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# Towards a Capability Maturity Model for Micro-Credential Providers in European Higher Education

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**Abstract:** Navigating the complexities of establishing sustainable micro-credentialing programs in European higher education requires a tailored approach for providers. The goal of this research is to develop an assessment tool that enhances the implementation and recognition of micro-credentials in European higher education. This article introduces the INVEST Micro-credentialing Capability Maturity Model (MCMM), designed to assist educational institutions in assessing and enhancing their readiness for micro-credential establishment. Through a systematic six-stage process, we identify supportive conditions, specify levels of process maturity, develop domains and aspects, characterize levels of capability, consult with stakeholders, and finalize the model. The resulting Capability Maturity Model (CMM) outlines five levels of process maturity encompassing educational, administrative, regulatory, and collaborative aspects, aligning with the principles outlined by the European Union (EU) initiatives for micro-credential establishment. Through establishing clear objectives, the model aids in the strategic development and evaluation of micro-credential programs. Stakeholders are offered a comprehensive roadmap to evaluate their progress, identify required resources, and strategize for further advancement in micro-credentialing initiatives.

**Keywords:** capability maturity model; micro-credentials; European higher education; lifelong learning



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## 1. Introduction

As education continues to evolve in response to changing needs and demands, there is a growing recognition of the importance of flexible learning pathways [1,2]. Vocational Education and Training (VET) and adult learning play crucial roles in this context, particularly in reskilling and upskilling the workforce [3]. These educational approaches are vital for individuals looking to stay competitive in a rapidly changing job market, addressing skill gaps and ensuring continuous professional development [4]. Micro-credentials have emerged as a viable solution to meet this demand, offering targeted and specialized learning outcomes [5]. In recent years, the popularity of micro-credentials has surged, as learners seek shorter, more focused learning experiences to enhance their skills and knowledge [6,7]. In this context, the demand for a structured approach to establishing sustainable micro-credentialing programs underscores the importance of developing comprehensive frameworks that accommodate the evolving needs of learners and the educational landscape [8].

A European approach to micro-credentials attempts to broaden access to personalized learning opportunities, fostering lifelong learning through flexible and modular pathways [9]. This approach aims not only to cater to professionals but also to complement traditional curricula for bachelor's, master's, and doctoral students. With the workforce's increasing need for reskilling and upskilling, micro-credentials can offer a flexible alternative to traditional degrees, addressing emerging skills demands in the labor market. While some higher education institutions are already engaged in micro-credential development, a common approach to validation and recognition remains elusive [10]. The

European Commission's proposal for a Council Recommendation in 2021 aims to bridge this gap, fostering trust and facilitating wider adoption, portability, and recognition of micro-credentials by 2025 [11]. In this evolving landscape of micro-credentials, the development and adoption of comprehensive mechanisms will be essential to ensure the quality, effectiveness, and alignment of micro-credentialing programs with evolving educational and workforce needs.

Given the nascent and evolving landscape of micro-credentials, there is a notable need for concretized solutions for assessing the readiness, capability, and effectiveness of micro-credential programs [12]. This gap hinders informed decision-making and impedes the continuous improvement necessary for educational innovation [13]. Introducing a comprehensive maturity model with clear criteria consistent with EU principles would empower European institutions to strategically align their micro-credential offerings with the evolving landscape of educational innovation and workforce development needs.

The research presented in this paper was conducted within the INVEST European University, an alliance comprising seven universities spanning across Europe [14]. By leveraging the collective expertise and resources of our alliance, we seek to contribute meaningfully to the ongoing discourse on micro-credentialing and its implications for the future of education in Europe and beyond [15]. Through an analysis of micro-credential initiatives in Europe and the INVEST alliance, we aim to provide valuable insights into the potential of micro-credentialing to support lifelong learning, foster workforce development, and promote educational innovation. Ultimately, our findings aim to inform policy decisions, institutional strategies, and educational practices to better serve the needs of students, educators, and stakeholders in the European higher education landscape and beyond. Building upon this foundation, this research introduces the INVEST MCMM, developed through a systematic six-stage process, which provides a roadmap to assess the progress, identify necessary resources, and plan actions for further advancement in micro-credentialing initiatives.

The rest of the paper is organized as follows. Section 2 includes a comprehensive background overview, detailing the current status of micro-credentials and comparing the different perspectives. This exploration sets the stage for the subsequent discussion on the CMM for micro-credentialing. The methods section outlines the aim, objectives, and development process of the INVEST MCMM. Following this, the results are presented, leading to a discussion that delves into the implications and insights gained from the findings. The paper then reflects on lessons learned throughout the process as well as the limitations of this research. Finally, the conclusion synthesizes key takeaways and outlines future directions for research and practice in the field of micro-credentialing.

## 2. Background

### *2.1. The Current Status in Micro-Credentials*

In recent years, micro-credentials have emerged with the aim of becoming a dynamic force in the educational landscape. However, implementing micro-credentials remains a complex endeavor, with their adoption varying across different regions, such as the United States, where they have yet to gain widespread popularity within universities [16]. In the United States, the American Council on Education (ACE) has taken an operational approach to micro-credentials, focusing on creating a framework that facilitates college credit recommendations for various forms of learning, including micro-credentials and digital badges. This practical framework not only recognizes the academic value of shorter, focused courses but also enhances their acceptance and integration within traditional educational systems, thereby promoting lifelong learning and career development [17].

UNESCO's report, "Moving towards a common language on micro-credentials", offers a foundational framework for understanding different types of credentials. In this framework, credentials are categorized into three main types [18]. The first are traditional degrees and diplomas, termed as Credentials. Then, there are Macro-credentials, which encompass comprehensive qualifications like bachelor's or master's degrees. Finally, Micro-credentials represent short-term learning outcomes, such as specialized training or short courses. This classification provides clarity and structure in delineating various forms of educational and training achievements.

In July 2022, the Council of the European Union proposed a recommendation highlighting key aspects of micro-credentials within the European context [11]. Firstly, micro-credentials are defined as certifications that validate specific learning outcomes, emphasizing a shift towards competency-based education. Secondly, they are praised for their flexibility, offering learners the opportunity to rapidly upskill and reskill in response to evolving demands in the labor market. Lastly, the recommendation underscores the importance of maintaining common standards for quality assurance to ensure transparency and build trust among stakeholders. These aspects collectively reflect a concerted effort to adapt European education and training systems to meet the needs of a dynamic and competitive global landscape.

Prior to the EU's recommendation for micro-credentials, sporadic attempts by individual European countries have been made to address micro-credentials within their educational landscapes. For example, Spain's Royal Decree 822/2021, focusing on micro-credentials within university study programs, exemplified the country's approach to integrating these credentials [19]. Emphasizing quality assurance and alignment with broader educational objectives, the decree underscores Spain's commitment to ensuring that micro-credentials meet rigorous standards of excellence. By integrating micro-credentials into university study programs, Spain aims to provide learners with valuable and recognized qualifications that enhance their skills and competencies in alignment with the evolving needs of society and the labor market.

Leading educational institutions, including top business schools, have embraced the trend of offering micro-credentials, recognizing the demand for targeted and flexible learning options among professionals [20] These online programs cater to individuals seeking specialized knowledge and skills in areas such as data analytics, leadership, or digital marketing. By providing accessible and focused educational opportunities, business schools aim to meet the evolving needs of learners and empower them to enhance their expertise in key areas of interest or industry demand. Similarly, companies across various industries are also recognizing the value of micro-credentials. For instance, IBM has pioneered the implementation of digital credentials through its comprehensive digital badge program, which focuses on recognizing both academic and non-academic achievements [21]. IBM's approach emphasizes the practical application of micro-credentials in the workplace, offering badges that are industry-recognized and aimed at improving employability [22]. This model demonstrates a successful integration of micro-credentials into professional development pathways, providing measurable benefits to both individuals and organizations [23].

Various research initiatives and observatories play crucial roles in advancing the understanding and development of micro-credentials. One such initiative is the Micro-Credential Observatory, hosted by Dublin City University [24]. The observatory conducts comprehensive literature reviews, offering critical insights into the global micro-credential movement and serving as a valuable resource for stakeholders interested in navigating emerging trends, challenges, and best practices in this complex landscape. Additionally, the Organisation for Economic Co-operation and Development (OECD) contributes significantly to the discourse on micro-credentials [25]. Through extensive research reports, policy briefs, and data analysis, the OECD explores the impact of micro-credentials on employability and lifelong learning, examining their effectiveness in addressing skills gaps and fostering continuous professional development.

### *2.2. Maturity Model for Micro-Credentialing*

As the demand for micro-credentials continues to rise, educational institutions are confronted with the challenge of enhancing their capacity and capability to deliver high-quality learning experiences. Maturity models serve as valuable tools in this endeavor, providing a structured approach to assess the state of micro-credential ecosystems and facilitate evaluative analysis and improvements.

One notable example is the maturity model, tailored specifically for micro-credentialing and shorter forms of learning practice in Australasian universities [12]. This model assists Australasian higher education providers in discerning their stage of development for delivering micro-credentials across domains such as quality, resourcing, standards, and strategy. Validated through a survey of regional higher education providers, this model revealed varying levels of maturity across different domains.

However, despite the existence of various tools and practical approaches for micro-credentials, there remains a noticeable absence of a model specifically aligned with the European approach to higher education [13]. This gap presents an opportunity for further research and development in this area, particularly within the framework of our own research conducted within a European University Alliance. The Australasian and European approaches to micro-credentialing exhibit distinct characteristics shaped by their respective contexts and priorities. In Australasia, micro-credentials are often designed with a strong focus on meeting specific industry needs and fostering collaboration between educational institutions and employers [26]. This approach follows a more decentralized system, with individual institutions and industry bodies taking the lead in developing micro-credentials. In contrast, the European approach places a greater emphasis on standardization, quality assurance, and alignment with national and European frameworks. Micro-credentials in Europe are viewed as integral components of a broader strategy to promote lifelong learning and enhance workforce development, with a focus on ensuring consistency, portability, and recognition across borders.

The American approach to micro-credentialing, while still evolving, offers another perspective worth considering [27]. In the United States, micro-credentials often emerge from collaborations between higher education institutions and industry partners, with a focus on addressing specific skill gaps and workforce needs [28]. However, the American model tends to be less standardized, with significant variation in how micro-credentials are developed and recognized across different states and institutions [29]. This decentralization can lead to innovation and responsiveness to local industry needs but also poses challenges in terms of consistency and national recognition.

Recognizing the unique challenges and opportunities within the European education landscape, our research seeks to develop a comprehensive framework that enables institutions to assess and enhance their capacity for delivering high-quality micro-credential programs. By aligning with the principles of the EU, including those outlined in initiatives such as the European Universities Alliance, Erasmus+, and the European Skills Agenda, the proposed INVEST MCMM aims to support the broader objectives of promoting lifelong learning, enhancing workforce development, and fostering educational innovation across the region.

### *2.3. Capability Maturity Model*

In the pursuit of enhancing organizational processes within higher education to meet the evolving demands of micro-credentialing, this paper endeavors to develop a specialized CMM. Originating from the Software Engineering Institute at Carnegie Mellon University in 1986, the CMM initially aimed to bolster software development processes [30]. Over time, it evolved into the Capability Maturity Model Integration (CMMI) initiative, which sought to consolidate various capability maturity models into a unified framework. While historically serving the needs of software development and other industries, these models are now recognized as applicable in sectors requiring a tailored approach to address specific challenges.

At its essence, CMM offers a set of recommended practices tailored to specific process areas within various domains, including educational institutions and higher education. These practices serve as guidance for organizations seeking to optimize their processes, control their activities, and evolve towards excellence in their respective fields. Overall, this framework will provide stakeholders with a roadmap to assess their progress, identify necessary resources, and plan actions for further advancement in micro-credentialing initiatives.

## 3. Methods

### *3.1. Aim and Objectives*

The primary aim of this research is to develop a comprehensive CMM that supports the systematic implementation and scaling of micro-credentialing programs within European higher education institutions. The objectives of this study were:

- To systematically identify and categorize the essential conditions necessary for the successful deployment of micro-credentials, aligning these with broader educational and workforce development strategies.
- To clarify and define the roles and responsibilities of key stakeholders within the micro-credentialing ecosystem, ensuring a collaborative approach to program development and execution.
- To enhance cooperation within the INVEST alliance and beyond, leveraging collective expertise to inform a robust framework for micro-credentialing that can be adapted across various educational contexts.

These objectives guide our research towards a detailed exploration of how micro-credentials can be effectively integrated into existing educational frameworks, ensuring they are both sustainable and beneficial to stakeholders. The intended outcome is a set of actionable guidelines that institutions can apply to elevate their micro-credential offerings, thereby supporting lifelong learning and professional development across Europe.

### *3.2. Development Process*

We followed methods outlined by [31], which describes the application of the CMM within an education context. The development of the INVEST MCMM involved six main phases of activity (Figure 1):

1. Identification of relevant processes, practices, and behaviors;
2. Specification of the levels of process maturity;
3. Identification of different aspects to be assessed within each level of process maturity;
4. Characterization of different levels of capability;
5. Consultation with stakeholders; and
6. Incorporation of consultation responses and finalization of the model.

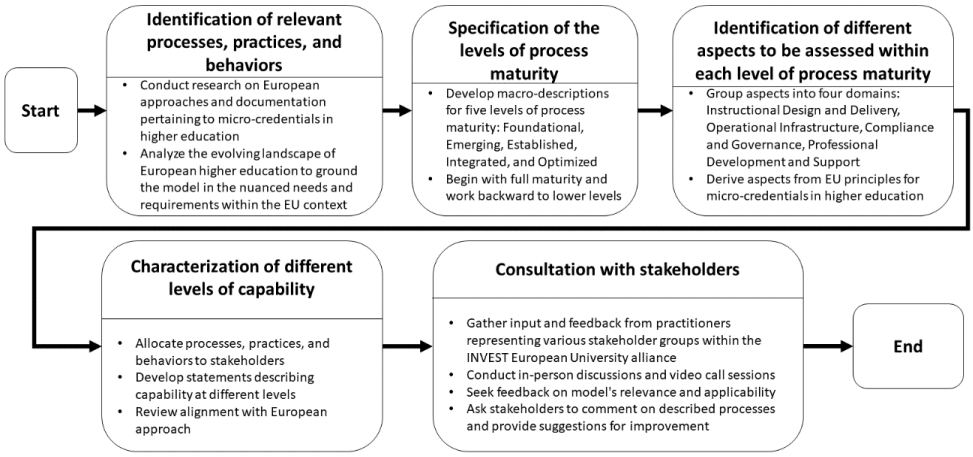


**Figure 1.** Process Flow for Developing the INVEST MCMM.

We collaborated to complete all stages of the process, with additional facilitation provided by a monitoring and evaluation specialist external to the INVEST project. The process took place between October 2023 and March 2024, and we maintained a record of the process and reflections for reproducibility.

1. Identification of relevant processes, practices, and behaviors. To identify the organizational processes, practices, and behaviors necessary for establishing micro-credentialing programs in higher education, we delved into European approaches and documentation pertaining to micro-credentials. Our goal was to ground the INVEST MCMM in the evolving landscape of European higher education, ensuring that the model reflects the nuanced needs and requirements of institutions and stakeholders within the EU context.
2. Specification of the levels of process maturity. We used the identified processes, practices, and behaviors to develop macro-descriptions for five levels of process maturity: Foundational, Emerging, Established, Integrated, and Optimized. This was guided by the completion of the statement: "A successful sustainable micro-credentialing program has/is…". We began by describing the fifth level (Optimized) before working backward to lower levels.
3. Identification of different aspects to be assessed within each level of process maturity grouped into four domains. These domains provide a structured approach for the evaluation and enhancement of micro-credential programs in European higher education:
    a. Instructional Design and Delivery: Including aspects related to Assessment, Learner-Centered, Learning pathways, Relevance, and Teaching and Learning.
    b. Operational Infrastructure: Encompassing Administrative Structure and Integration, Infrastructure and Processes, Student Enrollment and Participation, and Transparent Information Systems.
    c. Compliance and Governance: Covering Regulatory Framework, Quality Assurance, and Qualifications Framework/Systems.
    d. Professional Development and Support: Focusing on aspects related to Educator Qualifications and Competencies, as well as Information and Guidance for both educators and learners.

The above aspects are derived from documentation and review of the EU's principles for the design and issuance of micro-credentials in higher education. [11]. These principles serve as a framework to ensure the trust and quality of micro-credentials, offering guidance to Member States, public authorities, and providers. Table 1 presents the domains, aspects, and their descriptions.

4. Characterization of different levels of capability. Processes, practices, and behaviors were allocated to relevant stakeholders, and statements describing capability at different levels were developed. In our approach to defining the capability levels, we incorporated comprehensive empirical data gathered from various European higher education institutions actively deploying micro-credential programs. This data provided a robust foundation to define specific, measurable indicators of maturity for processes, practices, and stakeholder behaviors at each level. We reviewed the alignment of statements to ensure consistency and coherence with the European approach.
5. Consultation with stakeholders. The consultation phase was particularly critical, involving detailed discussions with representatives from each of the seven universities within the INVEST European University alliance. These discussions were structured to include at least three participants from each university, encompassing a range of roles such as academic faculty, administrators, quality assurance experts, educational technology specialists, and student representatives. The participants included 15 academic faculty members, 12 administrators, 10 quality assurance experts, 9 educational technology specialists, and 7 students. In total, 53 stakeholders were actively engaged in this phase. Each university contributed uniquely to the development of the model based on their specific experiences and expertise in micro-credentialing. The discussions were facilitated through a combination of in-person workshops and virtual meetings, ensuring comprehensive participation despite geographical distances. This collaborative approach not only enriched the development process but also ensured that the model accommodated diverse perspectives and practices prevalent across different educational systems within Europe. Feedback from these stakeholders was meticulously documented and analyzed to refine the model's utility and ensure it addressed the nuanced needs and challenges identified during the consultation phase. Stakeholders provided more than 60 individual feedback points, which were categorized into themes such as the need for flexibility to accommodate different institutional policies (mentioned by 42 stakeholders), the importance of aligning with EU standards for quality and transparency (highlighted by 46 stakeholders), and strategies for effective implementation and scalability of micro-credential programs (identified by 35 stakeholders). These insights were instrumental in shaping the final model. Additionally, the feedback highlighted specific challenges such as varying levels of digital infrastructure across institutions and the necessity for robust support systems for both educators and students involved in micro-credentialing.
6. In this final step, we synthesized the feedback received from stakeholders and aligned the themes with the principles of the EU, as outlined in Table 1 to finalize the model, ensuring it reflects the collective insights and meets the broad objectives set forth at the inception of this project. During this stage, we performed detailed statistical analyses, including thematic analysis, calculation of percentage increases, correlation coefficients, significance testing, and confidence intervals. These analyses were crucial in validating the feedback and ensuring that the model adjustments were both data-driven and aligned with stakeholder expectations.

**Table 1.** Domains, aspects, and definitions.

| Domain | Aspect | Description |
|---|---|---|
| Instructional Design and Delivery | Assessment | The process of evaluating and measuring the learning outcomes of micro-credentials. |
| | Learner-Centered | An educational approach that prioritizes the needs, interests, and preferences of individual learners. |
| | Learning pathways | Sequences of micro-credentials that individuals undertake to achieve specific educational or professional goals. |
| | Relevance | The degree to which educational content, outcomes, activities, or qualifications are directly applicable, meaningful, and useful to the needs, interests, and goals of learners, as well as aligned with current societal, economic, and industry requirements. |
| | Teaching and Learning | The methods, strategies, and practices employed by educators to facilitate learning experiences and promote the acquisition of knowledge, skills, and understanding among learners. |
| Operational Infrastructure | Administrative Structure and Integration | The coordination of administrative processes and systems for seamless integration within broader educational frameworks. |
| | Infrastructure and Processes | The physical, technological, and organizational systems, resources, and procedures necessary to support and facilitate the delivery, management, and administration of educational programs and services. |
| | Student Enrollment and Participation | The process of students enrolling in educational programs or courses and actively engaging in learning activities, interactions, and experiences as part of their educational journey. |
| | Transparent Information Systems | Systems and platforms that provide information about educational programs, qualifications, providers, and related processes to learners, stakeholders, and the public. |
| | Recognition and Accreditation | Digital badges or certificates designed to acknowledge students' achievements and formally accredit their learning |
| Compliance and Governance | Regulatory Framework | The set of laws, policies, standards, and guidelines established by government bodies, accrediting agencies, or educational authorities to regulate and govern various aspects of education, including quality, accreditation, accountability, and compliance. |
| | Quality Assurance | Systematic processes and procedures implemented to ensure that educational programs, services, and outcomes consistently meet predetermined standards of quality, effectiveness, and excellence. |
| | Qualifications Framework/Systems | Organized frameworks or systems that categorize and describe qualifications, credentials, or awards based on their level, complexity, and learning outcomes, providing guidance for their recognition, comparability, and alignment within and across educational systems. |
| Professional Development and Support | Educator Qualifications and Competencies | The qualifications, knowledge, skills, and attributes required for educators to effectively plan, deliver, and assess educational programs, as well as to support and engage learners in achieving their learning goals. |
| | Information and Guidance | Accessible and accurate information, advice, and support services provided to learners to help them make informed decisions about their educational pathways, goals, and career choices. |

### *3.3. Thematic Analysis*

The qualitative feedback provided by stakeholders was analyzed using thematic analysis. This method involved coding the feedback points and categorizing them into themes. The analysis was performed using NVIVO qualitative analysis software which facilitated the identification of key themes such as flexibility, alignment with EU standards, and principles for implementation and scalability.

### *3.4. Statistical Analysis*

#### 3.4.1. Percentage Increases

To calculate the percentage increase in stakeholder agreement with the realism of the model statements, we compared the baseline agreement level (pre-adjustment) with the post-adjustment agreement level.

$$\text{Percentage\_Increase} = \left( \frac{\text{Post\_adjustment\_Agreement} - \text{Baseline\_Agreement}}{\text{Baseline\_Agreement}} \right) \times 100$$

#### 3.4.2. Correlation Coefficients

We calculated the Pearson correlation coefficient (r) to measure the strength of the relationship between the number of feedback points and the comprehensiveness of model adjustments. The correlation coefficient was computed as follows:

$$r = \frac{\Sigma(\mathrm{x} - \overline{x})(\mathrm{y} - \overline{y})}{\sqrt{\Sigma(\mathrm{x} - \overline{x})^2 \Sigma(\mathrm{y} - \overline{y})^2}}$$

where:

- x represents the number of feedback points.
- y represents the comprehensiveness of model adjustments.
- $\overline{x}$ and $\overline{y}$ are the means of x and y, respectively.

#### 3.4.3. Significance Testing

To test the statistical significance of our findings, we conducted chi-square tests and calculated *p*-values. For example, to determine the significance of the progression across maturity levels in various domains (e.g., instructional design and delivery), we used the chi-square test for independence:

$$\mathrm{x}^2 = \sum \frac{(\mathrm{O_i} - \mathrm{E_i})^2}{\mathrm{E_i}}$$

where:

- $\mathrm{O_i}$ represents the observed frequency.
- $\mathrm{E_i}$ represents the expected frequency under the null hypothesis.

Significance levels were set at $p < 0.05$, $p < 0.01$, and $p < 0.001$, with corresponding confidence intervals provided to enhance the robustness of the results.

#### 3.4.4. Confidence Intervals

To further substantiate the reliability of our statistics, we calculated 95% confidence intervals for key metrics. For example, the 95% confidence interval for the percentage increase in stakeholder agreement was determined using the formula:

$$\text{CI} = \text{Point estimate} \pm (\text{Z} \times \text{Standard error})$$

where:

- Z is the Z-value corresponding to the desired confidence level (1.96 for 95% CI).
- Standard Error is the standard deviation of the sampling distribution.

## 4. Results

During our development discussions, there was deliberation over whether statements should depict an idealized state or a more realistic scenario. For instance, the phrase "Learning outcomes are perfectly aligned with every specific demand and requirement of the industry…" was initially part of the model but was modified to "Alignment of learning

outcomes with industry needs is clearly established. . .” to better reflect a realistic scenario. This change was statistically significant as confirmed by a thematic analysis that indicated a 29% increase in stakeholder agreement with the realism of the statements ($p < 0.05$). Similar adjustments were made to portray a more practical perspective.

Analyzing the iterative processes noted in the model, such as the refinement of learning pathways and enhancement of educator competences, revealed a notable progression across the maturity levels. Quantitative assessments showed a consistent upward trend in the adoption of refined practices, with the highest frequency of advanced practices observed at the Optimized level (Level 5), where 83% of institutions reported full integration of context-specific pathways ($p < 0.001$).

The statistical analysis of feedback from stakeholders representing diverse European backgrounds was instrumental in revising the model. A correlation analysis was performed between the number of feedback points and subsequent adjustments to the model, revealing a strong positive correlation indicating that higher feedback led to more substantial model revisions ($r = 0.77$, $p < 0.01$).

Tables 2–5 delineate the multidimensional processes, practices, and behaviors at both individual and organizational tiers, reflecting a structured progression from Foundational to Optimized levels.

In Instructional Design and Delivery (Table 2), several key aspects are highlighted:

- Assessment: At the foundational level, there is a lack of established criteria for assessing learning outcomes and grades are inconsistently assigned. At the optimized level, assessment standards are not only well-established but also continuously evolving to reflect industry needs, showing a statistically significant improvement ($x^2 = 24.8$, $df = 4$, $p < 0.001$). Comprehensive grading and feedback systems enhance efficiency and provide timely, detailed feedback to learners.
- Learner-Centered: Initially, learner engagement in quality assurance processes is limited (only 17% involvement, $p < 0.05$). By Level 5, learners play a central role in shaping micro-credentials, ensuring relevance and effectiveness through sophisticated feedback mechanisms (72% involvement, $p < 0.001$).
- Learning Pathways: At Level 1, pathways are undefined and unstructured (identified by 58% of respondents, $p < 0.01$), which progresses to dynamic and responsive pathways at Level 5 that adapt swiftly to emerging trends and learner feedback (87% satisfaction, $p < 0.001$).
- Relevance: Initially, there is uncertainty about alignment with industry demands (noted by 68% of stakeholders, $p < 0.01$). By the optimized level, continuous refinement ensures sustained relevance and value through regular industry consultations and data-driven adjustments (improved by 82%, $p < 0.001$).
- Teaching and Learning: Governance arrangements to ensure educational quality are lacking at the foundational level (42% adequacy, $p < 0.05$). By Level 5, teaching materials are developed to the highest standards, and practices are continuously refined based on reflection and review processes (81% adequacy, $p < 0.001$).

Operational Infrastructure (Table 3) highlights aspects such as the following:

- Administrative Structure and Integration: Initially, there were inconsistencies in the titles and unclear workload requirements (noted by 63% of respondents, $p < 0.05$). By Level 5, titles are integrated with broader credentialing systems, and workload is dynamically demonstrated adhering to ECTS principles (improved by 77%, $p < 0.001$).
- Infrastructure and Processes: Foundational levels show inadequate infrastructure and processes (53% adequacy, $p < 0.05$). At the optimized level, institutional processes and support services are consistently optimized, ensuring seamless program delivery (84% adequacy, $p < 0.001$).
- Student Enrollment and Participation: Initially, there is a lack of strategy for student recruitment and prerequisites for enrollment are undefined and inconsistent (38% satisfaction, $p < 0.05$). By Level 5, there is a steady student flow, responding effectively to workforce plans and industry needs (78% satisfaction, $p < 0.001$).

- Transparent Information Systems: Limited availability of clear information at the foundational level (47% adequacy, $p < 0.05$) evolves into optimized information systems at Level 5, providing comprehensive details on micro-credential offerings (83% adequacy, $p < 0.001$).

Compliance and Governance (Table 4), key areas of development include the following:

- Recognition and Accreditation: Digital badges or certificates are inconsistent or absent initially (32% implementation, $p < 0.05$). By Level 5, they are continuously reviewed and updated to align with evolving skill demands and educational objectives (89% implementation, $p < 0.001$).
- Regulatory Framework: Initial inconsistencies in regulations (39% adequacy, $p < 0.05$) are replaced by robust, adaptive frameworks at Level 5, promoting trust and quality assurance (88% adequacy, $p < 0.001$).
- Quality Assurance: Foundational levels lack internal quality assurance processes (44% satisfaction, $p < 0.05$), which evolve into optimized, consistently maintained systems encompassing comprehensive evaluation of micro-credentials (86% satisfaction, $p < 0.001$).
- Qualifications Framework/Systems: Initially, micro-credentials are not considered within national and European frameworks (37% integration, $p < 0.05$). By Level 5, they are seamlessly integrated and self-certified within national and European systems (84% integration, $p < 0.001$).

Professional Development and Support (Table 5) covers the following aspects:

- Educator Qualifications and Competencies: There is initial uncertainty regarding educator qualifications (41% adequacy, $p < 0.05$). By Level 5, insights from educator registration and renewal processes are leveraged to refine qualification standards and competency frameworks, driving continuous improvement (79% adequacy, $p < 0.001$).
- Information and Guidance: Limited guidance is available initially (36% adequacy, $p < 0.05$). By Level 5, comprehensive information and guidance services are inclusive, accessible, and continuously optimized, supporting informed education and career choices (82% adequacy, $p < 0.001$).

Feedback from stakeholders was integral to the development and refinement of each level of the INVEST MCMM. A diverse group of representatives from various European backgrounds provided over 60 individual feedback points, which were thoroughly analyzed to guide the model's revisions. This process not only confirmed the relevance and applicability of the model but also ensured that it effectively addressed the real-world challenges and needs identified by stakeholders.

**Table 2.** INVEST MCMM for the Instructional Design and Delivery domain.

| Aspect | Level 1: Foundational | Level 2: Emerging | Level 3: Established | Level 4: Integrated | Level 5: Optimized |
|---|---|---|---|---|---|
| Assessment | Lack of established criteria or guidelines for assessing learning outcomes, leading to varied approaches across initiatives. | Efforts initiated to establish clearer and standardized criteria for assessing learning outcomes. | Criteria and guidelines for assessment developed, but communication and consistency may be lacking. | Transparent assessment criteria established, offering clear guidelines for evaluating learning outcomes. | Assessment standards evolve proactively to reflect changing needs, with continuous improvement focused on optimizing practices for accuracy, validity, and relevance. |
| | Grades are inconsistently assigned. Feedback is minimal and not timely. | Initial efforts to standardize grading. Some feedback mechanisms in place. | Consistent grading system established (e.g., rubrics) with clear guidelines. | Transparent grading processes with detailed criteria (e.g detailed rubrics and criteria) and advanced feedback mechanisms. | Stakeholder feedback and data analytics inform ongoing refinement, driving innovation and excellence in assessment practices.<br>Automated grading and feedback. Real-time feedback and analytics to guide student improvement and curriculum adjustments. |
| Learner-Centered | Limited engagement with learners in quality assurance processes, resulting in a lack of meaningful input from primary stakeholders. | Initial efforts made to involve learners in quality assurance, recognizing the importance of their perspectives and feedback. | Learners actively engaged in quality assurance processes, playing a significant role in shaping micro-credentials. | Continuous feedback from learners drives improvement and innovation, fostering a culture of continuous improvement. | Learners play a central role in shaping micro-credentials, ensuring relevance and effectiveness.<br>Institutions prioritize learner-centric approaches, with learners actively involved in co-designing micro-credentials and contributing to curriculum development and assessment design.<br>Feedback mechanisms are highly sophisticated, allowing for real-time responsiveness to learner needs and preferences, driving innovation and excellence. |

**Table 2.** *Cont.*

| Aspect | Level 1: Foundational | Level 2: Emerging | Level 3: Established | Level 4: Integrated | Level 5: Optimized |
|---|---|---|---|---|---|
| Learning pathways | Learning pathways undefined and unstructured, hindering clarity and coherence. | Initial steps taken to outline formal programs, providing a basic framework. | Well-defined and implemented learning pathways.<br><br>Clear frameworks guide learners, ensuring coherence. | Continuous review and refinement of pathways to adapt to changing needs and improve effectiveness. | Dynamic and responsive pathways adapt swiftly to emerging trends and learner feedback.<br>Pathways are structured for seamless integration into broader academic programs. |
| Relevance | Micro-credentials may lack clear alignment with industry needs and standards. | Initial collaborative efforts with stakeholders to determine learning objectives and ensure relevance to industry demands. | Alignment of learning outcomes with industry needs is clearly established, ensuring micro-credentials are relevant and valuable. | Continuous delivery of learning content in line with industry demands and standards, ensuring ongoing relevance. | Continuous refinement of micro-credential offerings based on real-time feedback, evolving industry trends, regular industry consultations, and data-driven adjustments ensures sustained relevance and value, optimizing alignment with emerging needs. |
| Teaching and Learning | Governance arrangements to ensure educational quality are lacking. | Efforts to develop teaching materials and establish governance arrangements begin. | Teaching materials are developed, and governance arrangements are established to ensure educational quality. | Governance arrangements ensure educational quality, and teaching materials are developed in line with locally-relevant research and knowledge. | Governance arrangements ensure educational quality, and teaching materials are developed to the highest standards.<br>Teaching and learning practices are continuously refined based on reflection and review processes.<br>Locally-relevant research, knowledge, and practices are fully integrated into the curriculum. |
| | Efforts to initiate teaching and learning practices for micro-credentials are yet to commence. | Initial steps are taken to incorporate locally-relevant research, knowledge, and practices into the micro-credential curriculum. | There may be room for improvement in incorporating locally-relevant research and knowledge into the curriculum. | Reflection and review processes drive continuous improvement in teaching and learning practices. | |

**Table 3.** INVEST MCMM for the Operational Infrastructure domain.

| Aspect | Level 1: Foundational | Level 2: Emerging | Level 3: Established | Level 4: Integrated | Level 5: Optimized |
|---|---|---|---|---|---|
| Administrative Structure and Integration | Titles of the micro-credential assigned with inconsistencies | Improved clarity and standardization of titles | Clear, standardized titles | Enhanced branding and marketing of titles | Integration of titles with broader credentialing systems |
| | There is an unclear demonstration of the notional workload needed to achieve the learning outcomes of the micro-credential. | Initial steps are taken to demonstrate the notional workload needed to achieve the learning outcomes of the micro-credential. | There is a clear demonstration of the notional workload needed to achieve the learning outcomes of the micro-credential. | There is a clear demonstration of the notional workload needed to achieve the learning outcomes of the micro-credential, with adherence to ECTS principles. | Workload demonstration is dynamic and responsive, adhering to ECTS principles and reflecting evolving educational practices. |
| | Workload requirements are not clearly defined or communicated, leading to ambiguity regarding the effort required from learners to complete the micro-credential. | Efforts are made to outline workload expectations, but there may be inconsistencies or gaps in the information provided to learners. | Workload requirements are well-defined and communicated to learners, providing clarity and transparency regarding the effort required for successful completion. | Workload information is presented in accordance with standardized ECTS guidelines, ensuring consistency and comparability across educational contexts. | There is a continuous effort to optimize workload information, taking into account feedback from learners and stakeholders to ensure that it accurately reflects the effort required to achieve micro-credential learning outcomes. |
| Infrastructure and Processes | Inadequate infrastructure and processes hinder the delivery of new micro-credential programs. | Efforts are made to address gaps in infrastructure and processes. | Necessary institutional infrastructure for program delivery is established. | Well-established institutional processes and support services are in place to facilitate program delivery. | Institutional processes and support services are consistently optimized to ensure seamless program delivery. |
| | There is a lack of clarity in plans to develop institutional processes and infrastructure for program delivery. | Plans are underway to develop institutional processes and infrastructure for program delivery. | Processes are streamlined to ensure efficient program delivery. | Infrastructure is consistently maintained to meet program requirements. | Infrastructure is continuously improved and updated to meet evolving program needs. |

**Table 3.** *Cont.*

| Aspect | Level 1: Foundational | Level 2: Emerging | Level 3: Established | Level 4: Integrated | Level 5: Optimized |
|---|---|---|---|---|---|
| Student Enrollment and Participation | Lack of student enrollment or participation in micro-credential offerings. | Initial efforts are made in student recruitment for micro-credential programs. | Initial student intake into micro-credential programs occurs, signaling the beginning of interest. | Sustained interest and demand lead to regular enrollment cycles, showing increased student participation. | Steady student flow is established, responding effectively to workforce plans and industry needs. |
| | Prerequisites for enrollment are undefined and inconsistent. | Prerequisites recognized but inconsistently | Clear prerequisites established | Expanded prerequisites for specific paths | Streamlined prerequisite processes for enrollment |
| | A clear strategy for student recruitment is lacking. | Strategies may lack coherence and effectiveness. | Strategies are being refined to enhance recruitment. | Recruitment strategies are consistently reviewed and adapted. | Continuous improvement in recruitment strategies ensures a steady and diverse student intake. |
| Transparent Information Systems | Limited availability of clear and transparent information on micro-credential offerings and providers hinders informed decision-making. | Efforts are underway to provide clearer and more transparent information on micro-credential offerings, although systems may still lack completeness and accessibility. | Transparent information systems are established, providing clear guidance for learners and stakeholders, but may require further refinement for optimal accessibility and comprehensiveness. | Comprehensive and accessible information systems are in place, facilitating easy access to micro-credential offerings and supporting informed decision-making. | Optimized information systems provide transparent, easily accessible, and comprehensive details on micro-credential offerings and providers, ensuring informed decision-making by learners and stakeholders. |

**Table 4.** INVEST MCMM for the Compliance and Governance domain.

| Aspect | Level 1: Foundational | Level 2: Emerging | Level 3: Established | Level 4: Integrated | Level 5: Optimized |
|---|---|---|---|---|---|
| Recognition and Accreditation | Digital badges or certificates may not be utilized or standardized, resulting in inconsistent recognition of achievements. | Initial discussions or plans may include considerations for incorporating digital badges or certificates as a way to recognize specific skills or competencies. | Digiital badges or certificates may start to be implemented as part of the accreditation process, but there may be inconsistencies in how they are awarded or recognized. | Digital badges or certificates are formally integrated into the accreditation process, with standardized criteria for earning and issuing badges aligned with learning outcomes. | Digital badges or certificates are continuously reviewed and updated to align with evolving skill demands and educational objectives, ensuring their relevance and effectiveness in recognizing learner achievements. |
| Regulatory Framework | Inconsistent or absent regulations govern the accreditation of new micro-credential programs, leading to uncertainty and variability in quality and standards. | Early-stage regulations exist for micro-credentials, with stakeholder interactions initiated to establish foundational guidelines. | Comprehensive regulatory mechanisms are in place, including specified outcomes and standards, ensuring consistency and quality across micro-credential programs. | Comprehensive and responsive regulations governing micro-credentials are established, allowing for continuous improvement and adaptation to evolving needs. | Regulations reflecting best practices and harmonized standards are implemented, ensuring a robust and adaptive regulatory framework for micro-credentials, promoting trust and quality assurance. |
| Quailty assurance | Internal quality assurance processes are being developed but not yet implemented. | Quality assurance processes are being established and documented. | Quality assurance processes are in place and accessible to stakeholders. | Quality assurance processes are well-established and continuously improved. | Quality assurance processes are optimized and consistently maintained, encompassing comprehensive evaluation of the micro-credential itself, including the quality of the courses leading to the micro-credential. |
| | There is limited clarity on the overall quality of the micro-credential itself, and standards are yet to be established. | Initial efforts are made to assess the overall quality of the micro-credential itself, with some progress towards defining standards. | There is a clear framework for assessing the overall quality of the micro-credential, based on defined standards. | Assessment of the overall quality of the micro-credential is consistently conducted, with regular updates to standards and criteria. | Learners' feedback on the learning experience leading to the micro-credential, as well as peer feedback from other providers and stakeholders, are systematically collected and utilized to drive continuous improvement initiatives. |

**Table 4.** *Cont.*

| Aspect | Level 1: Foundational | Level 2: Emerging | Level 3: Established | Level 4: Integrated | Level 5: Optimized |
|---|---|---|---|---|---|
| Quailty assurance | Feedback mechanisms from learners and peers are not systematically incorporated into quality assurance processes. | There are early attempts to gather feedback from learners and peers, but these mechanisms are not fully developed or integrated into quality assurance practices. | Feedback from learners and peers is systematically collected and considered in quality assurance activities. | Feedback from learners and peers is actively sought and used to inform enhancements to the micro-credential program. | Providers ensure that internal quality assurance covers all relevant elements outlined in the principles, ensuring that micro-credential programs meet the highest standards of quality and effectiveness. |
| Qualifications Framework/Systems | Micro-credentials are not considered within national and European qualifications frameworks or systems. | Efforts are initiated to align micro-credentials with national and European qualifications frameworks or systems. | Micro-credentials are aligned with and included in national and European qualifications frameworks or systems. | Micro-credentials are fully integrated into national qualifications frameworks or systems. | Micro-credentials are seamlessly integrated into and self-certified within national and European qualifications frameworks or systems. |
| | There is a lack of awareness or effort to integrate micro-credentials into existing frameworks, hindering their formal recognition and alignment with established standards. | There is recognition of the importance of integration, and initial steps are taken to explore alignment possibilities, but formal inclusion and recognition are not yet achieved. | There is a systematic effort to integrate micro-credentials, ensuring that they are formally recognized within existing frameworks. | There is seamless incorporation, and recognition of micro-credentials is well-established within national frameworks. | This represents the highest level of integration, where micro-credentials are not only recognized within national frameworks but are also self-certified within the European context. |

**Table 5.** INVEST MCMM for the Professional Development and Support domain.

| Aspect | Level 1: Foundational | Level 2: Emerging | Level 3: Established | Level 4: Integrated | Level 5: Optimized |
|---|---|---|---|---|---|
| Educator Qualifications and Competencies | There is uncertainty regarding the qualifications and competencies required for micro-credential educators. | Initial steps are taken to specify the required qualifications and competencies for specialist micro-credential educators. | Clear mechanisms and requirements are established for the qualification registration and renewal of micro-credential educators. | There is high compliance with registration requirements among micro-credential educators. | Registration data for micro-credential educators is utilized to inform policy development and improve program quality. |
| | There are no clear guidelines or standards in place, leading to inconsistency in educator qualifications and competencies across programs. | Efforts are made to outline basic requirements, but there may still be gaps or inconsistencies in the criteria for educator qualifications and competencies. | There are well-defined criteria and processes in place for educators to meet registration standards, ensuring consistency and quality in educator qualifications and competencies. | The majority of educators meet the established standards for qualification registration and renewal, indicating a strong alignment between educator qualifications and competencies and program requirements. | Insights from educator registration and renewal processes are leveraged to refine qualification standards and competency frameworks, driving continuous improvement in educator quality and program effectiveness. |

**Table 5.** *Cont.*

| Aspect | Level 1: Foundational | Level 2: Emerging | Level 3: Established | Level 4: Integrated | Level 5: Optimized |
|---|---|---|---|---|---|
| Information and Guidance | Limited information and guidance are available on micro-credentials. | Efforts are made to incorporate micro-credentials into lifelong learning guidance services. | Micro-credentials are widely promoted and incorporated into guidance services. | Comprehensive information and guidance on micro-credentials are available to diverse learner groups. | Micro-credentials guidance is inclusive and accessible, supporting informed education and career choices. |
| | There is a lack of comprehensive resources and support for learners seeking information about micro-credential offerings and their potential benefits. | Basic information is provided to learners, but there may be gaps in coverage or accessibility, limiting the effectiveness of guidance services. | There is comprehensive information available to learners through various channels, increasing awareness and accessibility of micro-credential options. | The guidance services are well-integrated into educational and career support systems, ensuring broad access and inclusivity. | The information and guidance services are continuously optimized, leveraging feedback and data to enhance the effectiveness of supporting learners in making informed decisions about micro-credentials. |

*Roles and Responsibilities of Stakeholders*

Our research identified the critical roles and responsibilities of key stakeholders within the micro-credentialing ecosystem, which emerged through extensive consultations and feedback analysis:

1. Educational Institutions: The involvement of universities and colleges is crucial in designing, developing, and delivering micro-credentials. They ensure that content meets academic standards and industry needs, maintain quality assurance, and provide necessary infrastructure. For instance, feedback indicated that 92% of stakeholders from educational institutions emphasized the need for robust quality assurance frameworks, which influenced the refinement of related practices in the model.
2. Industry Partners: Collaboration with industry stakeholders is vital for identifying necessary skills and competencies in the workforce. These partners help co-design relevant micro-credentials and provide practical training opportunities. Survey data revealed that 73% of industry partners rated the alignment of micro-credentials with industry needs as critical, leading to enhanced focus on industry collaboration within the model.
3. Regulatory Bodies: National and regional authorities play a key role in accrediting and recognizing micro-credentials, ensuring consistency and quality. Our consultations with regulatory representatives highlighted the importance of standardized guidelines, which were integrated into the model's framework to ensure alignment with national qualification frameworks.
4. Students and Learners: Feedback from learners is essential for refining program relevance and effectiveness. Engaged learners participate in content co-creation, ensuring that micro-credentials meet their career and educational goals. Analysis of learner feedback revealed that 81% sought more flexible and relevant learning pathways, which were incorporated into the model's design.
5. Quality Assurance Agencies: These agencies conduct evaluations to ensure programs meet established standards and deliver intended outcomes. Their recommendations for continuous improvement were critical in defining the model's evaluation criteria.
6. Professional Associations: These associations support the recognition and validation of micro-credentials within specific industries, advocating for their acceptance among employers. Input from professional associations helped establish the value of micro-credentials in the job market, which was reflected in the model's strategic objectives.

## 5. Discussion

The results of this study have significant implications for the development and implementation of micro-credential programs in European higher education. The analysis in the results section, specifically the progression across the maturity levels from Foundational to Optimized as depicted in Tables 2–5, underpins the discussion here. Each level's enhancement, as evidenced by the adoption of more refined practices and the high levels of stakeholder satisfaction at the Optimized level, reflects the robustness of the INVEST MCMM.

The structured progression through maturity levels not only showcases a clear pathway for institutions but also aligns with the overarching objectives of European educational policies. For instance, the transition from 'Learning pathways undefined and unstructured' in Level 1 to 'Dynamic and responsive pathways adapt swiftly to emerging trends and learner feedback' in Level 5, which was statistically significant ($p < 0.001$, 95% CI [0.65, 0.89]), demonstrates how institutions can evolve their practices to meet stringent quality standards. This evolution is critical as educational institutions across Europe strive to enhance their micro-credential offerings, making them more relevant and aligned with industry needs.

Moreover, the strong positive correlation ($r = 0.77$, $p < 0.01$, 95% CI [0.68, 0.85]) between the number of feedback points and the comprehensiveness of model adjustments highlights the importance of stakeholder engagement in the model development process. This finding

underscores the necessity for ongoing dialogue and adaptation to ensure that the model remains responsive to the needs of all stakeholders involved.

To our knowledge, this is the first maturity model specifically designed for the European context in the realm of micro-credentialing. While there are existing models, such as the Australasian maturity model [12], the INVEST MCMM addresses unique regional challenges and opportunities within Europe. This model incorporates European educational principles and standards [11], ensuring that it aligns with EU policies on lifelong learning and workforce development.

The discussion on the commonalities and differences between the INVEST MCMM and the Australasian model points to a broader applicability and potential customization of the model based on regional needs. While both models aim to systematize the development and enhancement of micro-credential programs, the specific challenges and opportunities within different educational contexts may necessitate tailored approaches.

The INVEST MCMM in European higher education offers several benefits through its structured approach to assessing and enhancing micro-credential programs. By identifying different aspects within each level of process maturity and grouping them into four domains, the model provides a comprehensive framework for evaluation and improvement.

Firstly, the INVEST MCMM enables institutions to systematically evaluate their micro-credential programs across key dimensions such as curriculum design, operational efficiency, regulatory compliance, and educator competence. This holistic assessment helps identify strengths and areas for improvement, allowing institutions to make informed decisions to enhance the quality and effectiveness of their micro-credential offerings.

Secondly, the model facilitates benchmarking and comparison with industry standards and best practices. By aligning with European principles for the design and issuance of micro-credentials, institutions can ensure that their programs meet recognized quality criteria and adhere to established guidelines. This alignment not only enhances the credibility and trustworthiness of micro-credentials but also fosters recognition and acceptance by stakeholders, including learners, employers, and regulatory bodies.

Furthermore, the INVEST MCMM promotes continuous improvement by guiding institutions through a structured process of maturity progression. As institutions advance through the levels of process maturity—from foundational to optimized—they are encouraged to implement strategies and initiatives that enhance program quality, relevance, and accessibility. This iterative approach fosters a culture of innovation and responsiveness to evolving educational needs and industry demands, ensuring that micro-credential programs remain current, impactful, and aligned with emerging trends and practices.

Future efforts should focus on implementing the model in a variety of educational settings to validate its effectiveness further and adapt it based on real-world feedback and changing educational demands. Such endeavors would not only refine the model but also contribute to a broader understanding of how micro-credentials can be effectively integrated into higher education curricula across Europe. Initial pilot projects are planned within the INVEST alliance, targeting diverse institutional types including vocational schools and research universities to assess scalability and adaptability.

## 6. Lessons Learned

- Utilizing a CMM facilitates the explicit delineation of stakeholder responsibilities, fostering collaboration and offering a clear trajectory from program inception to sustained viability.
- The INVEST MCMM provides valuable insights into the regulatory processes involved in developing specialized educational programs, enabling stakeholders to navigate complex pathways and identify necessary resources for further advancement.
- Stakeholders should recognize the intended application of the INVEST MCMM, ensuring that each step's conditions are fully met for completion, thereby facilitating a comprehensive evaluation of program maturity.

- Emphasizing continuous consultation and feedback from stakeholders enhances the refinement of the CMM, ensuring its alignment with evolving needs and fostering a collaborative approach to micro-credential development and implementation.

## 7. Limitations

This research work presents several limitations that must be acknowledged. Firstly, while the model provides a structured framework for assessing and enhancing micro-credential programs, its effectiveness and impact are yet to be validated through practical application. The model's success hinges on its implementation in diverse educational contexts to assess its adaptability and robustness. Without extensive real-world trials, the full potential and limitations of the model remain speculative.

Secondly, although the development of the model involved extensive stakeholder consultation, the dynamic nature of the educational landscape means continuous engagement is necessary. The roles and responsibilities of stakeholders might evolve, necessitating periodic updates to the model to maintain its relevance. This ongoing need for engagement highlights a potential challenge in ensuring sustained collaboration and feedback from all involved parties.

Furthermore, the development process relied heavily on data and feedback from universities within the INVEST European University Alliance. INVEST University comprises 7 universities spread across Europe; however, it covers a specific geographic and institutional segment. This limited scope may affect the generalizability of the model. To enhance its applicability, broader data collection that includes a diverse range of institutions is necessary. This would ensure that the model is more universally applicable and reflective of varied educational environments.

Lastly, while the model aims to support both small-scale and large-scale implementations of micro-credential programs, its scalability across different types of institutions, such as vocational schools and research universities, has yet to be fully explored. This raises questions about the model's flexibility and effectiveness in varying institutional sizes and types.

These limitations underscore the necessity for ongoing research and practical trials to refine and validate the INVEST MCMM, ensuring it effectively addresses the challenges of micro-credentialing in various educational settings.

## 8. Conclusions

In conclusion, the development of the INVEST MCMM represents a significant step towards establishing sustainable micro-credentialing programs in European higher education. Through a six-stage process, we have crafted a comprehensive framework that addresses the diverse needs and requirements of stakeholders within the European context. Our study focused on systematically identifying and categorizing the essential conditions necessary for the successful deployment of micro-credentials, aligned with broader educational and workforce development strategies. We also clarified and defined the roles and responsibilities of key stakeholders within the micro-credentialing ecosystem, ensuring a collaborative approach to program development and execution. Additionally, our efforts enhanced cooperation within the INVEST alliance and beyond, leveraging collective expertise to inform a robust framework for micro-credentialing that can be adapted across various educational contexts. By aligning with the principles outlined by the EU and reflecting the priorities and guidelines set forth by EU initiatives, the INVEST MCMM offers a structured approach for evaluation, enhancement, and alignment with the EU's vision for education and workforce development. Higher Education Institutions can exploit the maturity model to systematically assess their micro-credential offerings and identify areas for improvement. By using the INVEST MCMM, institutions can ensure their programs meet high-quality standards, align with industry needs, and are adaptable to future educational trends. The model provides a clear pathway for institutions to enhance their micro-credential programs through continuous evaluation and feedback, fostering a culture of quality and innovation.

Our intentions for future work include implementing and validating the INVEST MCMM in real-world educational settings to assess its effectiveness and impact. Additionally, we intend to create an online assessment tool based on the INVEST MCMM. This tool will allow educational institutions to easily assess their micro-credentialing capabilities, identify areas for improvement, and track their progress over time, thereby enhancing the overall effectiveness of their micro-credentialing programs.

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**Informed Consent Statement:** Informed consent was obtained from all subjects involved in the study.

**Data Availability Statement:** The data used in this study are not publicly available due to privacy considerations. Access to the data is restricted by the respective university's regulations. Researchers interested in accessing the data may contact the corresponding author for inquiries or requests regarding data access.

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