those as part of *non-formal continuing education*, and to them the recognition processes differ. Our experience confirms this view is indeed one of our major challenges in LCAMP, because we need to respect and implement both contexts.

When micro-credentials are part of a preexisting, traditional degree program (assessment of a course that is already 5 ECTS in a degree at DHBW), it is a straightforward, academic credentialing approach that adds little value compared to the traditional approach – it would add the linkage to ESCO, but has no immediate value to the learner. The crucial added value lies in LCAMP's consequent framework alignment as described above to enable cross-border mobility / competence transferability. For this, working with the same data model and quality criteria is essential.

Another interesting case is non-formal, informal and work-based credentialing, considered by the HRK to allow certification for continual vocational training (like a worker taking a stand-alone nano-credential) – this applies to the LCAMP's context for life-long learning in HVET. Recognizing these kinds of credentials towards a degree (RPL) is trickier. HRK suggests here that recognition of prior learning (RPL) needs to adapt to micro-credentials, but sees administrative burden, as does the OECD (2023) & ETF (2022). Indeed, a test case of RPL in LCAMP would take significant effort. One solution is to pre-map certain micro-credentials to existing formal modules via equivalency tables, rather than case-by-case. Which we, LCT lead, expect to do this within D5.4 by the end of the EC funding.

The HRK research also outlines possible **stackability options** that could apply for LCAMP in order to stack micro-credentials into larger credentials. They mention that micro-credentials should ideally fit into existing frameworks: In LCAMP, we implicitly created "clusters" that prepare for stacking and recognition. For example, we have 3 credentials in *Industrial Data Analytics* that together cover material equivalent to a full course. We propose that if a learner completes all 3, they could be awarded the same credential as the traditional or perhaps skip the equivalent unit in that learner's diploma. However, formalizing stackability would require at least policy decisions (i.e. a university senate approving that ***micro-credential A (e.g. DHBW) = MC B (TkniKa) = MC C (MADE) (approx. equivalent)*** and can be stacked like courses at their own institution can). We have not reached this policy implementation yet, but we have suggested and documented combinations in our work preparing for D5.4 integrated learning pathways.

Notably, micro-credentials are often *smaller than typical university modules*, which can hinder recognition since universities usually recognize larger learning chunks of e.g. 5 ECTS for a DHBW course. Many of our LCAMP nano-credentials correspond to 1-2 ECTS or even less workload. A university or H-VET Institution nowadays might find it impractical to grant credit for each learning outcome; they might require a student to accumulate a few and then do RPL for a 5 ECTS elective. Thus, one pitfall is the mismatch in granularity between micro-credentials and existing credit systems. Introducing a concept of "nano-credit" or partial credit could be

explored, but this requires a significant shift in H-Ed / academia. This shift was identified and the conceptual endeavour tackled by Stenzel & Korsch (2025) with the support of the LCAMP Consortium to provide a feasible nano-credentialing methodology for H-VET (PoC) on how to address the open question by leveraging EDC frameworks via an CBE harmonization and digitalization PoC.

*Lessons on Institutional Change*

Through our work, we learned that institutional adoption of micro-credentials is a multidimensional change process – involving pedagogical practice, IT systems, quality assurance, and mindset. The **maturity model for micro-credentialing** (Ifenthaler et al., 2022) suggests that institutions go through stages: from not recognizing them, to exploratory pilots, to partial integration, to full strategic integration. Our consortium members are mostly in the exploratory/pilot stage, with a couple moving towards integration (e.g. DHBW CAS embedding MCs in its regular education offerings). We note that support from leadership (rectors, deans) was key – at the LCAMP conference, having institutional leaders speak about the importance of this work revitalizes belief in an effective rollout of LCAMP credentials and their recognition among the alliance.

Another observation is the synergy with existing initiatives: some partners are part of other **Dual H-VET alliances** where the Credential Concept has been published recently. By aligning with other credentialling initiatives, we could avoid duplication and get more buy-in from other CoVEs. The WP5 lead (LCT) recommended leveraging European-level developments (like Europass, etc.) to support institutional implementation, which we did by designing our credentials to be ready for the Europass infrastructure.

### 5.1.1. AD-HOC RECOGNITION AND POLICY ENVIRONMENT

As referenced, *Camilleri (2022)* and colleagues at ETF have discussed how micro-credentials are being recognized (or not) within and across borders. ETF pointed out the reliance on **multilateral agreements** (home institution, host institution, learner, companies) to recognise study periods or credentials, rather than automatic systems European VET faces similar issues; though ECTS provides a mechanism for course credit transfer, micro-credentials outside HEI degree programs don't automatically fall under ECTS unless explicitly assigned credits.

MC Policy shows that at least in Europe, there is active movement to support recognition. The Council Recommendation 2022 itself encourages Member States to apply the same rigor of recognition to micro-credentials as they do to other qualifications (hrk-modus.de). Some countries (e.g., France's RNCP or Spain's credential framework) are exploring adding micro-credentials to national qualification frameworks. If that happens, it becomes easier institutionally to recognize them formally.

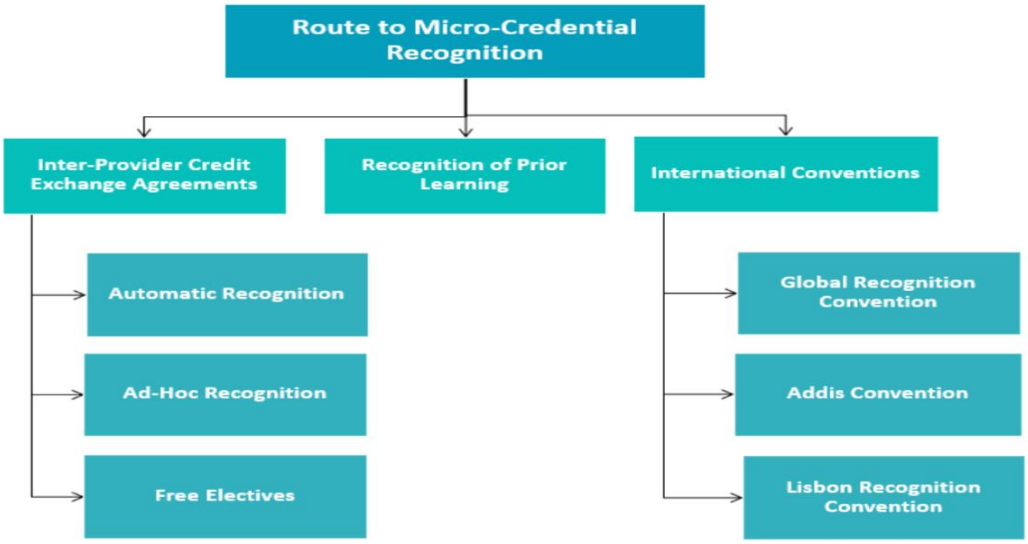



*Figure 8: Route to MC Recognition, ETF, 2022, p.40*

Camilleri's work on credential recognition (2022, p. 38-46) underscores the need for **digital systems** to facilitate this. E.g., using digital verification through blockchains or the European Blockchain Services Infrastructure (EBSI) to ensure authenticity of credentials. In our project, while we haven't deployed neither our credentials nor blockchain technology yet, we will ensure each credential and learner will have a unique ID and if issued as a badge, can be verified at stored within Europass. This addresses one recognition barrier: trust in authenticity (important for employers to avoid credential fraud).

The concept of **"ad-hoc" recognition** often implies that until systematic approaches are in place, institutions will recognize micro-credentials on a case-by-case basis via their existing RPL or credit transfer procedures (Camilleri, ETF, 2022, p.38-46) This is exactly what we anticipate in near term. For example, if a learner with our nano-credential applies to a university, the university's RPL committee will individually assess it (maybe interview the learner, check our syllabus, etc.). That's ad-hoc. It's laborious but doable when numbers are small. However, if micro-credentials become widespread, this approach isn't sustainable. There's a risk that institutions will simply not bother (thus nullifying the value of the micro-credential, except as a line on a CV). Therefore, one discussion point is the need for frameworks like the **European Credit Transfer for micro-credentials** or inclusion in the *European Qualifications Framework (EQF)* with proper levelling. Micro-credential pilots at DHBW often have an implied EQF (6,7) level; if these could be formally assigned an EQF level by some authority, it might ease recognition (similar to how a certificate from a recognized training at EQF 5 can be considered for credit at EQF 6 program, etc., albeit with limitations).

Camilleri and others have suggested that a **"credentials meta-registry",** where different providers register their micro-credentials with descriptions, allowing receiving institutions to easily look them up (like how one looks up foreign university degree accreditation), could facilitate cross-border recognition. The Europass portal is moving towards this functionality (2022, p.38-46). The LCAMP database could feed such a registry. Policy support in this direction

would reduce the ad-hoc nature of recognition, as WP5 lead emphasized.

*Institutional Strategy and Employer Readiness:*

Strategically, micro-credentials can provide many advantages to educational institutions. They allow reaching new learner demographics (like working professionals who want up- or reskilling, not a full degree), they encourage modular curriculum design (which can spur pedagogy innovation), and they enhance the institution's responsiveness to industry needs. Our partner institutions realized they could use micro-credentials to quickly roll out training on emerging topics without overhauling entire programs. For instance, instead of creating a new degree specialization in "AI Ethics in Advanced Manufacturing" which might take years to approve, they can start by offering a set of micro-credentials in that area in continuing education. This agile approach is a competitive advantage in the education market.

### 5.1.2. FROM THE EMPLOYER PERSPECTIVE:

Employers are increasingly shifting to **skills-based hiring**, where specific skills are valued alongside or even above formal degrees for certain roles. Micro-credentials, especially if standardized, could serve as verifiable evidence of those skills. A survey by the European Commission in 2020 found that a substantial number of employers see potential in micro-credentials but they seek assurance of quality and clarity on what they represent (EC, ETF 2022, p.13-14). Our experience (WP9, Communication) in talking to industry partners (like those who participate in LCAMP events) show their curiosity and openness. More communicative effort is required to convince hesitant industry stakeholders of the added value of micro-credential principals. Stakeholders liked the concept of bite-sized nano-qualifications for upskilling employees. Some companies are even issuing their own digital badges for internal training already (Bosch Rexroth, Festo LX). However, external recognition of those is limited. These findings motivate us in LCAMP to further engage with companies, SMEs, or employers to promote the LCAMP credential as future-skill-referenced LOs, also applicable by corporate skill-based training of the local industry (S3).

*The **"trust-but-verify" mentality** seems evident:*

Employers stress they would trust a candidate's micro-credential if it came from a known institution or had some credible backing (e.g. LinkedIn, Community endorsement, letter of recommendation), but they would still likely test the skill in an interview. That means LCAMP credentials alone probably won't eliminate the need to demonstrate skills in hiring, but they can support self-improvement by referencing the official issuing body, which would be an LCAMP partner H-VET institution as is DHBW or Skupnost VSS. Over time, as micro-credentials become more ubiquitous and possibly standardized (like how certain IT certifications are well-known), employer trust could increase. It took many years for things like "Cisco Certified Network Associate (CCNA)" to become a recognized industry credential; micro-credentials might follow a similar path but on a broader scale.

One strategic advantage we noted is workforce development: employers partnering with education providers as does our partner Swedish partner Court Nicolin Gymnasiet, (CNG) with Siemens Energy at local level to promote the LCAMP credential in line with what the renowned company expects and tailor future credentials to their needs. LCAMP consortium itself a VET-industry partnership (public & private, WP7), and through our work, some companies gave input on desired skills. This co-creation within the ecosystem can ensure immediate relevance. For institutions, such partnerships can result in sponsored programs or higher job placement rates, strengthening their status.

*Pitfalls to Avoid:*

We would like to relay a call for caution raised by some of our researchers that micro-credentials should not become merely a checkbox exercise or be seen as a panacea. If institutions create hundreds of micro-credentials without maintaining quality of education, it could lead to a *credentials fatigue* where neither learners nor employers value those MCs (a scenario sometimes referred to as a glut of credentials). Transparency is key – hence our emphasis on clear outcomes and standards.

Finally, we consider equity: In our upcoming pilot, when the LCAMP credentialing system (PoC) can be rolled out, (for now, most) learners participating in advanced tech credential courses will be people with prior degrees. We need to design pathways for less-represented groups too e.g. micro-credentials that help a vocational graduate to step into a higher role, or for someone without a degree to accumulate their learnings into one. A positive note: because micro-credentials are flexible, they could be offered in various modalities (online, evening classes, summer schools, in-person classroom, lab participation) which can open access to working adults or those with care responsibilities, thus supporting inclusion and life-long learning if done intentionally.

As per this discussion, while micro-credentials hold great promise, realizing their full benefit requires navigating complex education, administrative, and cultural terrain at the local level first. Our project's on-ground experience combined with external studies (HRK, ETF, EC, OECD etc.) suggests that success will depend on building trust through quality, fostering long-term cooperation for recognition, and maintaining a learner-centric focus (ensuring these credentials genuinely help learners advance). With these lessons in mind, we proceed to recommendations and future outlook in the next chapter.

# 6. CONCLUSION AND OUTLOOK

The development of the "Database of I4.0 Specific Courses and Micro-Credentials" marks an important step toward more flexible, competency-based education and training pathways in advanced manufacturing. In concluding this report, we summarize the key outcomes, reflect on what they mean for the broader H-VET landscape in Europe and beyond, and provide recommendations for policy and institutional practice. We also outline strategies for sustaining and scaling this initiative through transnational cooperation, ensuring that the work done in LCAMP WP5 continues to benefit learners and industries across Europe and beyond.

The LCAMP Learner-Centric Training working group has successfully created a comprehensive database comprising over 230 nano-credentials covering a wide spectrum of accredited Industry 4.0 competencies. Each micro-credential is well-defined (with clear learning outcomes, standardized EDC metadata, and alignment to the ESCO, EQF, LCAMP, Skill Gap intelligence, and other relevant European frameworks), ensuring transparency and relevance. We have effectively operationalized the concept of micro-credentials within a vocational and applied learning context, demonstrating that it is feasible to capture very practical, hands-on and academic skills sets in a newly created credential format. The Micro-credential database serves not only as a repository but as a clearing house concept for all key stakeholders within a credentialing ecosystem. The standards and frameworks, constituting the clearing house, guarantee a shared quality standard. This approach has, in itself, built a community of practice around micro-credential development.

By engaging educators and technology specialists in the process, we see increased capacity and awareness among the stakeholders. A tangible outcome is that some partners have already begun enlarging their national micro-credentials portfolio into their regular offerings (beyond the project pilot), showing a concrete mindset shift. Another outcome is the platform infrastructure, which is soon ready to be used by learners and key stakeholders – it will be integrated into the main LCAMP platform and accessible to the target audiences (students, workers, companies seeking training for employees) for further piloting of our PoC. Moreover, we achieved alignment of the diverse LCAMP Curricula with European policy: LCAMP's nano-credentials adhere systematically to the 2022 Council Recommendation's guidelines. This positions LCAMP well for any future European micro-credential integration not only with Europass but also for collaboration with further CoVEs and HEI Alliances. In short, LCAMP now has in place a functioning micro-credential ecosystem at a pilot scale: content, technology, quality standards and processes. Nonetheless, to fully unlock the potential of the credentialing approach, policy and Institutional recommendations would need to follow, which we outline hereafter:

**How to embed Micro-Credentials in National Qualification Frameworks and Quality Assurance Systems:**

National education authorities should consider ways to formally recognize micro-credentials. This could mean assigning them a national registry for approved micro-credentials. Quality assurance agencies might develop criteria for evaluating micro-credentials (similar to program accreditation but lighter). By doing so, institutions will feel more secure in offering them, and other institutions/employers will more readily recognize them. As noted by the HRK, having agreed standards and understanding is key (HRK Modus, 2023). The European approach provides a reliable template; nonetheless, hereafter, it's about implementing it at (cross-) national/institutional level.

**Establish and agree Credit Transfer and Stacking Mechanisms:**

Dual Universities and H-VET colleges would further need to update their recognition of prior learning (RPL) and credit transfer policies to accommodate micro-credentials. For instance, a policy could state that approved micro-credentials (meeting X criteria) can be awarded up to Y ECTS credits towards elective components. The design of stackable transnational Micro-credential pathways, is another next step where the consortium will need to define and regroup sets of micro-credentials that add up to larger awards (e.g., three micro-credentials might equal a certificate of competence in a sub-field), as piloted at DHBW and established at DHBW's

Centre of Advanced Studies located in Heilbronn (CAS) enabling pathways for lifelong learning via Micro-credentials already.

This creates clarity for learners and a roadmap that, if they accumulate certain credentials, they can exchange them for academic credit or a diploma. We recommend forming agreements (perhaps within the LCAMP Alliance or Erasmus+ partnerships) where LCAMP stakeholders mutually would pre-recognize each other's micro-credentials under certain conditions. This moves from ad-hoc to a network-based recognition (i.e., LinkedIn).

We encourage adopting the Europass Digital Credentials Infrastructure (EDCI) to issue the micro and nano-credentials in a verifiable digital format (with secure signatures) and a Lifelong Learner's ID. Ideally, all micro-credentials could first be issued during the piloting as "Open Badges" including the systemic implementation of EDC metadata, to be stored and shared by learners in their online profiles first (like LinkedIn, Europass, or digital CVs). This not only would make it easier for LCAMP to raise awareness and promote the unique credential system, but also help to verify and plug them into the emerging ecosystem (e.g., learners storing credentials in their Europass wallet). Policymakers at EU and national levels should continue to support common technical standards (ensuring interoperability between systems). The work by Camilleri et al. (2019, 2022) on mapping digital credential needs underscores this necessity for interoperability. In practice, LCAMP could envisage to integrate an open badge issuance platform with our database first, for piloting, so that when a new partner confirms that a learner has completed a course, a badge with EU standardized metadata is automatically issued to the learner.

### 6.1.1.MAINTAIN AND EXPAND THE I4.0 CREDENTIAL DATABASE

As technology evolves, so must the content of micro-credentials. We recommend that the LCAMP Alliance (which is being formed as another project outcome) take ownership of updating the database beyond the project's lifespan. There should be further periodic reviews (e.g., annual) to retire or update credentials that have become outdated (for example, a credential on "Industry 4.0 software" might need an update, if a new version or new standard arises). Furthermore, expand into new areas, possibly identified by the LCAMP Observatory as another project component. For instance, as Industry 5.0 (human-centric, sustainable manufacturing) and the LCAMP CLF gains traction, new micro-credentials could be developed in that domain. Transnational cooperation is particularly valuable here: One LCAMP partner might lead in a certain technology – they can develop a credential which others can adopt, avoiding duplication.

Continuous feedback and collaboration with employers, and learners is crucial to keep micro-credentials relevant and trusted. To further improve the results of the LCAMP MC Database, we recommend establishing an industry advisory panel for micro-credentials in each major subject area, especially since this was and still is a huge challenge in LCAMP. Such future panels, composed e.g. of the members of the LCAMP Advisory Board conceiving a future LCAMP Learning / Ad-hoc recognition agreement (Camilleri, 2022, p.39 & GA. P.33), could review and suggest updates to learning outcomes to match evolving skill needs to attract more and more companies to join the LCAMP CBE Nano-credential design, fostering trust and employer buy-in.

Employers who co-designed a credential are more likely to recognize it during hiring or use it for workforce development. Similarly, gathering feedback from learners who earn the credentials can highlight whether the credential provided value (Did it help in job advancement, for

instance?). This feedback loop, which hasn't been established yet, could improve the quality and future reputation of the LCAMP micro-credentials. Policymakers can support such engagement by creating forums or incentives for work-based-education collaboration (for example, national funds that encourage polytechnics and local companies to jointly develop micro-learnings for new technologies). LCAMP partners are constantly putting effort into this joint endeavour to attract more alliance members. Both the education sector and the labor market in the advanced manufacturing sector need greater awareness of what LCAMP nano-credentials could become and how to utilise them in the future. The LCT-lead (DHBW) recommends a concerted outreach effort, organized by the LCAMP OIC (WP4), the Alliance (WP2) and the LCAMP PR (WP9) to set this into practice: E.g., workshops for teaching staff (to understand how to implement nano-credentials in learning, teaching and SMEs), information sessions for employers (through associations (Suedwestmetall, Skupnost VSS, TKNIKA IVEMA, AFIL etc.), explaining how to interpret and make use of the newly created credential infrastructure, also in recruitment), and guidance for learners (how to combine and leverage their micro-credentials). A cultural shift is underway from seeing learning no more as a one-time (degree) but as life-long and continuous enabled by stackable accredited micro-learnings; Supporting this shift requires clear communication and success stories.

The OECD has noted that without clear understanding across institutions and systems, the impact of micro-credentials is limited (OECD, 2024). Thus, all stakeholders should be educated on the role and value of LCAMP nano-credentials. This, for example, is exclusively fostered by the expert group at **HRK MODUS** initiative in Germany to successfully bridge traditional VET (secondary) and HEI (tertiary) systematically and systemically via harmonized legislation and recognition principles.

**Transnational Cooperation Strategies:**

The nature of Industry 4.0 is global and so should be the approach to a more agile skills recognition concept. LCAMP itself is a model of transnational education cooperation (with partners from Spain (Basque Country), Germany, Slovenia, Italy, Türkyie, Sweden, France, Italy, and Canada). We see the challenges we are facing in LCAMP, with operationalising a micro-credentialing infrastructure, as a strength to be continued. We propose the dissemination of the LCAMP "Nano-Credentials Concept" via the LCAMP Alliance (WP2) applicable among Centres of Vocational Excellence (CoVEs) and other interested institutions across Europe, in light that widely spread CBE based EDCI credentialing strategies do not apply in H-VET ecosystems yet. A learning ecosystem as is the LCAMP CoVE can maintain a shared nano-credential catalogue, set joint quality standards, and facilitate agreements multilaterally (a network of trust) rooted and quality assured within its native curricula of the local regional issuing body. The European Commission's support for CoVE projects like LCAMP and the European Universities initiative indicates momentum toward the portability of our LCAMP credentials. (Camilleri, ETF, 2022)

By aligning our newly developed nano-credential efforts with European frameworks, i.e., making them accessible in all EU languages via ESCO, and compatible with ECTS, we make cross-border learning pathways easier. A learner in one country could take a micro-credential course from another partner and still have it valued locally – this is a practical vision LCAMP should strive for. Concretely, LCAMP partners intend to open the database to associated partners in other countries and invite them to contribute and use LCAMP credentials, creating an even

larger ecosystem. Transnational collaboration is also key for keeping pace with technological change. One region might be pioneering a certain Industry 4.0 tech – by sharing micro-credentials across borders, other regions can quickly adopt those skill training without lag. For example, if a Swedish partner develops a micro-credential on Green Manufacturing, LCAMP's platform can host it and partners in Spain or Germany can immediately offer it to their learners, possibly localizing the content. This collective approach (integrating OERs) ensures Europe as a whole has an agile response to skill needs. We recommend continued EU support (through Erasmus+, Cedefop Skills Intelligence) for networks that exchange micro-credentials and develop common credentialing methodologies.

In our view, LCAMP WP5's work on micro-credentials in advanced manufacturing is not a one-off task but the beginning of a new mode of lifelong learning also for VET, evidently still in its early stages of development. Looking ahead, its roll-out in mind, we anticipate that scalable nano- and micro-credentials for H-VET and its industry stakeholders will become an integral part of our future education and training landscape. They will likely be incorporated into formal education (as additional credential layers within degree programs) and into corporate HR systems (as units of employee upskilling and reskilling) The latter, we will pursue with great effort to incorporate our CoVE's associated stakeholder network via the LCAMP Alliances. The European Higher Education Area is already considering how to include micro-credentials within Bologna Process frameworks, and our project's outcomes can inform those high-level policy developments. For LCAMP, the immediate next step is to validate and operationalize the platform, leveraging an ad-hoc agreement, to go from the development phase to an active service where learners can enrol in LCAMP courses and profit from our nano-credential courses and earn Knowledge, Skills and Attitudes certified by LCAMP's local educational entities (S3). We will monitor uptake and outcomes (e.g., track how many learners earn credentials and what they do with them) as soon as the systems will allow it. This will provide data to further refine the offerings. We also plan to connect the LCAMP credentials platform with other initiatives like the Europass portal so that our content is visible and accessible widely.

In a broader sense, the trend of digital transformation (Industry 4.0) in manufacturing is paralleled by a needed transformation in education "Education 5.0", one might say. Micro-credentials are one of the digital tools and vehicles enabling Education 5.0 – agile, digital, personalized, on-demand, competency-based and aligned with the EDCI. Our deliverable (PoC) demonstrates that with cooperation and the right frameworks, quality-assured digital credentials can be implemented effectively. It empowers learners to take charge of their skill development, allows educational institutions to innovate in what they offer, and helps employers fill skill gaps in a more targeted way.

We conclude that micro-credentials, in line with our leveraged fine-grained H-VET approach, when well-designed and quality-assured, add value to the traditional system by bridging formal, informal and non-formal work-based learnings and by focusing on competencies crucial for the modern I.40 workplace. MCs are not a replacement for comprehensive traditional education, but a complementary, more agile educational principle that provides flexibility and responsiveness.

To fully unlock their potential, stakeholders at all levels must collaborate: policymakers aligning frameworks, institutions integrating micro-credentials into their traditional curricula, employers recognizing and demanding them, and learners embracing lifelong learning mindsets. The LCAMP consortium and DHBW, as the lead of the LCT, stand ready to continue this journey. We will use the insights and partnerships gained to further refine the learner-centric training approaches with partners, ensuring that the workforce in advanced manufacturing remains

skilled, adaptable, and competitive. By sharing our results and recommendations through publications and direct engagement with other initiatives, we aim to contribute to the shaping of a European space where scalable micro-credentials are widely accepted and where learning never truly stops at one diploma but accumulates through a lifetime ensuring skilled workforce across Europe and beyond.

In summary, the deliverable D5.3 not only delivers a tangible product (the database of I4.0 courses and micro-credentials) but also paves the way for more agile digital and international good practices in competency-based micro-credentialing across borders. It exemplifies how collaborative innovation in the education sector can meet the needs of the rapidly evolving industry sector, asking for constantly growing cooperation and clear quality principles across key stakeholders. The outlook is optimistic: with continued cooperation, iterative improvement, and supportive policy, micro-credentials will also become a cornerstone of vocational excellence and lifelong learning.

# 7. REFERENCES


Berkling, K., Hänisch, T., & Schütz, F. (2023). Transforming CS curricula into EU-standardized micro-credentials. Athens Journal of Technology and Engineering, 10(3), 161–174. https://doi.org/10.30958/ajte.10-3-

Braungart, M., McDonough, W. (2014). Cradle to Cradle. Remaking the Way, We Make Things.

Bloom, B.S., Engelhart, M.D. et al. (1956). Taxonomy of educational objectives: The classification of educational goals. Handbook I: Cognitive domain.

Camilleri, Anthony F. (2019). Diplomas Track Deep Dive: Ensuring Interoperability. EBSI use-case groups Joint workshop.

Camilleri, A. F., Digital Credentials Consortium, et al. (2022). Credentials to employment: The last mile. Digital Credentials Consortium. https://digitalcredentials.mit.edu/docs/Credentials-to-Employment-The-Last-Mile.pdf

Camilleri, A. F., & Ardie, S. W. (2022). Digital Credential Recognition: Mapping and Identification of Digital Credit Transfer System Needs in ASEAN. SHARE Project Report.

Council of the European Union. (2022). Council Recommendation of 16 June 2022 on a European approach to micro-credentials for lifelong learning and employability (2022/C 243/04). Official Journal of the EU, C243, 10–18.

Cedefop. (2024). Transparency and transferability of learning outcomes: a 20-year journey: Analysis of developments at European and national level. Cedefop research paper. Publications Office of the European Union. https://data.europa.eu/doi/10.2801/3413866

Cedefop & UNESCO-UNEVOC. (2025). Meeting skill needs for the green transition: skills anticipation and VET for a greener future: Cedefop practical guide 4. Publications Office of the European Union. DOI: 10.2801/6833866 https://www.cedefop.europa.eu/en/publications/4220

Ehlers, U.-D., Future Skills für die Welt von morgen: Das Future-Skills-Triple-Helix-Modell der Handlungsfähigkeit in emergenten Praxiskontexten. 355-374. Hochschulforum Digitalisierung (Hrsg.). (2021). Digitalisierung in Studium und Lehre gemeinsam gestalten: Innovative Formate, Strategien und Netzwerke. https://doi.org/10.1007/978-3-658-32849-8

European Training Foundation (2022). Guide to design, issue, and recognize micro-credentials. HYPERLINK "https://www.etf.europa.eu/sites/default/files/2023-05/Micro-Credential%20Guidelines%20Final%20Delivery.pdf" https://www.etf.europa.eu/sites/default/files/2023-05/Micro-Credential%20Guidelines%20Final%20Delivery.pdf

European Commission. (n.d.). ESCO – European Skills, Competences, Qualifications and Occupations. [Web page]. Retrieved from ec.europa.eu.

European Training Foundation (ETF). (2023). Guide to Design, Issue and Recognise Micro-Credentials. (KIC team led by A. Camilleri). Turin: ETF.

Hänisch, T., Schmitt, L., & Schütz, F. (2024). Transforming CS curricula into EU-standardized micro-credentials – The hard parts. Athens Journal of Technology and Engineering, 11(3), 219–234.

Ifenthaler, D., et al. (2022). A maturity model for micro-credentialing implementation in higher education. Journal of Applied Research in Higher Education, 14(2), 661-674.

Kolb, D. A., Rubin, I. M., & McIntyre, J. M. (1984). Organizational psychology: readings on human behavior in organizations. Englewood Cliffs, NJ: Prentice-Hall.

Kolb, D. A. (2015). Experiential learning: Experience as the source of learning and development (2nd ed.). Pearson Education.

Lave, J., & Wenger, E. (1991). Situated Learning: Legitimate Peripheral Participation. Cambridge University Press.

Lombardo, M. M., & Eichinger, R. W. (1996). The Career Architect Development Planner. Minneapolis: Lominger. (Source of the 70:20:10 model concept – 70% experiential, 20% social, 10% formal learning

MicroCredX Consortium. (2023). Micro-Credentials Exchange Network Implementation Framework. Knowledge Innovation Centre Publication.

OECD (2024), Bridging Talent Shortages in Tech: Skills-first Hiring, Micro-credentials and Inclusive Outreach, Getting Skills Right, OECD Publishing, Paris, https://doi.org/10.1787/f35da44f-en.

OECD (2024), Agile Occupational and Training Standards for Responsive Skills Policies, Getting Skills Right, OECD Publishing, Paris. https://doi.org/10.1787/bacb5e4a-en.

OECD. (2021). Micro-credentials for Lifelong Learning and Employability (Education Working Paper No. 216). Paris: OECD Publishing.

OECD Education & Skills. (2021, September 29). Promoting social inclusion through micro-credentials. OECD Education and Skills Today [Blog].

OECD (2019). OECD Learning Compass 2030 – Background. Paris: OECD.

Patterson, L., & Hepburn, G. (2025). Distance Education: Implementing a competency-based assessment approach to micro-credentials. https://doi.org/10.1080/01587919.2024.2441247

Rupp, K.-D. & Mkrtchyan, L. (2025). Implementation of Learning Pathways for Advanced Manufacturing.EU4Dual.ConferenceBooklet.

Stenzel, J. & Korsch, M. (2025). Leveraging Micro-Credential Concepts to foster scalable Pathways for Lifelong Learning among H-VET Providers and the Industry in Europe and Beyond.EU4Dual. ConferenceBooklet.
The German Rectors' Conference (HRK). (2023). Micro-Credentials at Higher Education Institutions – Strategy Development and Quality Assurance. (hrk-modus.de)
Wrede, O., & Rausch, A. (2023). Employers' perspectives on micro-credentials in hiring. Inside Higher Ed, March 3, 2023.
Zhang, J., and Richard E. West. (2020), designing microlearning Instruction for professional development through a competency-based approach, TechTrends, 64(2), 310-318. http://dx.doi.org/10.1007/s11528-019-00449-4

**Webpages:**

https://www.simplypsychology.org/learning-kolb.html

# 8. INDEX OF IMAGES

Figure 1: Key Stakeholders of a Micro-Credentialing Ecosystem, OECD, 2023, p.10 ..... 9
Figure 2: Modified after OECD Competency Model 2030 (OECD, 2019) ..... 13
Figure 3: The Experiential Learning Cycle and Basic Learning Style (Kolb, 1984, 2015), p.141, modified after SIMPLYPSYCHOLOGY ..... 16
Figure 4: Strategic Harmonization & Digitalization Frameworks for Nano-Credentialing in HVET ..... 18
Figure 5: Left: Clearning House Template/Prototype; right: Final Course Catalogue entry ..... 21
Figure 6: Course of Study Computer Science at DHBW and established Container Modules for Micro-Credentialing and Nano-Credential perspective (PoC), with consistent CBE-EDC granularity parametric ..... 23
Figure 7: Granularization & Harmonization Workflow in LCT (WP5) ..... 25
Figure 8: Route to MC Recognition, ETF, 2022, p.40 ..... 36

# 9. INDEX OF TABLES

Table 1: Contributions by partner (indicative figures). Breakdown by thematic area (category) and number of nano-credentials available per LCAMP partner. ..... 29

# LCAMP

Learner Centric Advanced Manufacturing Platform



Co-funded by
the European Union

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Education and Culture Executive Agency (EACEA). Neither the European Union nor EACEA can be held responsible for them.