

# Beyond Badges: A Bibliometric Exploration of Micro-Credential Research in Higher Education (2015 – 2025)

## ABSTRACT

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Micro-credentials have emerged as a key innovation in higher education, offering short, flexible, and skills-oriented certifications that support employability and lifelong learning. Despite their growing adoption, persistent challenges related to quality assurance, interoperability, and governance continue to fragment practice across pedagogical, technological, and policy domains. This study maps the intellectual landscape of micro-credential research between 2015 and 2025 through a bibliometric analysis of 571 Scopus-indexed publications, following rigorous screening and eligibility procedures. Citation indicators and network visualisations were generated using Bibliomagika® (Ahmi, 2024) and VOSviewer. The findings reveal sustained and accelerating growth in scholarly output, particularly after 2019, indicating increasing institutional engagement with flexible credentialing models. However, research productivity and influence remain unevenly distributed, with the United States dominating output and citation impact, while countries such as Australia demonstrate higher citation efficiency. Thematic analysis identifies five major clusters: pedagogical foundations and competency-based learning, learner engagement and assessment practices, digital credentialing and technological infrastructure, instructional innovation and educational ecosystems, and alternative credential pathways and employability. Importantly, the convergence of keyword and co-authorship analyses shows that the field is not only conceptually segmented but also structurally fragmented, with collaboration concentrated within clusters and limited integration across domains. The findings indicate that micro-credential research is pedagogically anchored, technologically emerging, institutionally evolving, and economically relevant yet weakly integrated with employability discourse. This configuration reflects a field developing through parallel trajectories rather than as a cohesive system. By integrating Diffusion of Innovation (DOI) and Resource-Based View (RBV) perspectives, this study advances understanding of micro-credentials as a socio-technical-policy framework shaped by asynchronous diffusion processes and unequal resource configurations. While the field is transitioning from early exploration towards structured consolidation, its continued advancement depends on strengthening integration across pedagogical, technological, and policy domains. The study provides evidence-informed insights for educators, institutions, and policymakers to support the development of coherent, scalable, and inclusive micro-credential systems aligned with Sustainable Development Goal 4 (United Nations, 2023).

**Keywords:** Bibliometric analysis, employability, higher education, lifelong learning, micro-credentials, research fragmentation, socio-technical-policy framework, thematic clustering

## 1. Introduction

Over the past decade, higher education systems have undergone significant transformation driven by globalisation, technological advancements, and increasing demand for flexible learning pathways. Ahsan et al. (2023) and Ngoc Ha et al. (2025) noted that these changes have transformed learner expectations and institutional structures, positioning micro-credentials as a prominent educational innovation. Also referred to as modular and competency-based credentials, micro-credentials are designed to enhance employability, promote lifelong learning, and adapt to evolving labour market demands (Ahsan et al., 2023; Ngoc Ha et al., 2025). Micro-credentials are typically offered online and are used to verify focused skills and competencies that meet industry demands and lifelong learning goals (Oliver, 2019; Tamoliūnė et al., 2023).

The growing significance of micro-credentials was further reinforced by Varadarajan et al. (2023), who pointed out that the COVID-19 pandemic made their importance more apparent. The rapid adoption of online learning during this period exposed the limitations of traditional, time-bound qualifications, particularly their inflexibility in addressing rapidly evolving skills needs. As a result, micro-credentials are being positioned by both governments and universities as strategic tools to broaden access to education and support large-scale reskilling efforts. Reflecting on this shift, national policy frameworks and institutional innovation agendas have begun to include these credentials (Moodie & Wheelahan, 2021; Ngoc Ha et al., 2025). Despite this growing momentum, concerns persist regarding their credibility (Oliver, 2019), scalability, and long-term sustainability (Ahsan et al., 2023; Ngoc Ha et al., 2025).

From a research perspective, the body of literature on micro-credentials has expanded rapidly; however, it remains conceptually and methodologically fragmented. Existing studies vary widely in scope, dataset size, and analytical approach, resulting in limited cumulative knowledge development (Ahsan et al., 2023; Ngoc et al., 2022; Tamoliūnė et al., 2023). While some studies focus on specific themes, technologies, or institutional contexts, others adopt descriptive or narrative approaches that do not systematically capture the structural evolution of the field (Cudney et al., 2022; Selvaratnam & Sankey, 2021). Consequently, there is limited understanding of how micro-credential research has developed over time, how knowledge production is distributed across regions and institutions, and which themes and publications have exerted the greatest intellectual influence (Narong, 2025; Rullyana et al., 2025). This fragmentation is further reflected in the dispersion of micro-credential research across multiple domains, including pedagogy, technology, and policy, with limited integrative synthesis linking these dimensions (Martín-Ramos et al., 2025; Vordenberg et al., 2024). Ahsan et al. (2023) and Tamoliūnė et al. (2023) further highlighted that such fragmentation constrains the development of coherent theoretical explanations and weakens the capacity of research to inform evidence-based policy and institutional strategies.

Although bibliometric approaches have been widely applied in related domains such as Massive Open Online Courses (MOOCs) and Open Educational Resources (OER), where they have been used to map intellectual structures, thematic evolution, and collaboration networks (Irwanto et al., 2023; Krishnan et al., 2025), their application to micro-credential research remains limited and methodologically inconsistent. Existing bibliometric studies often rely on single databases, small or narrowly defined datasets, or descriptive trend analyses, without integrating temporal patterns, thematic structures, collaboration networks, and intellectual influence within a unified analytical framework (Narong, 2025; Yüksel, 2025; Strielkowski, 2025; Johan et al., 2025; Rullyana et al., 2025). As a result, the intellectual structure and global development of micro-credential research remain insufficiently understood.

In order to address these limitations, this study adopts a bibliometric approach to systematically examine the evolution of micro-credential research between 2015 and 2025. Using the Scopus database for its extensive coverage of peer-reviewed literature, the study integrates performance analysis and network

visualisation techniques through Bibliomagika® (Ahmi, 2024) and VOSviewer (Van Eck & Waltman, 2014) to analyse publication trends, research productivity, thematic clusters, and intellectual influence. This approach enables a comprehensive and replicable mapping of the field's development.

To strengthen explanatory power, this study is guided by Diffusion of Innovation (DOI) theory and the Resource-Based View (RBV) (Guo & Huang, 2024). DOI is employed to interpret temporal patterns of research development, particularly the emergence, acceleration, and consolidation of scholarly output (Guidolin & Manfredi, 2022; Takahashi et al., 2024). RBV, in turn, is used to explain disparities in research productivity and influence across countries and institutions, based on differences in resources such as funding, technological infrastructure, and research capacity (Vargo et al., 2020). These theoretical lenses are integrated within a socio-technical-policy perspective, which conceptualises micro-credential research as an ecosystem shaped by the interaction of pedagogical practices, technological infrastructures, and policy frameworks.

Accordingly, this study addresses the following research questions:

1. What are the publication trends and evolutionary patterns of micro-credential research between 2015 and 2025?
2. What are the patterns and disparities in research output and impact across countries, institutions, and authors in micro-credential research?
3. What are the prevailing thematic clusters in micro-credential research?
4. Which publications have exerted the greatest intellectual influence on the field?

By addressing these questions, this study provides an empirically grounded and theory-informed understanding of the intellectual landscape of micro-credential research. It contributes to the field by offering an integrated analytical perspective that moves beyond descriptive accounts towards a systematic explanation of its development, thereby supporting more informed research, policy, and institutional practices.

## 2. Literature Review

### 2.1 Conceptualising Micro-Credentials as a Multi-Dimensional Construct

Micro-credentials are commonly defined as short, targeted certifications that validate specific knowledge or skill sets outside traditional degree programmes (Abdul Halim et al., 2024; UNESCO, 2022). Their modular and stackable nature enables learners to accumulate smaller units of learning that can contribute towards broader qualifications, thereby supporting flexible and lifelong learning pathways (Ngoc Ha et al., 2025; Tamoliūnė et al., 2023). In addition, micro-credentials are often delivered through digital platforms and may take various forms, including alternative certificates and digital badges (Ahsan et al., 2023; Oliver, 2019).

Despite this general agreement, the literature reveals considerable conceptual variation. Some studies categorise micro-credentials under broader constructs such as “alternative credentials” (Abdul Halim et al., 2024), while others associate them closely with digital badges and platform-based certification systems (Santally et al., 2024). This variation extends beyond terminology and reflects deeper epistemological differences across disciplines. Educational research tends to conceptualise micro-credentials as pedagogical tools grounded in competency-based and learner-centred approaches, whereas technology-oriented studies frame them as digital artefacts embedded within platform ecosystems and verification infrastructures such as blockchain. Policy-oriented scholarship, in contrast, positions micro-credentials within governance, quality assurance, and labour market alignment frameworks (UNESCO, 2022).

Regional perspectives further illustrate this diversity. Asian scholarship often emphasises workforce reskilling and employability, European research focuses on policy integration and standardisation, while

Anglo-American studies highlight micro-credentials as mechanisms for enhancing labour market competitiveness (Ngoc Ha et al., 2025; Santally et al., 2024). While this diversity demonstrates the adaptability of micro-credentials across contexts, it also contributes to conceptual fragmentation, complicating cross-study comparison and limiting coherent policy alignment (UNESCO, 2022). These variations reinforce the need for integrative analytical approaches that capture the interaction between pedagogical, technological, and policy dimensions.

## 2.2 Micro-Credentials in Higher Education: Opportunities, Tensions, and Structural Inequalities

The integration of micro-credentials into higher education has generated both optimism and critical debate. On one hand, micro-credentials are recognised for their potential to enhance employability, widen participation, and provide flexible pathways that complement traditional qualifications (Ahsan, 2023; Santally et al., 2024). Evidence from sectors such as technology, healthcare, and business demonstrates that they can support professional development and increase learner motivation (Varadarajan et al., 2023). However, the literature consistently highlights persistent challenges related to quality assurance, standardisation, and recognition. Concerns regarding employer acceptance, comparability across institutions, and long-term credibility remain central to ongoing debates (Moodie & Wheelahan, 2021; Ngoc Ha et al., 2025). These issues are not merely operational but reflect deeper structural tensions within higher education systems. Adoption patterns further demonstrate uneven development across regions. In Australia and the European Union, structured frameworks have been established to guide implementation, whereas in many other contexts micro-credentials remain at pilot or exploratory stages with inconsistent certification processes (Lang, 2023; Šarcevic, 2024). This uneven development reflects broader structural inequalities in global higher education.

From a Resource-Based View (RBV) perspective, these disparities can be attributed to differences in access to critical resources such as funding, technological infrastructure, institutional capacity, and policy support (Vargo et al., 2020). Institutions with stronger resource endowments are better positioned to implement and scale micro-credentials, thereby reinforcing their dominance in both practice and research output. Complementing this, Diffusion of Innovation (DOI) theory explains these variations as different stages of adoption, where early adopters shape global discourse while others remain in emerging or transitional phases (Guidolin & Manfredi, 2022; Takahashi et al., 2024). These perspectives collectively highlight that the development of micro-credentials is structurally conditioned by both resource availability and diffusion dynamics.

## 2.3 Fragmentation and Limitations in Bibliometric Research

Despite the rapid expansion of micro-credential research, the field lacks a systematically mapped intellectual structure. Much of the existing literature remains descriptive, focusing on opportunities and challenges without examining patterns of knowledge production, collaboration networks, or intellectual influence (Ahsan, 2023; Tamoliūnė et al., 2023). Recent bibliometric and review-based studies have attempted to examine the development of micro-credential research; however, a comprehensive and integrative understanding remains limited due to variations in scope, dataset size, and analytical approaches. Existing studies range from small-scale analyses focusing on specific domains, such as artificial intelligence in Open and Distance Learning (Harizan & Ally, 2025), to larger-scale investigations identifying thematic clusters and publication trends (Strielkowski, 2025; Narong, 2025). While these studies provide useful insights, they are often constrained by reliance on single databases, geographically concentrated datasets, or predominantly descriptive analytical approaches (Rullyana et al., 2025; Yüksel, 2025; Johan et al., 2025). Even large-scale analyses, such as Savita et al. (2025), remain limited by their dependence on author-provided keywords and limited contextual interpretation.

Notably, existing literature is dominated by systematic and narrative reviews rather than comprehensive bibliometric analyses, indicating an imbalance between qualitative synthesis and quantitative mapping approaches (Alharthi, 2025; Yildirim, 2025; Warnars, 2024; Ahsan, 2023; Alsobhi, 2023; Tamoliūnė et al., 2023). These limitations highlight the absence of a methodologically consistent and integrative

bibliometric study capable of capturing temporal evolution, thematic structures, collaboration networks, and intellectual influence within a unified analytical framework. As shown in Table 1, these studies vary considerably in dataset size, database selection, and analytical techniques, further reinforcing the fragmented nature of the field. This methodological inconsistency constrains cumulative knowledge development and limits the ability to generate theory-driven insights. Without systematic mapping, it remains difficult to identify dominant research domains, emerging trends, and structural disparities, thereby reducing the practical relevance of existing research for policy and institutional decision-making.

Table 1. Summary of Selected Bibliometric Studies on Micro-Credentials

Study	Scope & Dataset	Methodology	Key Findings	Limitations	Contribution to Current Study
Harizan & Ally (2025)	46 articles examining AI integration in micro-credentials within Open and Distance Learning (ODL)	Hybrid bibliometric and thematic analysis	AI integration remains fragmented, limiting field consolidation; identifies key research gaps and future directions	Narrow focus on AI and ODL; small dataset (n = 46)	Bridges theory–practice gap; informs industry applications and future research directions
Strielkowski (2025)	608 Scopus-indexed publications (1992–2025)	Bibliometric network analysis using VOSviewer	Identifies six thematic clusters, including motivation, alternative credentialing, lifelong learning, AI-enhanced learning, teacher professional development, and equity	Single database (Scopus); geographical concentration in developed regions	Highlights role of micro-credentials in AI-driven higher education; emphasises need for digital infrastructure
Narong (2025)	401 Scopus-indexed documents	Systematic analysis with descriptive statistics, keyword co-occurrence, and science mapping	Field remains in early stage; strong concentration in developed countries; focus on STEM, healthcare, and blockchain	Scopus-only dataset; limited maturity of knowledge base	Establishes post-pandemic research baseline and thematic benchmarks
Rullyana et al. (2025)	551 publications (Scopus and	PRISMA, performance analysis, and	Rapid growth after 2018; dominant	Emphasis on trend mapping;	Identifies global trends and underexplored

	WoS, 2014–2024)	science mapping (VOSviewer, RStudio)	contributions from the United States; themes include blockchain, gamification, and personalised learning	limited conceptual integration	areas such as information literacy and curriculum integration
Yüksel (2025)	85 WoS-indexed articles	Bibliometric and keyword co-occurrence analysis using VOSviewer	Strong association with higher education, employability, and digital badges; identifies five thematic clusters	Limited dataset; restricted to English WoS publications	Provides higher education–focused insights and identifies key research areas
Johan et al. (2025)	85 Scopus-indexed journal articles (2015–2023)	Bibliometric and performance analysis using VOSviewer	Social sciences dominate the field (54.2%); major contributors include the US, Australia, and Canada; limited collaboration networks	Scopus-only dataset; narrow disciplinary focus; inclusion of in-press articles	Highlights lack of research collaboration and need for interdisciplinary engagement
Savita et al. (2025)	3,743 WoS-indexed publications (1970–2024)	Bibliometric and text analytics (Python/pyBibX), word cloud, and co-occurrence analysis	Significant growth between 2014–2020; key themes include motivation, digital badges, and ethical data concerns	Reliance on author keywords; limited contextual and regional analysis	Provides longitudinal mapping and highlights need for ethical governance and impact evaluation

Note(s): MCs = micro-credentials; WoS = Web of Science; ODL = Open and Distance Learning.

Accordingly, bibliometric analysis offers a robust and replicable approach to address these limitations by enabling the systematic identification of intellectual structures, thematic patterns, and collaboration networks (Van Eck & Waltman, 2014).

## 2.4 Conceptual Framework: A Socio-Technical–Policy Perspective

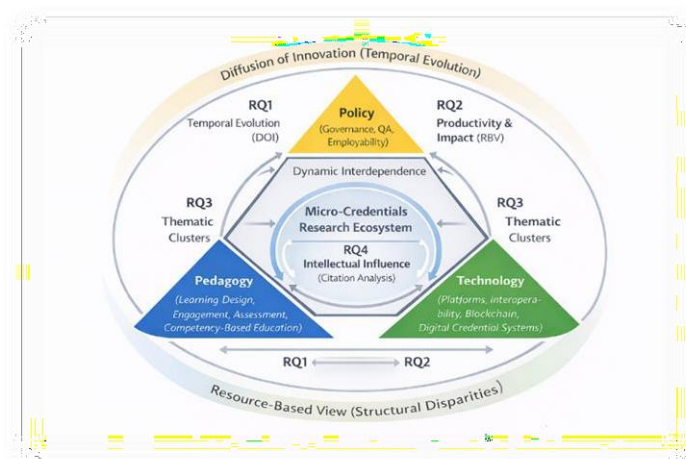
In order to address the fragmentation identified in the literature, this study adopts a socio-technical–policy framework that conceptualises micro-credential research as an interconnected ecosystem shaped

by the interaction of pedagogical, technological, and policy dimensions. This perspective recognises that micro-credentials operate as a system of interdependent components rather than isolated elements. The pedagogical dimension encompasses learning design, learner engagement, and assessment practices that underpin micro-credential development. The technological dimension focuses on digital platforms, interoperability, and credential verification systems, including emerging technologies such as blockchain. The policy dimension includes governance structures, quality assurance mechanisms, and employability alignment that influence institutional adoption and recognition. These dimensions are mutually constitutive and often develop unevenly. Technological advancements may outpace policy frameworks, while pedagogical innovation may be constrained by institutional governance structures. This interdependence highlights the need for an integrative analytical approach that captures both alignment and imbalance within the system.

This framework is integrated with Diffusion of Innovation (DOI) and the Resource-Based View (RBV) to enhance its explanatory capacity. DOI accounts for the temporal evolution of micro-credential research, particularly the progression from emergence to consolidation phases (Guidolin & Manfredi, 2022; Takahashi et al., 2024), while RBV explains disparities in research productivity and influence by linking them to variations in resource availability and institutional capacity (Vargo et al., 2020). These perspectives provide a comprehensive analytical lens. While the socio-technical-policy framework identifies the key domains shaping the field, DOI explains how the field evolves over time, and RBV explains why certain actors dominate this evolution. This integrated approach enables the study to move beyond descriptive mapping towards theory-driven explanation, directly supporting the research objectives.

This integrated conceptualisation is illustrated in Figure 1, which presents micro-credential research as a dynamic socio-technical ecosystem shaped by the interdependence of pedagogical, technological, and policy dimensions. The figure visually demonstrates how these domains interact to form the intellectual structure of the field, while also highlighting their uneven development. In particular, the outer layers represent the theoretical lenses guiding this study, where Diffusion of Innovation (DOI) explains temporal evolution (RQ1), and the Resource-Based View (RBV) accounts for disparities in research productivity and impact (RQ2). The framework further aligns thematic clustering (RQ3) and intellectual influence (RQ4) with the internal structure of the ecosystem. As such, Figure 1 serves as an analytical scaffold guiding the interpretation of bibliometric findings.

Figure 1. Socio-Technical-Policy Analytical Framework for Micro-Credential Research.



**Note (s):** The framework conceptualises micro-credential research as a dynamic ecosystem shaped by the interaction of pedagogical, technological, and policy dimensions. These domains are analysed through bibliometric techniques aligned with four research questions, examining temporal evolution,

productivity disparities, thematic structures, and intellectual influence. Diffusion of Innovation (DOI) informs the interpretation of temporal growth patterns, while Resource-Based View (RBV) explains disparities in institutional and geographical research productivity. The framework functions as an analytical scaffold guiding data interpretation rather than a descriptive model.

### 3. Methodology

#### 3.1 Database Selection

This study employed the Scopus database as the primary data source for bibliometric analysis (Ahsan et al., 2023; Irwanto et al., 2023; Krishnan et al., 2025). Scopus was selected for its comprehensive coverage of peer-reviewed journals, conference proceedings, books, and book chapters across education, computer science, and interdisciplinary domains (Irwanto et al., 2023; Krishnan et al., 2025). Compared with Web of Science or Google Scholar, Scopus provides broader indexing and consistent metadata formats, which are essential for reliable keyword extraction and citation mapping (Ahsan et al., 2023; Irwanto et al., 2023). Moreover, the choice of Scopus aligns with prior bibliometric studies on digital learning and credentialing (Ahsan et al., 2023; Irwanto et al., 2023). The data were extracted on 21 August 2025 at 10:28pm to ensure transparency and to acknowledge the dynamic nature of the database.

#### 3.2 Search Strategy

After determining the database, a comprehensive search strategy was developed using Boolean operators and truncation to capture core concepts and related terminology associated with micro-credentials. The final search string applied in Scopus was as follows:

```
TITLE-ABS-KEY ( "micro-credential*" OR "micro credential*" OR "digital badge*"
OR "alternative credential*" OR "open badge*" OR "digital certificate*" )
AND PUBYEAR > 2014 AND PUBYEAR < 2026
AND ( LIMIT-TO ( LANGUAGE , "English" ) )
AND ( EXCLUDE ( PREFNAMEAUID , "undefined" ) )
```

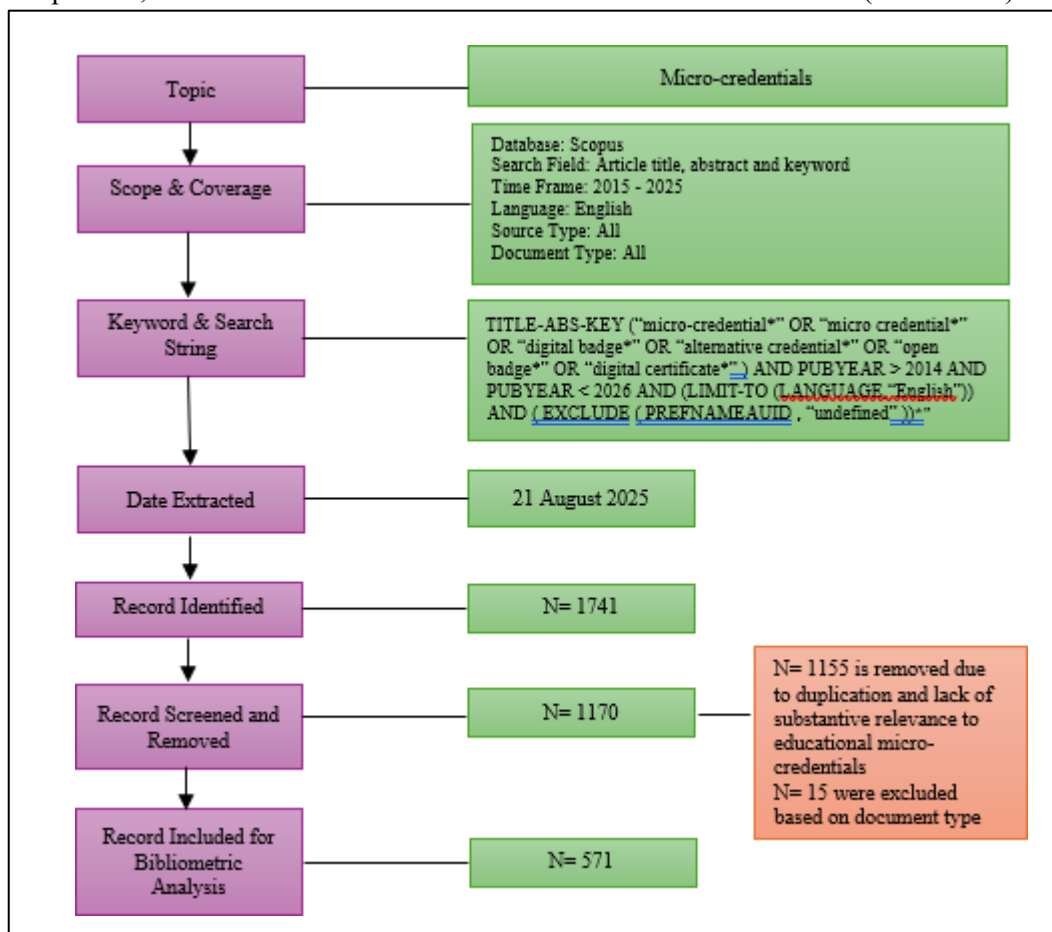
The TITLE-ABS-KEY field was selected to balance inclusiveness and precision by retrieving records in which the key concepts appeared in titles, abstracts, or author keywords. In addition, the filter EXCLUDE (PREFNAMEAUID, "undefined") was applied to remove records with missing or undefined author identifiers. This decision was made to improve the accuracy of author-level and co-authorship analyses. A sensitivity check further indicated that this exclusion did not materially alter the composition of the dataset or the overall thematic structure. At the preliminary stage, terms such as nanodegree, micro-course, and virtual badge were also tested. However, these terms were then excluded because they frequently retrieved records associated with commercial training platforms, standalone short courses, or gamification rewards rather than formal educational credentialing frameworks. Their inclusion substantially increased the retrieval of vendor-driven or non-academic records and reduced conceptual specificity. Additional sensitivity checks were conducted by temporarily including these terms; however, they introduced a substantial proportion of non-academic records and did not alter the core thematic structure, thereby supporting their exclusion. The process of identifying and screening the publications is presented in Figure 2, which follows the methodological approach of Zakaria et al. (2021) and Zhang et al. (2025), and is structured in accordance with the PRISMA guidelines (Moher et al., 2009).

#### 3.3 Screening and Eligibility

Following the search process, the initial Scopus search retrieved 1,741 records. The records were exported in CSV format with full bibliographic fields, including authors, affiliations, abstracts,

keywords, references, and citation counts. The screening process was then conducted manually in Microsoft Excel, while Bibliomagika® was used to support dataset validation and preprocessing. Next, the records were screened according to predefined inclusion and exclusion criteria. During this stage, 1,155 records were removed following duplicate identification and lacked substantive relevance to educational micro-credentials. In addition, 15 records were excluded based on document type, comprising 8 notes, 4 editorials, 1 errata, 1 letter, and 1 short survey. After the screening and eligibility assessment, the final dataset consisted of 571 publications, including journal articles (276), conference papers (164), book chapters (110), reviews (14), and books (7). Figure 2 illustrates the final set of 571 publications included in the bibliometric dataset. To ensure conceptual consistency, studies were included only if they explicitly examined micro-credentials, digital badges, open badges, or alternative credentials in educational contexts; addressed pedagogical, institutional, learner, or assessment dimensions; were peer-reviewed outputs indexed in Scopus; and provided either empirical or conceptual contributions. Conversely, studies were excluded if they focused exclusively on blockchain infrastructure, cryptographic certificates, or cybersecurity systems without pedagogical relevance; examined credentialing systems in non-educational contexts; treated badges merely as gamification tools; presented purely technical system designs without educational application; were duplicate records; or referred to credentials only superficially without substantive engagement with alternative credentialing in education.

Figure 2. Flow diagram of search strategy showing the publication identification and screening process, the inclusion of 571 records in the final bibliometric dataset (2015–2025).



Source: Moher et al. (2009), Zakaria et al. (2021), Zhang et al. (2025)

### 3.4 Time Frame and Scope

Once the eligible records had been identified, the scope of the analysis was defined. The study covered publications from 2015 to 2025, thereby capturing a decade of emergence and consolidation in micro-credential research. Consistent with the study's eligibility criteria, only English-language, peer-reviewed outputs were retained, while non-academic records such as trade publications, editorials, errata, and short surveys were excluded. The final dataset of 571 publications exceeds the minimum commonly recommended for bibliometric analysis and is therefore sufficient to support stable network visualisation and citation-based interpretation (Rogers et al., 2020).

### 3.5 Data Cleaning and Harmonisation

After the final dataset had been established, metadata cleaning and harmonisation were conducted to improve consistency and reliability. This process was carried out using Bibliomagika® (Ahmi, 2024) and OpenRefine (Ahmi, 2023). Institutional names were standardised to the parent organisation level. For example, faculty- or campus-level variants such as "Purdue Univ." were harmonised to "Purdue University". Affiliations were consolidated at the institutional rather than faculty or city level, and country names were standardised to recognised sovereign entities. For instance, "Park University" was carefully distinguished from "University Park," as the former refers to a private university in Missouri, United States, whereas the latter denotes a geographical location associated with Pennsylvania State University.

OpenRefine was used to cluster and merge variant author keywords to ensure conceptual consistency. Examples of harmonisation included "competencies" to "competency," "microcredential" to "micro-credentials," "HE" to "higher education," and "organization" to "organisation." The harmonisation process followed a consistent set of rules, including singular-plural standardisation, British-American spelling alignment, abbreviation expansion, and the merging of semantically equivalent terms. In addition, Bibliomagika Split was applied to disaggregate compound metadata fields.

### 3.6 Data Analysis Tools and Procedures

After cleaning and harmonising the metadata, the bibliometric analysis was conducted using Bibliomagika® and VOSviewer. Bibliomagika® (Ahmi, 2024) was used to generate descriptive statistics and citation indicators, including publication counts, document-type distributions, subject-area frequencies, total citations, h-index, g-index, and citations per publication. In addition, citation normalisation was incorporated by reporting both total citations (TC) and citations per year (C/Y) to account for differences in publication age. Due to limitations in Scopus export regarding self-citation filtering, citation counts were retained as reported; however, this limitation is acknowledged in the discussion section.

VOSviewer (version 1.6.20) was used to construct and visualise bibliometric networks, specifically keyword co-occurrence and co-authorship networks. For the keyword co-occurrence analysis, the following parameters were applied: full counting method, association strength normalisation, and a minimum keyword occurrence threshold of 5. A total of 1,108 keywords were identified, of which 57 met the inclusion threshold. The minimum cluster size was set to 1, and clustering was performed using the default VOSviewer algorithm. These settings ensured that only frequently occurring and conceptually meaningful keywords were retained, thereby enhancing the robustness and interpretability of the network structure. Based on these criteria, five distinct thematic clusters were generated. For the co-authorship analysis, the unit of analysis was set at the author level. The analysis employed the full counting method with a minimum threshold of one document per author. A total of 1,429 authors were identified, all of whom met the inclusion threshold. The minimum cluster size was set to 1, and clustering was conducted using the default VOSviewer settings. Based on these parameters, six clusters

were generated, representing distinct collaboration groups within the micro-credential research landscape.

To assess the robustness of network clustering, standard VOSviewer parameters (association strength normalisation and default clustering resolution) were applied. While formal modularity and silhouette coefficients are not directly generated in VOSviewer, cluster coherence was assessed through interpretive validation by examining the semantic consistency of grouped keywords. While temporal network segmentation (e.g., dividing into sub-periods) can provide additional insights, this study captures temporal evolution through longitudinal publication trends (RQ1) and keyword emergence patterns. Future research may extend this analysis using time-sliced network visualisation.

Configuration settings and screenshots are provided in the supplementary materials. The combined use of Bibliomagika® and VOSviewer enabled triangulation across descriptive, citation-based, and network analyses, thereby enhancing the robustness of the findings (Ahsan et al., 2023; Van Eck & Waltman, 2014). All steps were documented carefully to ensure transparency and support replication.

#### 4. Findings and Discussion

The analysis was guided by four research questions:

Table 2. Mapping of Research Questions to Data Sources, Analytical Methods, and Bibliometric Outputs

Research Question	Data Source	Analytical Method	Tool(s) Used	Key Parameters & Outputs (Tables/Figures)
RQ1: Publication trends and evolutionary patterns (2015–2025)	Scopus metadata (publication year, citation counts)	Longitudinal bibliometric analysis of publication output and citation dynamics to identify growth phases and evolutionary patterns	Bibliomagika®	Time span: 2015–2025; indicators: TP, TC, C/P, h-index. <b>Outputs:</b> Table 3 (main information); Figure 3 (annual publication and citation trends; foundation, acceleration, consolidation phases)
RQ2: Patterns and disparities in research output and impact across countries, institutions, and authors	Author affiliations, country data, and citation metrics	Productivity and impact analysis at author, institutional, and country levels; comparative analysis of citation performance to identify disparities	Bibliomagika®	Full counting method; minimum threshold: $\geq 5$ publications (authors), $\geq 10$ (institutions), $\geq 9$ (countries). <b>Outputs:</b> Table 4 (authors), Table 5 (institutions), Table 6 (countries)
RQ3: Prevailing thematic clusters in micro-credential research	Author keywords; subject area classification	Keyword co-occurrence analysis and clustering to identify dominant research themes; disciplinary distribution analysis to contextualise thematic structure	VOSviewer; Bibliomagika®	Full counting; minimum keyword occurrence = 5; clustering resolution (default). <b>Outputs:</b> Table 7 (subject area distribution); Figure 4 (keyword co-occurrence network and thematic clusters); Table 8 (keyword clusters)
RQ4: Publications with the greatest intellectual influence	Citation data (Scopus); author relationships	Citation analysis to identify highly influential publications; co-authorship network analysis to examine	Bibliomagika®; VOSviewer	Ranking criteria: total citations (TC), citations per year (C/Y), recency. Network visualisation parameters (association strength). <b>Outputs:</b> Table 9

	intellectual collaboration patterns	(Top 20 highly cited articles); Figure 5 (co-authorship network)
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This alignment ensured coherence between dataset construction, analytical procedures, and interpretation of results, providing a rigorous and replicable bibliometric roadmap of micro-credential research.

RQ1: What are the publication trends and evolutionary patterns of micro-credential research between 2015 and 2025?

The first research question aimed to examine how micro-credential research has developed over time. This study combines bibliometric indicators (Table 3) with publication and citation trends shown in Figure 3. Together, these provide a clear picture of how the field has grown, how much attention it has received, and how it is evolving.

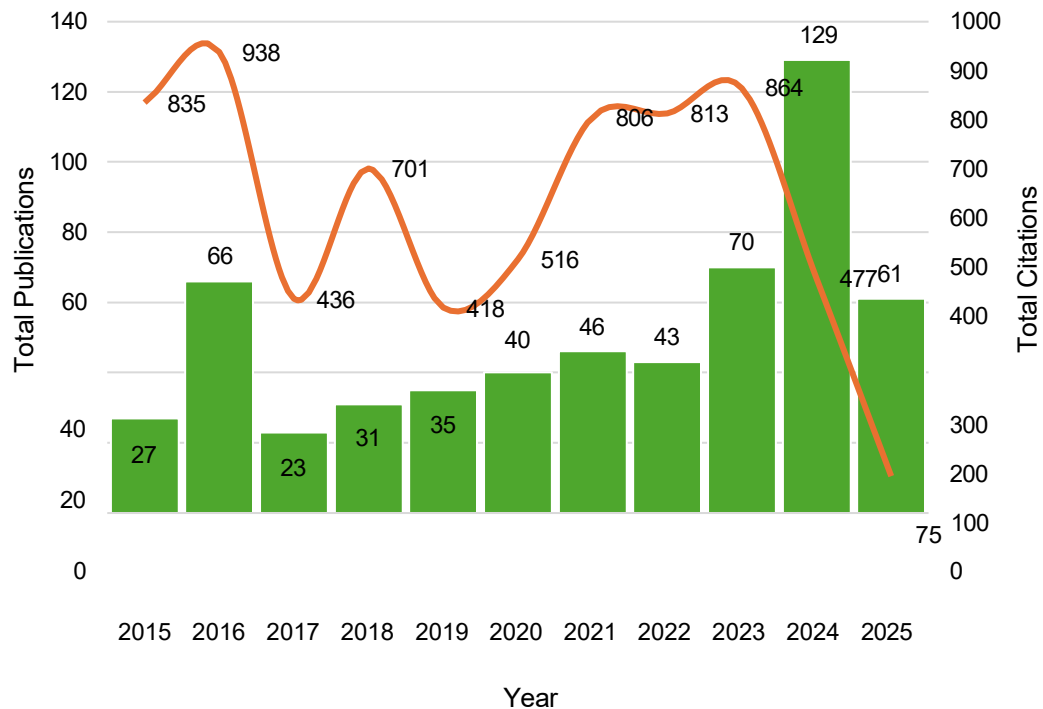
Table 3. Main Information

Main Information	Data
Publication Years	2015 - 2025
Total Publications	571
Citable Year	12
Number of Contributing Authors	1730
Number of Cited Papers	462
Total Citations	6,879
Citation per Paper	12.05
Citation per Cited Paper	14.89
Citation per Year	687.90
Citation per Author	3.98
Author per Paper	3.03
Citation sum within h-Core	5,466
h-index	42
g-index	62
m-index	3.500

Source: Generated by the author(s) using biblioMagika® (Ahmi, 2024)

The bibliometric profile presented in Table 3 shows that micro-credential research is growing steadily but is still developing as a field. The dataset includes 571 publications produced between 2015 and 2025, involving 1,730 contributing authors. This reflects a growing and increasingly collaborative research community. The citation indicators suggest that the field is gaining attention but has not yet fully matured. The average citation per paper (12.05) and per cited paper (14.89) indicate a moderate level of influence, which is common for newer research areas. At the same time, the relatively high citation per year (687.90) shows that interest in this topic has increased, especially in recent years. The overall impact of the field can also be seen through the h-index (42), g-index (62), and m-index (3.500). These values suggest that while many studies are being published, a smaller number of key publications are receiving more attention and shaping the direction of the field. In other words, the field is growing, but influence is still concentrated in selected works. Authorship patterns also support this observation. On average, there are 3.03 authors per paper, indicating that research in this area is often collaborative. This is expected because micro-credentials involve different areas such as education, technology, and policy, which often require input from multiple disciplines.

To further address RQ1, Figure 3 illustrates how the field has changed over time. The overall trend shows a gradual increase in publications, rising from approximately 27 publications in 2015 to a peak of around 129 publications in 2024, before a slight decline to about 61 publications in 2025. This pattern indicates steady growth, with more noticeable acceleration after 2019 indicating that micro-credentials have become more widely discussed, particularly following the shift towards online learning during the COVID-19 period.



**Figure 3.** Total Publications and Citations by Year

*The phases are categorised as foundation (2015–2018), acceleration (2019–2021), and consolidation (2022–2025).*

Source: Generated by the author(s) using biblioMagika® (Ahmi, 2024)

Based on this trend, the development of the field can be understood in three phases, which broadly reflect the Diffusion of Innovation (DOI) pattern of gradual emergence, expansion, and consolidation. The first phase (foundation from 2015–2018) represents the early stage, where publication output remained relatively low, fluctuating between approximately 27 and 45 publications per year. Despite the lower volume, citation levels during this period were relatively high, indicating that early studies played an important role in shaping key concepts and directions in the field.

The second phase (acceleration from 2019–2021) shows a clearer and more consistent increase in publications, growing from about 35 publications in 2019 to 46 in 2021. During this period, research began to expand into different areas, and more scholars became interested in the topic. As a result, influence became more distributed across studies rather than being concentrated in a few early works.

The third phase (consolidation from 2022–2025) reflects a more rapid increase in publication output, rising from around 43 publications in 2022 to 70 in 2023, and reaching a peak in 2024 (approximately 129 publications). This suggests that micro-credentials have become a widely recognised topic across different disciplines. However, citation counts for recent years appear lower, which is expected because newer publications have had less time to accumulate citations.

Overall, the findings show a clear pattern of development. In the early stage, the field was shaped by a small number of influential studies. This was followed by a period of expansion, where more researchers contributed, and the topic gained wider attention. More recently, the field has grown rapidly, but

research has become more diverse and less centralised. This suggests that micro-credential research is

moving from an early stage of development towards a more established field. However, it is still in the process of strengthening its theoretical and conceptual foundations. While publication output continues to increase, the field has not yet reached full maturity, and there is still room for further development and integration.

RQ2: What are the patterns and disparities in research output and impact across countries, institutions, and authors in micro-credential research?

To address the second research question, examining the patterns and disparities in research output and impact across authors, institutions, and countries in micro-credential research, the analysis begins with the contributions of the most productive authors. The focus is placed on authors with a minimum of five publications, with key bibliometric indicators including total publications, cited papers, total citations, citation impact, and h, g, and m-indices examined in detail.

Table 4. Most Productive Authors with a minimum of five publications

Author's Name	Current Affiliation	Country	TP	NCP	TC	C/P	C/CP	h	g	m
Hickey, Daniel Thomas	Indiana University	United States	12	11	130	10.83	11.82	5	1	0.417
West, Richard Edward	Brigham Young University	United States	10	9	216	21.60	24.00	8	1	0.667
Davis, Katie	University of Washington	United States	7	7	200	28.57	28.57	6	7	0.500
Abramovich, Samuel	University at Buffalo	United States	7	5	74	10.57	14.80	3	7	0.273
Newby, Timothy James	Purdue University	United States	6	6	181	30.17	30.17	6	6	0.667
Jovanović, Jelena M.	University of Belgrade	Serbia	6	6	154	25.67	25.67	3	6	0.250
Devedžić, Vladan B.	University of Belgrade	Serbia	6	6	161	26.83	26.83	4	6	0.333
Cheng, Zui	Shenzhen University	China	6	6	160	26.67	26.67	6	6	0.667
Fanfarelli, Joseph R.	Marist College	United States	6	4	48	8.00	12.00	3	6	0.250
Horstman, Theresa	University of Washington	United States	5	4	26	5.20	6.50	2	5	0.286
McDaniel, Rudy	University of Central Florida	United States	5	5	59	11.80	11.80	4	5	0.333
McGreal, Rory	Athabasca University	Canada	5	4	200	40.00	50.00	4	5	0.800
Gamrat, Chris W.	Pennsylvania State University	United States	5	4	27	5.40	6.75	4	5	0.333
Tierney, Gavin	California State University	United States	5	4	26	5.20	6.50	2	5	0.286
Willis, James E.	Indiana University	United States	5	5	33	6.60	6.60	3	5	0.250

**Note:** TP=total number of publications; NCA=Number of contributing authors; NCP=number of cited publications; TC=total citations; C/P=average citations per publication; C/CP=average citations per cited publication; h=h-index; g=g-index; m=m-index.

Source: Generated by the author(s) using biblioMagika® (Ahmi, 2024)

At the author level, the results show that productivity and influence are not always aligned. For example, Hickey is the most productive author with 12 publications, but the average citation per paper (C/P =

10.83) is relatively moderate. In contrast, authors such as Davis (C/P = 28.57), Newby (C/P = 30.17), and McGreal (C/P = 40.00) have fewer publications but higher citation impact. This indicates that some authors contribute fewer but more influential studies. Hence, the findings suggest that influence in this field is concentrated among a smaller group of authors rather than evenly distributed.

A similar pattern can be observed at the institutional level (Table 5). Leading institutions, particularly from the United States, such as Indiana University, Purdue University, and the University of Washington, produce a high number of publications. However, high productivity does not always mean high impact. For instance, Indiana University shows strong output but lower citation impact (C/P = 10.17), while Curtin University has fewer publications but much higher impact (C/P = 41.90). Purdue University demonstrates a more balanced profile, combining both productivity and influence. This suggests that institutions play different roles, with some acting as major contributors in terms of volume, while others contribute fewer but more impactful studies.

Table 5. Most Productive Institutions with a Minimum of Ten Publications

Affiliation	Country	TP	NCA	NCP	TC	C/P	C/CP	<i>h</i>	<i>g</i>	<i>m</i>
Indiana University	United States	18	32	17	183	10.17	10.76	8	13	0.667
Purdue University	United States	16	40	14	301	18.81	21.50	10	16	0.833
University of Washington	United States	15	30	13	251	16.73	19.31	9	15	0.750
Pennsylvania State University	United States	14	34	11	196	14.00	17.82	6	14	0.500
Brigham Young University	United States	11	19	9	216	19.64	24.00	8	11	0.667
Curtin University	Australia	10	15	9	419	41.90	46.56	5	10	0.417

**Note:** TP=total number of publications; NCA=number of contributing authors; NCP=number of cited publications; TC=total citations; C/P=average citations per publication; C/CP=average citations per cited publication; *h*=*h*-index; *g*=*g*-index; *m*=*m*-index.

Source: Generated by the author(s) using biblioMagika® (Ahmi, 2024)

At the country level (Table 6), the results show clear differences in global participation and influence. The United States leads in both publication output (TP = 216) and total citations (TC = 2,857), indicating a dominant position in the field. However, when citation impact is considered, countries such as Australia (C/P = 24.53), Canada (C/P = 22.04), and New Zealand (C/P = 19.64) show higher average influence per publication. On the other hand, countries such as Malaysia (C/P = 7.47), China (C/P = 5.53), and Indonesia (C/P = 2.89) are increasing their publication output but still have lower citation impact. This indicates that while participation is becoming more global, influence remains uneven.

Table 6. Top countries with a minimum of 9 publications

Country	TP	NCA	NCP	TC	C/P	C/CP	<i>h</i>	<i>g</i>	<i>m</i>
United States	216	571	183	2857	13.23	15.61	26	53	2.167
Australia	55	122	51	1349	24.53	26.45	20	36	1.667
United Kingdom	40	86	34	390	9.75	11.47	11	19	0.917
Malaysia	30	128	22	224	7.47	10.18	6	14	0.545
Canada	28	50	25	617	22.04	24.68	9	24	0.750
Spain	22	57	17	256	11.64	15.06	7	16	0.778
Germany	20	48	16	289	14.45	18.06	7	17	0.636
China	17	53	14	94	5.53	6.71	6	9	0.500

Country	TP	NCA	NCP	TC	C/P	C/CP	<i>h</i>	<i>g</i>	<i>m</i>
Turkey	16	29	13	83	5.19	6.38	5	9	0.455
New Zealand	14	39	14	275	19.64	19.64	7	14	0.778
Ireland	14	43	11	236	16.86	21.45	7	14	1.000
Finland	13	38	10	163	12.54	16.30	6	12	0.667
Italy	11	30	8	43	3.91	5.38	4	6	0.500
South Africa	11	18	8	199	18.09	24.88	4	11	0.333
Indonesia	9	38	6	26	2.89	4.33	2	5	0.333
Austria	9	22	8	53	5.89	6.63	3	7	0.600

**Note:** TP=total number of publications; NCA=number of contributing authors; NCP=number of cited publications; TC=total citations; C/P=average citations per publication; C/CP=average citations per cited publication; *h*=*h*-index; and *g*=*g*-index.

Source: Generated by the author(s) using biblioMagika® (Ahmi, 2024)

To sum up, these findings point to a clear pattern in the structure of the field. A small group of countries and institutions contributes a large share of the research output, while influence is concentrated among selected authors and institutions. This creates a situation where some parts of the world play a more central role in shaping research directions, while others are still developing their presence. From a Resource-Based View (RBV) perspective, these differences can be explained by variations in access to resources such as funding, research infrastructure, and international collaboration networks. Countries and institutions with stronger resources are more likely to produce more research and gain higher visibility. In contrast, those with fewer resources may contribute to the field but face challenges in achieving similar levels of impact.

Overall, the findings show that micro-credential research is expanding globally, but it remains uneven in terms of productivity and influence. While more countries and institutions are participating, the field is still shaped by a relatively small number of dominant contributors. This suggests that although the field is growing, there is still a need for more balanced development and wider distribution of research influence.

RQ3. What are the prevailing themes in micro-credential research?

The prevailing themes in micro-credential research were examined using three approaches: subject-area distribution (Table 7), keyword co-occurrence analysis (Figure 4), and thematic cluster interpretation (Table 8). These methods provide an overview of both the disciplinary background and the main research themes in the field.

The subject-area analysis shows that most studies are located within the Social Sciences (73.73%), followed by Computer Science (39.75%) and Engineering (15.24%). This indicates that micro-credential research is mainly driven by educational and policy-related concerns, while technological disciplines play a supporting role. The presence of other areas such as Business, Psychology, and Arts and Humanities further demonstrates that the field is gradually expanding to include organisational and human-centred perspectives. This disciplinary distribution provides the foundation for the thematic structure observed in the keyword co-occurrence network (Figure 4), where pedagogical and educational concepts emerge as central nodes linking multiple research areas.

Table 7. Subject Area Distribution

No.	Subject Area	TP	(%)
1	Social Sciences	421	73.73%
2	Computer Science	227	39.75%



Table 8 provides a clearer summary of these five clusters by grouping related keywords into meaningful themes and explaining their roles within the field. The clusters show how micro-credential research is organised across different areas, including pedagogy, technology, and employability.

**Table 8.** Keyword Clusters in Micro-Credential Research (2015–2025)

Cluster	Colour	Theme Label	Representative Keywords	Thematic Interpretation
Cluster 1	Red	Pedagogical Foundations and Competency-Based Learning	Micro-credentials, higher education, lifelong learning, competency, skills, curriculum, professional development, e-learning, teacher education	Represents the core educational foundation of micro-credential research, emphasising competency-based learning, skills development, and curriculum integration within higher education. This cluster highlights how micro-credentials are conceptualised as flexible learning units supporting lifelong learning and workforce readiness.
Cluster 2	Green	Learner Engagement and Assessment Practices	Motivation, gamification, assessment, engagement, student engagement, feedback, learning, online learning	Focuses on learner-centred pedagogical processes, particularly engagement, motivation, and assessment strategies. This cluster reflects how micro-credentials are designed to enhance participation, self-regulation, and learning outcomes through interactive and performance-based approaches.
Cluster 3	Blue	Digital Credentialing and Technological Infrastructure	Open badges, digital credentials, blockchain, technology, implementation, higher education institutions, soft skills	Captures the technological dimension of micro-credentials, including digital credentialing systems, verification mechanisms, and platform-based implementation. The presence of blockchain indicates increasing attention to secure, portable, and interoperable credential systems.
Cluster 4	Yellow	Instructional Innovation and Educational Ecosystems	Digital badges, instructional design, information literacy, educational innovation, academic libraries, training, case study	Reflects applied educational practices and institutional innovation, particularly in instructional design and knowledge ecosystems such as academic libraries. This cluster highlights how micro-credentials are integrated into broader teaching and learning environments
Cluster 5	Purple	Alternative Credential Pathways and Employability	MOOC, employability, informal learning,	Represents flexible and alternative learning pathways linked to labour market outcomes. This cluster emphasises recognition,

			recognition, short courses, badging	employability, and non-traditional education routes, positioning micro-credentials within broader lifelong learning and workforce development frameworks.
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From a socio-technical–policy perspective, the identified clusters can be interpreted as representing three interrelated dimensions of micro-credential research: pedagogical (learning and assessment), technological (digital infrastructure and credentialing systems), and institutional–policy (implementation, governance, and employability).

#### 4.1 Cluster 1: Pedagogical Foundations and Competency-Based Learning

Situated within the pedagogical dimension of the socio-technical–policy framework and consistent with the dominance of Social Sciences in Table 7, this cluster forms the core educational foundation, with micro-credentials (occurrence = 199; total link strength = 307) acting as the dominant node, strongly connected to higher education, lifelong learning, and competency-based education. The prominence of these terms highlights that micro-credentials are primarily conceptualised as mechanisms for skills development, curriculum innovation, and continuous learning pathways within formal education systems. The inclusion of professional development, learning analytics, and microlearning further indicates a shift towards data-informed and modular pedagogical approaches, where learning is increasingly personalised and performance-driven. At the same time, the presence of employers and skills reflects a growing alignment between academic learning outcomes and labour market expectations, reinforcing the role of micro-credentials as bridges between education and employability. However, despite this strong pedagogical grounding, the comparatively lower occurrence of terms such as teacher education and curriculum suggests that instructional implementation and educator readiness remain underexplored, indicating a potential gap between conceptual frameworks and practical application.

#### 4.2 Cluster 2: Learner Engagement and Assessment Practices

Also situated within the pedagogical dimension, this cluster focuses on learner engagement and assessment practices, with key terms such as *motivation* (occurrence = 28), *gamification* (26), *assessment* (20), and *engagement* (6). The co-occurrence of these terms highlights the increasing emphasis on enhancing learner participation and improving learning outcomes through interactive and technology-supported strategies. The integration of badges, credentials, and digital badging indicates that assessment is not only evaluative but also representational, where achievements are translated into visible and transferable credentials. This reflects a shift from traditional assessment models towards formative, continuous, and outcome-based evaluation systems. Moreover, the presence of *goal setting*, *feedback*, and *student engagement* indicates that learning in micro-credential environments is often framed within self-regulated learning paradigms, where learners actively monitor and direct their own progress. Nevertheless, the less strongly connected link strength between this cluster and technological infrastructure clusters implies that engagement strategies are not yet fully integrated with advanced digital systems, suggesting a partial disconnect between pedagogical innovation and technological capability.

### 4.3 Cluster 3: Digital Credentialing and Technological Infrastructure

Situated within the technological dimension and aligned with the presence of Computer Science and Engineering in Table 7, this cluster captures the digital infrastructure and credentialing systems, with *open badges* (occurrence = 38) and *digital credentials* as central nodes, supported by terms such as *blockchain*, *technology*, and *implementation*. The inclusion of *blockchain* reflects increasing interest in secure, verifiable, and decentralised credentialing systems, addressing issues of trust, authenticity, and portability. The presence of *higher education institutions*, *workforce development*, and *soft skills* demonstrates that digital credentialing systems are not only technical solutions but also institutional and economic tools, enabling the recognition of diverse competencies across educational and professional contexts. However, the relatively lower total link strength compared to Cluster 1 indicates that this technological domain remains less integrated with core pedagogical discourse, reinforcing the notion that technological advancement is progressing somewhat independently of instructional design and learning theory. Additionally, the inclusion of *participatory design* and *implementation* highlights the complexity of adopting these technologies, suggesting that institutions must navigate organisational, technical, and user-experience challenges when operationalising digital credential systems.

### 4.4 Cluster 4: Instructional Innovation and Educational Ecosystems

Positioned at the intersection of pedagogical and institutional dimensions, this cluster reflects the application of micro-credentials within educational ecosystems, with *digital badges* (occurrence = 143; total link strength = 257) and *instructional design* as central elements. The strong presence of *educational innovation*, *educational technology*, and *training* indicates that micro-credentials are increasingly embedded within structured teaching and learning frameworks. The inclusion of *information literacy*, *academic libraries*, and *library instruction* indicates that micro-credentials are being integrated into broader educational ecosystems, extending beyond traditional classrooms to support lifelong and interdisciplinary learning. Essentially, this cluster acts as a mediating layer between pedagogical theory (Cluster 1) and technological systems (Cluster 3), translating conceptual ideas into practical instructional strategies and institutional practices. However, the appearance of *case study* as a recurring term indicates that much of the research in this area remains context-specific and exploratory, with limited large-scale or generalisable evidence. This suggests that while implementation is growing, the field is still in a developmental and experimental phase.

### 4.5 Cluster 5: Alternative Credential Pathways and Employability

Reflecting the policy and labour market dimension, this cluster highlights the role of micro-credentials in employability and flexible learning pathways, with key terms such as *MOOC*, *employability*, *informal learning*, and *recognition*. These terms reflect the role of micro-credentials in supporting non-traditional learning pathways, including short courses, online platforms, and workplace-based learning. The presence of *badging* and *recognition* underscores the importance of credential visibility and acceptance, particularly in relation to employer recognition and career advancement. This aligns with broader trends towards unbundled and stackable learning models, where learners accumulate credentials across different platforms and contexts. However, this cluster appears more peripheral in the network and weakly connected to the central pedagogical clusters, suggesting that employability and recognition are not yet fully integrated into the dominant research discourse. This indicates a fragmentation between education-focused research and workforce-oriented applications, limiting the potential for micro-credentials to function as a cohesive ecosystem.

When considered together, Table 7, Figure 4, and Table 8 reveal a consistent structural pattern in which disciplinary foundations shape thematic development, which is then organised into distinct but interconnected research clusters. Table 8 confirms that these clusters are both structurally coherent and thematically meaningful. However, the distribution of clusters reveals uneven development across the field. The pedagogical domain remains the most dominant, while technological and employability-oriented research areas are still emerging and comparatively less integrated. When interpreted through the socio-technical–policy framework, the clusters reveal a multi-dimensional structure in which pedagogical, technological, and policy dimensions develop in parallel but remain only partially integrated. Pedagogical research, represented by Clusters 1 and 2, occupies a central position, emphasising competency-based learning, engagement, and assessment practices. In contrast, technological research (Cluster 3) reflects a growing but still evolving focus on digital credentialing systems, while policy and workforce-related research (Cluster 5) remains relatively peripheral and weakly connected to the core discourse. Cluster 4 plays a mediating role by linking pedagogical concepts with institutional implementation, highlighting the translation of theory into practice within educational ecosystems. To sum up, the five clusters indicate that micro-credential research is pedagogically anchored, with a strong emphasis on competency-based learning and engagement; technologically emerging yet not fully integrated with instructional practices; institutionally evolving, with increasing but fragmented implementation; and economically relevant, although still weakly connected to employability discourse. The co-existence of emerging terms such as blockchain and digital credentials alongside established educational concepts further indicates that the field is gradually transitioning towards implementation and system-level development. Nevertheless, the relatively limited integration between clusters indicates that these dimensions continue to develop in parallel rather than as a cohesive system. This fragmentation indicates that these dimensions are not yet fully integrated, limiting the development of a coherent micro-credential ecosystem. Consequently, advancing micro-credential research depends on bridging these domains through more integrative theoretical frameworks and empirically grounded studies that connect pedagogy, technology, and policy more systematically.

**RQ4. Which publications have exerted the greatest intellectual influence on the field?**

To examine intellectual influence comprehensively, this study integrates citation analysis (Table 9) with co-authorship network visualisation (Figure 5). While citation metrics identify highly influential publications, co-authorship patterns provide insight into how influence is produced and shared through collaborative research networks.

Table 9. Top 20 Highly Cited Articles

No.	Author(s)	Title	Source Title	Cites	Cites per Year
1	Moore et al. (2025)	Systematic review of digital microcredentials: trends in assessment and delivery	Distance Education	10	5
2	Bruguera et al. (2025)	Micro-credentials and soft skills in online education: the employers’ perspective	Distance Education	7	3.5
3	Charles et al. (2024)	Micro-Credentials in Vocational and Professional Training	Integrating Micro-Credentials with AI in Open Education	6	2
4	Ironsi & Ironsi (2025)	Efficacy of micro-credential learning environments for developing students’ 21st century skills: toward achieving sustainable development goals	International Journal of Educational Management	5	2.5

5	Gamage & Dehideniya (2025)	Unlocking Career Potential: How Micro-Credentials Are Revolutionising Higher Education and Lifelong Learning	Education Sciences	5	2.5
6	Durak & Çankaya (2024)	The Rise of Micro-Credentials: A New Certification System for Career Development	Integrating Micro-Credentials with AI in Open Education	5	1.666667
7	Datta et al. (2025)	Reskilling and Upskilling for Decarbonization: Analyzing Micro-Credential Programs for Energy Workforce Development	Journal of Continuing Higher Education	4	2
8	Charles & Hill (2025)	Micro-credentials and AI in higher education: Transforming professional development	Prompt Engineering and Generative AI Applications for Teaching and Learning	3	1.5
9	Hamutoğlu et al. (2024)	Triggering Competitiveness From a Global Perspective: MOOCs and Micro-Credentials	Integrating Micro-Credentials with AI in Open Education	3	1
10	Kovilpillai et al. (2024)	AI Enhanced Micro-Credentials for Efficiency and Accessibility: Using Gen-AI to Improve the Design, Development, and Delivery of Micro-Credentials	Integrating Micro-Credentials with AI in Open Education	3	1
11	Hou et al. (2025)	Does quality assurance matter for micro-credentials in higher education? Legitimacy, regulatory framework, and challenges in four Asian contexts	Studies in Higher Education	2	1
12	Varadarajan et al. (2025)	Institutional readiness for the implementation of micro-credentials in higher education	Distance Education	2	1
13	Patterson & Hepburn (2025)	Implementing a competency-based assessment approach to micro-credentials	Distance Education	2	1
14	Zhang & Alasmari (2025)	Micro-credentials in Saudi higher education: stakeholder perceptions and policy implications for economic transformation and bridging skills gaps	Journal of Professional Capital and Community	2	1
15	Sullivan (2025)	A Rubric for Microcredential Evaluation: Strengthening Quality Assurance	Innovative Higher Education	2	1
16	Tanim et al. (2025)	Dr. FANS: A Decentralized Micro-credential Verification System Towards Higher Qualifications	2025 International Conference on Electrical, Computer and Communication Engineering, ECCE 2025	2	1
17	Stamatakis et al. (2024)	Micro-Credentials Establish New Realities in Digital Education	Integrating Micro-Credentials with AI in Open Education	2	0.666667
18	Halttunen et al. (2024)	Role of Micro-credentials and Open Badges in Sustainable Tourism Education	Nordic Coastal Tourism: Sustainability, Trends, Practices, and Opportunities	1	0.333333
19	LaRue Keeley (2025)	The Scope and Depth Micro-Credential Framework: Aligning	Innovative Approaches in Vocational and Regional Education	1	0.5

		Education With Evolving Industry Demands			
20	Narong (2025)	Research trends on micro-credentials: a keyword co-occurrence analysis and science mapping	Journal of Further and Higher Education	1	0.5

Source: Generated by the author(s) using biblioMagika® (Ahmi, 2024)

Table 9 indicates that intellectual influence in micro-credential research is concentrated in a relatively small number of recent publications. When citations are normalised using citations per year (C/Y), Moore et al. (2025) emerges as the most influential study (TC = 10; C/Y = 5), suggesting rapid scholarly uptake within a short period. Similarly, Bruguera et al. (2025) (C/Y = 3.5) and Ironsi and Ironsi (2025) (C/Y = 2.5) demonstrate strong citation performance, reflecting growing attention to employability, skills development, and learning outcomes. In addition, studies such as Gamage and Dehideniya (2025) and Hou et al. (2025) highlight the importance of institutional readiness and quality assurance, while Charles and Hill (2025) and Kovilpillai et al. (2024) reflect increasing interest in technological integration and digital credential systems.

These influential publications can be grouped into four thematic areas: (1) workforce alignment and employability, (2) institutional readiness and governance, (3) technological integration and digital infrastructure, and (4) sectoral and application-based contexts. The distribution of highly cited studies across these domains indicates that intellectual influence is not concentrated within a single research stream but is dispersed across multiple areas. From a Diffusion of Innovation (DOI) perspective, the prominence of recent publications with relatively high C/Y values suggests that the field is transitioning from early exploration to a growth phase, where new ideas are rapidly diffused but have not yet stabilised into a unified theoretical framework. From a Resource-Based View (RBV) perspective, the concentration of influential publications within certain journals and institutional contexts reflects the role of resource availability, research capacity, and network positioning in shaping scholarly impact.

No.	Theme	Example	Focus
1.	Workforce alignment and employability	Bruguera et al., 2025; Ironsi & Ironsi, 2025; Gamage & Dehideniya, 2025	Focusing on skills development and labour market relevance
2.	Institutional readiness and governance	Hou et al., 2025; Varadarajan et al., 2025; Patterson & Hepburn, 2025; Sullivan, 2025)	Addressing implementation, quality assurance, and policy alignment
3.	Technological integration and digital infrastructure	Charles & Hill, 2025; Kovilpillai et al., 2024; Durak & Çankaya, 2024	Focusing on platforms, AI, and digital credential systems
4.	Sectoral and application-based contexts	Datta et al., 2025; Tanim et al., 2025	linking micro-credentials to specific industries and contexts

To complement this citation-based perspective, the co-authorship network provides insight into how intellectual influence is structured through collaboration. Figure 5 shows that the network is organised into several colour-coded clusters, each representing a distinct research community. The yellow cluster, centred around Daniel T. Hickey and James E. Willis, reflects pedagogical and professional learning. The red cluster, including Kathryn S. Coleman, Sheryl Grant, and Kim Flintoff, represents digital infrastructure and credential systems. The green cluster, represented by Rupert Ward and Alan Hayes, captures learner engagement and skills development. The blue cluster, consisting of Jelena Jovanović, Bojan Tomić, and Vladan Devedžić, represents institutional and policy-oriented research.

Within these clusters, authors demonstrate strong intra-cluster collaboration, indicating cohesive and thematically aligned research communities. However, inter-cluster connections remain relatively weak, suggesting that collaboration is largely confined within specific domains. This structure indicates that knowledge production is organised around distinct thematic communities rather than a fully integrated network.

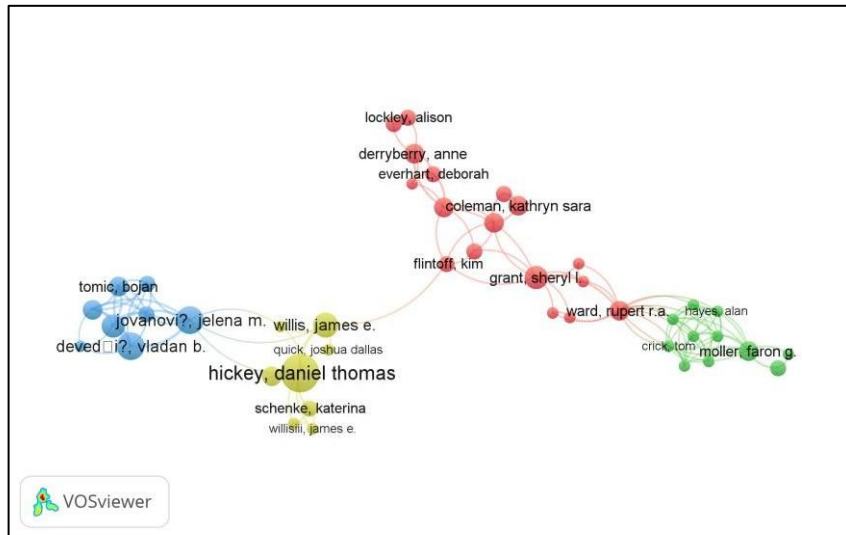


Figure 5. Network visualization of the author's co-authorship analysis

Source: Generated by the author(s) using VOSviewer (van Eck & Waltman, 2014)

Importantly, a comparison between Table 9 and Figure 5 reveals that the most highly cited publications are not necessarily produced by the most central authors within the co-authorship network. For example, highly cited studies such as Moore et al. (2025) and Bruguera et al. (2025) demonstrate strong citation impact but are not prominently positioned within the major collaboration clusters. Similarly, influential contributions on institutional readiness and governance, such as Gamage and Dehideniya (2025) and Hou et al. (2025), do not appear as central nodes within the co-authorship structure. This indicates that citation influence is distributed across multiple authors and thematic areas rather than concentrated within a single collaborative core.

Conversely, authors who are central within the co-authorship network, such as Hickey and Willis in the pedagogical cluster, and Jovanović and Devedžić in the institutional and policy-oriented cluster, demonstrate strong collaborative ties and contribute to cohesive research communities but do not feature prominently among the most highly cited publications in Table 9. This contrast indicates that authors who shape collaboration networks are not necessarily those whose individual publications receive the highest citation impact.

When the citation and co-authorship analyses are considered together, a clear structural pattern emerges. Highly cited publications contribute to the development of specific thematic domains but do not function as strong bridging points between clusters. As a result, intellectual influence is distributed across multiple areas rather than integrated within a unified research core. This confirms that influence in micro-credential research is not concentrated within a single group of highly collaborative scholars but is instead dispersed across distinct research communities.

Overall, the findings show that intellectual influence in micro-credential research is distributed rather than concentrated, emerging rather than fully established, and shaped through collaborative clusters rather than individual dominance. At the same time, the limited overlap between citation influence and collaboration structure highlights a fragmented intellectual landscape, where highly cited work and collaborative networks do not fully converge. This structural fragmentation suggests that the field

remains in a stage of consolidation, where theoretical coherence and interdisciplinary integration are still developing.

From a broader perspective, these findings indicate that micro-credential research is evolving as a multi-dimensional field, where pedagogical, technological, and policy-oriented domains develop at different rates and through distinct research communities. While the field is progressing towards greater maturity, its continued advancement depends on strengthening cross-cluster collaboration and integrating fragmented domains into a more cohesive and theoretically grounded framework.

## 5. Discussion

This study provides a comprehensive bibliometric analysis of micro-credential research between 2015 and 2025, addressing four research questions related to publication trends, research productivity, thematic development, and intellectual influence. Rather than restating descriptive findings, this discussion interprets the observed patterns by examining the underlying mechanisms that explain their emergence, the implications for the development of the field, and their contribution to existing knowledge.

The findings in RQ1 indicate that micro-credential research has evolved from a relatively niche area into a rapidly expanding and increasingly structured domain. Publication output increased steadily over the decade, with a marked acceleration after 2019 and a peak in 2024. This trajectory can be explained using the Diffusion of Innovation (DOI) framework, which posits that the adoption of innovations is shaped by factors such as relative advantage, compatibility, and observability (Rogers et al., 2014). Micro-credentials offer clear advantages in terms of flexibility, skills alignment, and responsiveness to labour market demands, making them attractive to higher education institutions (Gamage & Dehideniya, 2025; Varadarajan et al., 2023). Their compatibility with digital and online learning environments further supported rapid adoption, particularly during the COVID-19 pandemic, which accelerated the shift towards alternative credentialing models (Brown et al., 2023). In addition, increased visibility through institutional pilot initiatives and policy support enhanced observability, encouraging wider adoption across institutions (Selvaratnam & Sankey, 2021).

From a DOI perspective, the field appears to have progressed from early adoption towards the early majority stage, where micro-credentials are no longer experimental but increasingly embedded within institutional strategies (Ahsan et al., 2023; Tamoliūnė et al., 2023). This shift signifies entry into a consolidation phase. However, the relatively lower citation counts for recent publications, particularly in 2024 and 2025, reflect a citation maturation effect rather than declining relevance, as scholarly recognition typically lags behind publication output in emerging fields (Gomez et al., 2022; Nielsen & Andersen, 2021; Pruteanu et al., 2025). More importantly, the distribution of citations across numerous recent studies demonstrates that the intellectual foundations of the field are still forming, with influence dispersed rather than concentrated in a set of canonical works. This dispersion is further reinforced by the RQ4 findings, where highly cited publications are distributed across multiple thematic areas and are not concentrated within a single dominant research stream or collaborative core, indicating that intellectual consolidation is still in progress.

At the same time, the findings in RQ2 reveal clear disparities in research productivity and influence across countries, institutions, and authors. The United States dominates both publication output and citation impact, while countries such as Australia and Canada demonstrate relatively higher citation efficiency despite lower publication volumes (Brown et al., 2023; McGreal & Olcott, 2022; Varadarajan et al., 2023). This pattern can be interpreted through the Resource-Based View (RBV), which posits that systems with stronger resource configurations such as funding, digital infrastructure, research capacity, and policy support are more likely to achieve sustained competitive advantage (Barney, 1991). In addition, the dominance of English as the primary language of academic publishing further amplifies visibility and citation potential for institutions in the Global North (Arnado, 2021; Gomez et al., 2022).

These findings suggest that research influence is not solely determined by productivity but is also shaped by structural and institutional conditions, highlighting the need for more inclusive and globally distributed research collaboration. In particular, the divergence observed in RQ4 between citation influence and collaboration centrality suggests that access to resources not only affects publication output but also influences whether scholars are positioned within high-visibility citation networks or within cohesive collaborative communities.

The thematic analysis in RQ3 reveals that micro-credential research is organised into five major clusters: pedagogical foundations, learner engagement, technological infrastructure, instructional innovation, and employability pathways. While these domains are clearly identifiable, they tend to develop in parallel rather than as a fully integrated system. Pedagogical research remains dominant, focusing on competency-based learning, digital badges, and learner engagement (McGreal & Olcott, 2022; Pirkkalainen et al., 2022; Varadarajan et al., 2023). Technological research increasingly explores digital credentialing systems, including blockchain and platform-based infrastructures (Orman et al., 2023; Suroño & Jusuf, 2025). Policy-oriented research addresses institutional readiness, employability, and quality assurance (Brown et al., 2023; Fonzo & Evangelista, 2025; Orman et al., 2023).

This thematic fragmentation is reinforced by the co-authorship network structure in RQ4, which reveals that collaboration is concentrated within clusters rather than across them. When interpreted together, the keyword and co-authorship analyses indicate that micro-credential research is not only conceptually segmented but also socially organised into relatively discrete research communities. Pedagogical clusters remain central and densely connected, while technological and policy-oriented clusters are comparatively peripheral and weakly integrated. This convergence between conceptual and collaborative fragmentation reflects that the field is developing through parallel trajectories rather than cumulative and interdisciplinary knowledge building. The RQ4 analysis further demonstrates that highly cited publications tend to contribute to specific clusters without acting as bridging mechanisms between them, reinforcing the persistence of structural fragmentation at both conceptual and collaborative levels.

From a socio-technical–policy perspective, this pattern reflects an imbalance in system development, where pedagogical innovation advances more rapidly than technological integration and policy alignment. According to DOI theory, such separation represents a transitional phase in the diffusion process, where different components of an innovation evolve independently before achieving full integration (Rogers et al., 2014). This indicates that the field has not yet reached conceptual or structural maturity, with diffusion operating across interconnected sub-systems rather than as a unified process.

The analysis of intellectual influence further supports this interpretation. Highly cited publications are relatively recent and distributed across multiple thematic areas, including workforce alignment, institutional readiness, technological innovation, and sector-specific applications. This distribution suggests that the field lacks a single dominant theoretical framework. Instead, influence is dispersed across multiple emerging domains, reflecting a field that is still forming its intellectual identity. Co-authorship analysis similarly shows that influence is generated through collaborative clusters rather than individual dominance, reinforcing the collective nature of knowledge production in this area. At the same time, the limited overlap between highly cited works and central collaboration nodes highlights that citation visibility and collaborative influence operate as distinct but interconnected mechanisms within the field.

In short, the cluster structure reveals that micro-credential research is pedagogically anchored, with strong emphasis on competency-based learning and learner engagement; technologically emerging, particularly in relation to digital credentialing systems; institutionally evolving, through growing but fragmented implementation practices; and economically relevant, although still weakly connected to employability discourse. This configuration indicates that the field remains structurally fragmented, with pedagogical, technological, and labour market dimensions developing in parallel rather than as an

integrated system. This structural separation may constrain the development of coherent theoretical frameworks and limit the capacity of research to inform holistic policy and institutional strategies.

To sum up, the findings confirm that micro-credential research is transitioning from early exploration towards structured consolidation. From a DOI perspective, the field is progressing towards broader institutional adoption, driven by perceived advantages and increasing visibility. From an RBV perspective, disparities in research influence reflect uneven resource distribution and institutional capacity. From a socio-technical–policy perspective, the field is multi-dimensional but not yet fully integrated. These findings contribute to the literature by demonstrating that micro-credential research should be understood as an interconnected socio-technical–policy system shaped by both innovation dynamics and resource configurations. While the field has expanded rapidly and gained global attention, its continued advancement depends on strengthening integration across pedagogical, technological, and policy domains. Future work should continue to explore mechanisms that enable stronger integration across these domains to support more coherent theoretical and practical development.

## 6. Implications and Future Research

The findings of this study generate important implications for theory, practice, and policy by providing a deeper understanding of how micro-credentials are developing as a complex and evolving field within higher education systems. Building on these findings, the following section outlines the implications for theory, practice, and policy.

### 6.1 Theoretical Implications

From a theoretical perspective, this study extends existing frameworks by demonstrating that the development of micro-credential research is not only driven by adoption dynamics but also shaped by structural and systemic imbalances. The observed publication growth and adoption patterns reinforce the relevance of Diffusion of Innovation (DOI), confirming that micro-credentials are transitioning from early experimentation towards broader institutional uptake (Rogers et al., 2014). However, the findings also reveal that diffusion does not occur uniformly across all dimensions of the innovation. Instead, pedagogical, technological, and policy components evolve at different rates, reflecting varying levels of complexity, compatibility, and institutional readiness. More importantly, the combined keyword and co-authorship analyses extend DOI by showing that diffusion in micro-credential research occurs unevenly across interconnected sub-systems rather than as a unified process. Pedagogical innovation appears to diffuse more rapidly, while technological and policy dimensions lag behind, indicating asynchronous adoption patterns. This suggests that DOI in complex educational innovations should be reconceptualised as a multi-layered and non-linear process, where different components of an innovation mature independently before achieving full integration. This reinforces the need to conceptualise diffusion as multi-layered and non-linear in complex educational systems.

At the same time, the Resource-Based View (RBV) provides a robust explanation for disparities in research productivity and influence. The dominance of countries such as the United States and the high citation efficiency of systems such as Australia reflect differences in institutional resources, including research funding, digital infrastructure, human capital, and policy support (Barney, 1991; Abdul Halim et al., 2024; Alsobhi et al., 2023). These findings indicate that research influence is not determined solely by output but by the strategic configuration and mobilisation of resources within institutional and national contexts.

This study advances the socio-technical–policy perspective by empirically demonstrating that fragmentation exists at both conceptual and collaborative levels. The alignment between keyword clusters and co-authorship clusters shows that micro-credential research is structured into relatively

discrete domains, where pedagogical, technological, and policy-related knowledge develops in parallel rather than through integrated frameworks. This underscores the need for future theoretical models that explicitly connect these dimensions and conceptualise micro-credentials as interconnected systems rather than isolated components (Ahsan et al., 2023; Selvaratnam & Sankey, 2021).

## 6.2 Practical Implications

From a practical perspective, the findings highlight the need for higher education institutions to adopt more coordinated and system-level approaches in implementing micro-credentials. The separation between pedagogical, technological, and policy domains suggests that institutional practices may also be fragmented. In many cases, instructional design, platform development, and quality assurance are handled independently, pointing to a system-level misalignment rather than isolated operational problems. Without coordinated integration, micro-credentials risk being implemented as fragmented initiatives that fail to deliver coherent learning pathways, recognised outcomes, or scalable solutions. Therefore, institutions should prioritise cross-functional governance models that align educators, instructional designers, IT specialists, and administrators within a unified framework.

To operationalise this integration, institutions may adopt a structured readiness approach that assesses key dimensions of implementation. These include alignment with national qualification frameworks, clarity of learning outcomes, robustness of assessment design, platform interoperability, employer relevance, and stackability into credit-bearing pathways. Practical indicators may include the proportion of micro-credentials mapped to qualification frameworks, employer uptake within a defined period, and the extent to which micro-credentials can be accumulated into formal qualifications, which together provide practical indicators for monitoring progress and effectiveness.

In addition, the increasing prominence of technological themes such as digital credentials and blockchain highlights the need for investment in robust digital infrastructure that supports secure verification, interoperability, and scalability (Alsobhi et al., 2023). However, technological development must be aligned with pedagogical principles to ensure that micro-credentials support meaningful learning outcomes rather than functioning solely as technical certifications. This requires integrating competency-based learning, assessment design, and learner engagement strategies within digital platforms (Tamoliūnė et al., 2023).

Furthermore, institutions in emerging regions, including Asia and the Middle East, can enhance their research visibility and impact by strengthening international collaboration and aligning micro-credential initiatives with recognised qualification frameworks. Such alignment improves credibility, supports global recognition, and enhances competitiveness within lifelong learning ecosystems (Ahsan et al., 2023; Varadarajan et al., 2023; Santally et al., 2024). Importantly, institutional strategies should focus not only on increasing publication output but also on improving research quality, collaboration networks, and interdisciplinary engagement.

## 6.3 Policy Implications

From a policy perspective, the study underscores the importance of developing coherent and integrated frameworks to support the recognition, portability, and scalability of micro-credentials. The fragmentation observed across thematic domains mirrors the cluster structure identified in the bibliometric analysis, where policy-related research remains peripheral and weakly connected to pedagogical and technological domains. This suggests that policy development has not kept pace with innovation in teaching and technology, highlighting a critical gap in governance alignment.

Policymakers should therefore prioritise the development of harmonised quality assurance frameworks that align national systems with international standards such as the European Qualifications Framework (EQF) and the ASEAN Qualifications Reference Framework (AQRF) (Oliver, 2019; Lang, 2023; McGreal et al., 2025). This is essential for ensuring the comparability, recognition, and transferability of micro-credentials across institutions and regions.

In addition, the uneven geographical distribution of research highlights the need for targeted capacity-building initiatives in underrepresented regions (Ahsan et al., 2023; Brown et al., 2021; Tamoliūnė et al., 2023; Selvaratnam & Sankey, 2021). Policymakers can support this by promoting international partnerships, funding collaborative research, and facilitating knowledge exchange between institutions with different levels of readiness (Gamage & Dehideniya, 2025; McGreal & Olcott, 2022). These efforts are essential to reduce global disparities and ensure that micro-credentials contribute to inclusive and equitable education systems.

Importantly, policy development should also align with global education priorities, particularly Sustainable Development Goal 4 (SDG 4), which emphasises inclusive access to quality education and lifelong learning opportunities (Ahad et al., 2025; Brown et al., 2021; McGreal et al., 2022; UNESCO, 2022; United Nations, 2023). By embedding micro-credentials within national education strategies, policymakers can support workforce development, enhance employability, and promote social mobility. However, achieving these outcomes requires strong alignment between governance structures, institutional capacity, and technological systems (Pirkkalainen et al., 2022; Varadarajan et al., 2023).

Overall, the implications of this study suggest that the future development of micro-credentials depends on the ability of institutions and policymakers to move beyond fragmented and parallel approaches towards integrated socio-technical-policy systems. Without such integration, the field risks remaining conceptually and operationally fragmented. By contrast, stronger alignment across pedagogy, technology, and policy can enhance the effectiveness, credibility, and scalability of micro-credentials, enabling them to function as a sustainable and transformative component of higher education and lifelong learning systems.

#### **6.4 Future Research Directions**

The findings of this study highlight several important gaps and emerging issues that provide clear directions for advancing micro-credential research. These directions are derived directly from the observed patterns in publication trends, thematic development, and intellectual structure, thereby offering a systematic pathway for future scholarship.

First, the rapid increase in publications after 2019 suggests that the expansion of micro-credential research cannot be explained solely by the COVID-19 pandemic. While the pandemic accelerated the adoption of online learning and flexible credentialing systems, the sustained growth beyond this period indicates the influence of broader institutional and policy drivers. Further studies should therefore examine the specific mechanisms that sustain adoption over time, including the role of national education policies, digital transformation strategies, and industry partnerships. From a Diffusion of Innovation (DOI) perspective, further studies could investigate how factors such as relative advantage, compatibility, complexity, and observability operate differently across institutional contexts and influence adoption trajectories at different stages of diffusion. Future work could also examine how these factors interact across pedagogical, technological, and policy dimensions to better understand variation in adoption patterns across contexts.

Second, the findings reveal significant disparities in research productivity and citation impact across countries and institutions. While some systems dominate in terms of output, others achieve higher citation efficiency with fewer publications. This raises important questions about the relationship

between research quality, visibility, and resource configurations. Future studies should explore how different combinations of resources such as funding, digital infrastructure, human capital, and international collaboration networks shape research influence. Drawing on the Resource-Based View (RBV), research could examine which resource configurations are most effective in generating high-impact scholarship and how institutions in underrepresented regions can strategically position themselves within global research networks.

Third, the thematic and co-authorship analyses reveal that micro-credential research is both conceptually and structurally fragmented, with pedagogical, technological, and policy domains developing in parallel rather than as an integrated system. Subsequent research should prioritise empirical investigations that examine how these domains can be effectively integrated in practice, rather than focusing solely on their conceptual separation. For example, empirical investigations could explore whether technological innovations such as blockchain and digital credential systems effectively support pedagogical goals, or whether pedagogical requirements drive technological adoption. In addition, studies are needed to examine how policy frameworks influence the alignment between curriculum design, assessment practices, and credential recognition. Addressing this gap is critical for moving the field towards a more coherent socio-technical–policy framework.

Fourth, although technological innovation is gaining increasing attention, particularly in areas such as blockchain, artificial intelligence, and digital credentialing systems, its relationship with educational outcomes remains under-theorised. Empirical research is needed to move beyond technical implementation and examine how these technologies influence learner engagement, assessment validity, and skill development. Future studies should focus on how digital credential systems support personalised learning pathways and how emerging technologies can be integrated with learner-centred pedagogical approaches, thereby helping to bridge the gap between technological advancement and educational effectiveness.

Fifth, the co-authorship network analysis reveals fragmented collaboration patterns, with strong intra-cluster connections but limited interaction across clusters. This suggests a need for research that examines the dynamics of interdisciplinary collaboration and its impact on knowledge development. Future studies could investigate whether more integrated collaboration networks lead to stronger theoretical contributions, more innovative methodologies, and greater practical relevance. In particular, research that brings together scholars from education, technology, and policy domains may provide valuable insights into how the field can overcome fragmentation and achieve greater conceptual coherence.

Sixth, the geographical distribution of research highlights the underrepresentation of regions such as Asia, Africa, and parts of the Middle East in high-impact publications. Although contributions from these regions are increasing, they remain less visible within global citation and collaboration networks. Future research should prioritise context-sensitive studies that examine how micro-credentials are implemented across diverse cultural, economic, and institutional environments. Ensuring inclusivity and representation of global diversity is critical to avoid the dominance of a limited number of regions.

Finally, the present study adopts a bibliometric approach and therefore provides a macro-level understanding of the field. Further studies should complement this perspective with empirical and longitudinal studies that examine the real-world impact of micro-credentials on learners, institutions, and labour markets. This includes investigating learner outcomes, employability trajectories, and the long-term effectiveness of micro-credential programmes in supporting lifelong learning. Longitudinal designs would be particularly valuable in capturing how micro-credentials evolve from pilot initiatives into fully integrated components of higher education systems.

Overall, these directions emphasise the importance of moving beyond isolated and descriptive approaches towards more integrated, empirically grounded, and context-sensitive research. In addition,

future research should prioritise integrative approaches that connect different domains of micro-credential research, enabling more cohesive theoretical development and practical implementation.

## 7. Limitations

Several limitations should be acknowledged when interpreting the findings of this study. These limitations are not only methodological but also shape the scope, representation, and generalisability of the conclusions drawn.

First, this study relies exclusively on the Scopus database. While Scopus provides extensive coverage of peer-reviewed literature and structured bibliographic data suitable for bibliometric analysis, it does not capture the full spectrum of micro-credential research. In particular, practitioner-oriented publications, policy reports, institutional documents, and grey literature are often excluded. This is a notable constraint given that micro-credentials are inherently practice-driven and closely linked to policy frameworks and institutional implementation. Consequently, the findings primarily reflect academic discourse rather than the broader ecosystem of practice and governance in which micro-credentials operate.

Second, the analysis is limited to English-language publications, introducing a linguistic bias that may systematically exclude relevant research produced in other languages. This is particularly significant for regions where micro-credentials are actively evolving, such as China, Latin America, and parts of Europe and Southeast Asia. As English dominates scholarly communication, this restriction may overrepresent Anglophone or internationally indexed systems while underrepresenting locally grounded perspectives. The combined use of Scopus and English-language filtering therefore biases the dataset towards globally visible scholarship, limiting the inclusivity of the analysis.

Third, citation-based indicators are subject to temporal and structural limitations. Recent publications, particularly those from 2024 and 2025, have had limited time to accumulate citations, which may underestimate their actual influence. Although normalisation techniques such as citations per year were applied, citation metrics inherently favour older publications. In addition, citation counts include self-citations, which may marginally inflate impact measures. These limitations should be considered when interpreting patterns of intellectual influence and scholarly prominence, particularly in emerging and rapidly evolving research areas.

Fourth, bibliometric analysis provides a macro-level perspective of research trends, thematic structures, and collaboration networks but does not capture the contextual depth of individual studies. While this approach is effective for identifying large-scale patterns, it cannot fully explain how micro-credentials are designed, implemented, or experienced within specific educational settings. As a result, the findings should be complemented by qualitative, mixed-method, and longitudinal studies that provide deeper insights into pedagogical practices, institutional dynamics, and learner outcomes.

Fifth, although systematic procedures were applied in data cleaning, keyword harmonisation, and clustering, a degree of subjectivity remains inherent in these processes. Decisions related to merging terms, standardising keywords, and interpreting thematic structures may influence the configuration of clusters and networks. While these steps were guided by established protocols and documented for transparency, they remain interpretive and may affect the representation of the field's intellectual structure.

To summarise, these limitations indicate that the findings represent a structured overview of English-language, Scopus-indexed scholarship rather than a fully comprehensive representation of global micro-credential research. Recognising these constraints is essential for appropriately contextualising the results and for guiding future research towards more inclusive, multi-source, and context-sensitive approaches.

## 8. Conclusion

This study set out to examine the development and structure of micro-credential research in higher education through a comprehensive bibliometric analysis of publications indexed in Scopus between 2015 and 2025. By integrating publication trends, productivity patterns, thematic clustering, and collaboration networks, the study provides a multi-dimensional understanding of how the field has evolved over time. The findings indicate that micro-credential research has grown rapidly, particularly after 2019, reflecting increasing institutional and policy interest in flexible and skills-based learning pathways. Despite this growth, the field remains unevenly developed, with significant disparities in research productivity and influence across countries, institutions, and authors. These disparities highlight the importance of resource availability, research capacity, and global visibility in shaping scholarly impact.

A key contribution of this study is demonstrating that micro-credential research is structured into multiple domains, including pedagogical design, learner engagement, technological infrastructure, instructional innovation, and employability pathways. These domains are reflected in distinct but only partially connected research communities, indicating that the field is developing through parallel research streams rather than as a fully integrated system. The analysis further demonstrates that intellectual influence is distributed across recent publications and collaborative clusters rather than concentrated within a small number of dominant authors or theoretical frameworks. This suggests that micro-credential research is still in a stage of consolidation, where its intellectual foundations are evolving and its conceptual boundaries are still being defined.

From a theoretical perspective, the study contributes to existing knowledge by extending Diffusion of Innovation (DOI) and Resource-Based View (RBV) frameworks. The findings show that adoption and development in micro-credential research occur unevenly across interconnected dimensions, reflecting a multi-layered diffusion process and resource-dependent patterns of influence. At the same time, the study advances a socio-technical-policy perspective by demonstrating that pedagogical, technological, and governance dimensions are interdependent but not yet fully aligned. From a practical and policy perspective, the findings highlight the need for greater integration across these domains to ensure that micro-credentials are implemented as coherent and scalable systems rather than fragmented initiatives. This includes aligning curriculum design, assessment practices, digital infrastructure, and policy frameworks to support effective and recognised learning pathways.

In conclusion, this study demonstrates that while micro-credential research has achieved significant growth and diversification, its continued advancement depends on strengthening integration across pedagogical, technological, and policy domains. Greater alignment across these dimensions will be essential for supporting coherent theoretical development, effective implementation, and meaningful contribution to higher education and lifelong learning systems.

### ETHICAL APPROVAL

Not applicable

**CONSENT TO PARTICIPATE**

Not applicable

**CONSENT TO PUBLISH**

Not applicable

**DECLARATION OF GENERATIVE AI AND AI-ASSISTED TECHNOLOGIES**

During the preparation of this work the author(s) used ChatGPT in order to do the paraphrasing and some data interpretation. After using this tool/service, the author(s) reviewed and edited the content as needed and take(s) full responsibility for the content of the publication.

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