ARTIFICIAL INTELLIGENCE IN MICRO-CREDENTIALS FOR OPEN AND DISTANCE LEARNING: A TECHNOLOGICALLY ENHANCED SYSTEMATIC REVIEW

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ABSTRACT

Micro-credentials are increasingly meeting the growing need for a flexible workforce and are particularly well suited to the open and distance learning (ODL) environment. While artificial intelligence (AI) is driving educational advancements, its integration into micro-credentials for ODL remains fragmented, hindering further growth. This research seeks to address this issue through a systematic review using specialised software to comprehensively analyse the relevant literature. Employing a hybrid approach that combines bibliometric and thematic analyses, this study examines 46 articles on AI's role in micro-credentials within ODL contexts. This review identifies significant research gaps and offers suggestions for future directions in this emerging field. The findings provide valuable, updated insights with theoretical and practical implications. For industry practitioners, the review serves as a comprehensive resource, helping to bridge the gap between academic research and real-world applications. Ultimately, this study contributes to the existing body of knowledge and paves the way for further exploration of AI integration into micro-credentials in ODL, thus offering new opportunities for future research and development.

Keywords: Artificial intelligence, bibliometric analysis, micro-credentials, open and distance learning, SPAR-4-SLR, systematic review.

INTRODUCTION

The integration of artificial intelligence (AI) into micro-credential courses within open and distance learning (ODL) in higher educational institutions marks a pivotal shift in the educational paradigm aimed at enhancing accessibility, personalisation, and efficiency. This evolution aligns with rapid technological advancements and the increasing demand for flexible, lifelong learning opportunities that cater to a diverse global learner population. AI plays an important role in transforming ODL through micro-credentials by involving adaptive learning systems, personalised content delivery, and the automation of administrative tasks, which collectively aim to improve learning outcomes and student engagement. By leveraging AI technologies, institutions can offer more personalised and adaptive learning experiences, meeting the individual needs of learners and addressing the diverse competencies required in today's dynamic job market. This integration also promises to enhance the scalability and effectiveness of ODL programmes, making higher education more accessible to a broader audience. However, the integration of AI into micro-credential courses within ODL contexts is not without its challenges. Many areas are yet to be explored, given the current state of knowledge.

Nevertheless, emerging trends and innovative practices in the use of AI in micro-credentials within ODL highlight the potential for significant improvements in personalised learning, accessibility, and learner support. Thus, the integration of AI into micro-credential courses within ODL in higher education institutions may offer promising opportunities to redefine the learning experience, making it more personalised, accessible, and aligned with the needs of 21st-century learners. By addressing the challenges and leveraging emerging trends, higher education institutions can harness the power of AI to enhance the value and impact of their ODL programmes and micro-credentials.

BACKGROUND OF STUDY

ODL is an educational system that eliminates barriers related to time, location, and access, emphasising the role of technology in facilitating education for learners who are physically separated from their instructors (Ghosh et al., 2012). ODL leverages technology and flexible methodologies to provide accessible, inclusive, and learner-centred education. Micro-credentials are particularly relevant in ODL settings, as they provide a flexible learning pathway that caters to learners desiring to upskill or reskill. Micro-credentials, aligned with the gig economy, are short, industry-based learning units facilitated by digital platforms that contribute to education privatisation, transferring employment preparation costs to individuals and tightening higher educations' ties to immediate workplace demands, rather than broader occupational skills (Wheelahan & Moodie, 2022). In addition, micro-credentials are focused, and competency-based certifications designed to support reskilling and upskilling, making them highly relevant in today's fast-paced and dynamic job market. Micro-credentials offer a means for learners to gain new skills or enhance existing ones without committing to long-term educational programmes (Orman et al., 2023). These credentials are often delivered online and obtainable through platforms, such as Coursera, Udemy, and EdX. Micro-credentials typically include metadata that transparently shows the learner's identity, awarding body, date of issue, study hours needed, type of assessment, and form of participation (Caetano et al., 2023).

The rise of micro-credentials reflects a shift towards more flexible, affordable, and accessible education options that are stackable and tailored to the evolving needs of learners and the job market. This flexibility allows learners to study at their own pace and from any location. It is designed to provide specific skills or knowledge that can be immediately applicable in the workplace. This has become increasingly important in the context of the COVID-19 pandemic, which has accelerated the adoption of online learning and highlighted the need for adaptable educational models (Ahmat et al., 2021). In particular, micro-credentials are valuable for professional development as they enable educators and other professionals to update their skills, stay current with industry trends, and demonstrate their competencies to employers. This form of credentialing is increasingly being recognised and valued by employers, enhancing employability and career progression (Hunt et al., 2020). Micro-credentials can be standalone certifications or combined (stacked) to contribute to broader qualifications, such as degrees or professional certifications. Stackability makes them versatile tools in the educational landscape, allowing learners to progressively build a portfolio of skills (Sargent et al., 2023). Micro-credentials offer a new approach to professional development by providing opportunities to document learning using work samples, videos, and other artefacts. This method enables teachers and other professionals to share their learning and achievements more broadly and can lead to recognition and rewards in their careers (Berry et al., 2016).

AI has emerged as a leading-edge technological trend. AI can significantly transform ODL by addressing various challenges and enhancing learning experiences for students and educators. AI also has the potential to enhance ODL through personalised learning experiences, automating administrative tasks, and improving student engagement and performance. AI enables personalised learning by tailoring educational content to meet the individual needs of learners. This customisation can improve engagement and comprehension by adjusting the pace and complexity of the material based on each student's progress and learning style (Yu et al., 2017). In addition, AI-powered support systems, such as chatbots and virtual tutors, provide students with instant feedback and assistance. These systems can answer common questions, guide learners through difficult concepts, and offer personalised tutoring, thereby enhancing the overall learning experience (Wen & Lin, 2008). AI can also analyse vast amounts of data to identify patterns and predict student outcomes, which helps educators intervene early when a student is struggling while personalising instruction

to improve academic performance (Dogan et al., 2023). AI-driven interactive platforms, including virtual and augmented reality, can create immersive learning environments. These technologies engage students more deeply by providing hands-on experiences and simulations that enhance understanding and retention (Rad et al., 2021). AI can also automate administrative tasks, such as grading, scheduling, and plagiarism detection, allowing educators to focus more on teaching and student interaction. This increases efficiency and reduces educators' workloads (Fadzil & Munira, 2008). The adaptability of AI systems to the diverse needs and backgrounds of learners offers an inclusive educational environment that ensures that all students have the opportunity to succeed regardless of their starting point (Holmes & Anastopoulou, 2019). By leveraging AI technologies, educational institutions can offer more flexible, efficient, and effective learning solutions.

Integrating AI into micro-credentials within ODL can significantly enhance the effectiveness, accessibility, and personalisation of learning experiences. AI technologies facilitate various aspects of the educational process, from personalised learning paths to automated support systems, making education more adaptable to individual learners' needs. AI enables personalised learning by tailoring educational content to each learner's unique needs. This is achieved through adaptive learning systems that adjust the complexity and pace of the material based on the learner's progress and preferences. Such systems are particularly beneficial in ODL settings, where direct interaction with instructors is limited (Fadzil & Munira, 2008). The development of AI-powered virtual teaching assistants, such as T-BOT and Q-BOT, helps both students and tutors by providing real-time tutoring and evaluation. These AI agents can engage with students through natural language, offering support and feedback, which enhances the learning experience on platforms such as Moodle (Rodriguez et al., 2008). Integrating AI into the learning management system (LMS) may streamline and enhance various educational processes, such as content delivery, student assessment, and feedback. AI technologies automate administrative tasks, provide personalised learning paths, and offer analytics to monitor and improve student performance (Firat, 2023). AI-driven insights also help educators design more effective courses by analysing student data to identify learning patterns and areas for improvement. This leads to the creation of more engaging and effective educational content (Goksel & Bozkurt, 2019).

Despite the emerging interest in AI, which significantly impacts the higher educational research landscape, systematic literature reviews concerning the integration of AI into micro-credentials, particularly in the context of ODL, are relatively new and rarely focused. To date, the existing systematic literature reviews have yet to provide a holistic, comprehensive, non-fragmented, and updated state of research and development of the integration of AI in micro-credentials, particularly in the context of ODL. The extent of the research is fragmented, potentially impeding the field's advancement when challenged by conflicting viewpoints and limited replications.

LITERATURE REVIEW

Thi Ngoc Ha et al. (2023) reviewed micro-credential research and practices in higher education based on the academic literature published from 2012 to 2022. The authors analysed 29 articles to determine the awareness, benefits, challenges, and factors impacting the effectiveness of micro-credentials. The findings indicate that although micro-credentials have potential advantages for higher education, their implementation is not straightforward for students or institutions. Currently, micro-credentials are in the early stages of integration into higher education, and more research is needed to fully understand their long-term viability and impact. However, the review underscored the challenges associated with the implementation of micro-credentials, as these are not micro tasks for students to complete or for higher education providers to offer meaningful learning experiences for students. Therefore, the viability and effectiveness of micro-credentials in higher education, particularly in the long term, have yet to be assessed.

Alsobhi et al. (2023) conducted a systematic literature review of studies published between 2016 and 2022, assessing them against established requirements for blockchain-based systems and identifying research gaps, thus providing insights into recent developments in micro-credentialing systems for higher educational institutions. The review suggested that an intelligent blockchain-based micro-credential framework for higher education students to manage micro-credentials and provide learning recommendations for students has yet to be explored and further developed.

A review of the emerging role of micro-credentials and digital badges in higher educational institutions suggests that they represent a significant shift in learning models through technology. Ahsan et al. (2023) reviewed 56 peer-reviewed articles published between 2015 and 2021 and highlighted the increasing interest in micro-credentials within higher education. The findings suggest a need for further investigation of the technological impacts and various stakeholder perspectives on micro-credentials. The study synthesises key themes into a conceptual framework for implementing micro-credentials in higher education and points out research gaps, thus contributing to the evolving discussion on how micro-credentials can revolutionise higher education degree delivery and student learning achievements. However, the use of machine learning or other AI-based research tools was not identified in the review.

A review by Mena-Guacas et al. (2023) examined the progression of teaching methods in short-term courses through a systematic PRISMA methodology-based review. The review focused on studies that detailed the teaching methods designed for courses not exceeding 90 days and excluded longer courses and incomplete studies. Conducted on 9th April 2022, the research used the Scopus database, and the 42 selected articles were rigorously reviewed and analysed multiple times by different researchers. The findings were categorised into learning experience, teaching methodology, technological resources, and assessment methods, highlighting a shift towards experiential learning in short-term courses over traditional memory-based activities.

In addition, it is important to become acquainted with gaps in the integration of AI into micro-credentials in ODL. Since ODL often lacks personalised learning pathways tailored to individual student needs, making it challenging to address diverse learning preferences and requirements effectively, AI can help by providing adaptive learning experiences (Garrido et al., 2016). As ODL programmes grow, scaling personalised support becomes increasingly difficult; however, AI solutions can be efficiently employed to scale, providing consistent support to a large number of learners simultaneously (Dai et al., 2022). ODL learners often face delays in receiving feedback, which can hinder their progress (Forkan et al., 2023). AI is believed to provide instant feedback and guidance, thus enhancing the learning experience and keeping students engaged. Moreover, the administrative workload in managing micro-credentials, such as grading and verification, is high; therefore, AI can help in automating these processes, improving efficiency, and allowing educators to focus more on teaching (Hatzi et al., 2012).

Based on the coverage of past reviews and the gaps identified, there is an urgent need to undertake a systematic literature review motivated by the absence of insights regarding the integration of AI into micro-credentials that render a sufficient basis for reviews on current research. The availability of research on AI across various disciplines also limits the comprehensive understanding of these areas. The dearth of reviews that incorporate the essence of AI into micro-credentials within ODL has triggered an urgency to provide a comprehensive and holistic state-of-the-art review that captures the current and potential state-of-the-art research and development of AI in micro-credentials for ODL settings. This has raised multiple questions, as follows:

RQ1: What is the trend of publication and citation in research that incorporates AI in micro-credential courses within the ODL context?

RQ2: What are the major themes in AI in micro-credentials for ODL research?

RQ3: What avenues are available for future research that intends to incorporate AI into micro-credential courses within the ODL context?

This study reviews the integration of AI into micro-credentials within the context of ODL. This review aims to address the knowledge gaps by highlighting comprehensive, holistic, and updated insights regarding the development and integration of AI into micro-credentials within the ODL context, which could stimulate future research agendas in its relevant domains. The objectives of this study are (1) to address and map the existing research that incorporates AI into micro-credential courses within the ODL context using review protocols and analytical techniques supported by bibliometric software technology; (2) to identify major themes in the current body of knowledge that constitutes AI in micro-credentials for ODL; and (3) to propose and suggest potential future trends for further understanding and benefits, theoretically and practically. The subsequent parts of the study highlight the methodology and research protocols, findings on the current trends and developments, major themes, and discussions on the research gaps for future research avenues of the abovementioned topics.

METHODOLOGY

A domain-based review was employed using a hybrid approach that combines bibliometric and thematic analyses aided by the most appropriate and latest software. The review observed the Scientific Procedures and Rationales for Systematic Literature Reviews (SPAR-4-SLR) protocol (Paul et al., 2021). SPAR-4-SLR provides a comprehensive methodological framework for conducting systematic literature reviews. This protocol emphasises a rigorous and transparent approach to the literature review, incorporating clearly defined steps, such as formulating research questions, systematic searching, screening for relevance, quality appraisal, data extraction, and synthesis of findings. SPAR-4-SLR aims to enhance the reliability and reproducibility of systematic literature reviews by ensuring methodological rigour and reducing bias. SPAR-4-SLR has been applied in various research contexts to improve the systematic review process. For instance, Ahiadu and Abidoye (2023) used this protocol to review the impact of economic uncertainty on property performance, highlighting the utility of SPAR-4-SLR in systematically organising and analysing large datasets. Similarly, Alkadi and Abed (2023) applied the SPAR-4-SLR protocol in their review of consumer acceptance of fintech payment services, demonstrating its effectiveness in structuring and analysing comprehensive literature datasets.

SPAR-4-SLR consists of three stages (assembling, arranging, and assessing) and six substages that follow sequentially (identification, acquisition, organisation, purification, evaluation, and reporting). The assembling stage involves gathering all relevant studies from various databases using predefined search criteria. This stage focuses on ensuring a comprehensive collection of articles that align with the research questions. It includes defining search terms, selecting appropriate databases, and applying inclusion and exclusion criteria to filter the initial search results. The arranging stage involves organising and categorising the studies collected from the assembling stage. This includes systematically sorting the studies based on relevance, thematic areas, and research questions. It also involves the removal of duplicates and the initial screening of titles and abstracts to ensure that the studies meet the predefined criteria for further detailed analysis. The assessing stage of the SPAR-4-SLR protocol entails evaluating the quality and relevance of the selected studies. This includes critical appraisal using predefined criteria to assess the methodological rigour, validity, and reliability of the studies, thereby ensuring that only high-quality research contributes to the final synthesis.

During the final synthesis, the articles were arranged and assessed using appropriate software before being coupled into several major research streams. The articles were reviewed through a subsequent thematic analysis, in which different authors independently read the articles to identify the major themes discussed in each research stream. An inductive coding approach was employed to explore the essence of each generated cluster and to distinguish between major themes across the identified research streams. The gaps across the research streams were highlighted to identify future research considerations and suggestions.

Assemble

This stage involved the identification and acquisition of publications for review. Only articles published in the World of Science (WoS) and Scopus databases between 2010 and 2024 were considered, as these are the largest multidisciplinary databases that host the publications mostly used in bibliometric studies (Galetsi et al., 2019; Visser et al., 2021). The assembling stage ended on 13 March 2024. The search query used comprised the Boolean operator 'AND', and a truncation of major keywords of the topic, i.e. 'micro-credentials' AND 'open and distance learning', AND 'artificial intelligence'. Based on the search query, 108 publications were assembled, signifying the maturity of the domain for review.

Arrange

The arranging stage involved the organisation and purification of published articles using the inclusion and exclusion criteria. Only full research, early access, and review articles were included. Proceedings, book chapters, and data papers were excluded. A total of 95 articles comprising 75 articles from WoS and 20 articles from Scopus gathered in the assembling stage were finally retained for the subsequent stage.

Assess

The final stage of the review protocol involved the evaluation and reporting of the articles. Article evaluations were performed using bibliometric analyses that run algorithms and quantitative techniques to extract specific compilations of the research stream of scholarly literature (Kraus et al., 2022). There were two components of bibliometric analysis in this study: science mapping and performance analysis (Lim & Kumar, 2023). Using performance analysis, the study assessed publications and citations in the shared fields of AI, micro-credentials, and ODL. This study also presented science mapping using keyword co-occurrence analysis (Igami et al., 2014) and bibliographic coupling (Waltman et al., 2010) to form clusters of publications based on the co-occurrence of keywords and similarities in shared references, respectively. The analyses were performed using Bibliometrix-R and visualised using VOSviewer.

The outcome of the analyses exhibited a two-dimensional map that located items based on the similarity of keywords and references. A higher degree of relatedness between the articles was indicated by the closer proximity between the items. A minimum threshold for keyword co-occurrence and bibliographic coupling was established to ensure that all selected articles were included in the analysis. To better ensure a sharper focus on the core articles for each cluster, the minimum number of occurrences of keywords and total citation link strength were set at three. This resulted in 46 articles, which were coupled into six major thematic clusters. The articles in the clusters were conscientiously reviewed using interpretive analysis. Each researcher read the articles independently and picked out important and major themes for each research stream.

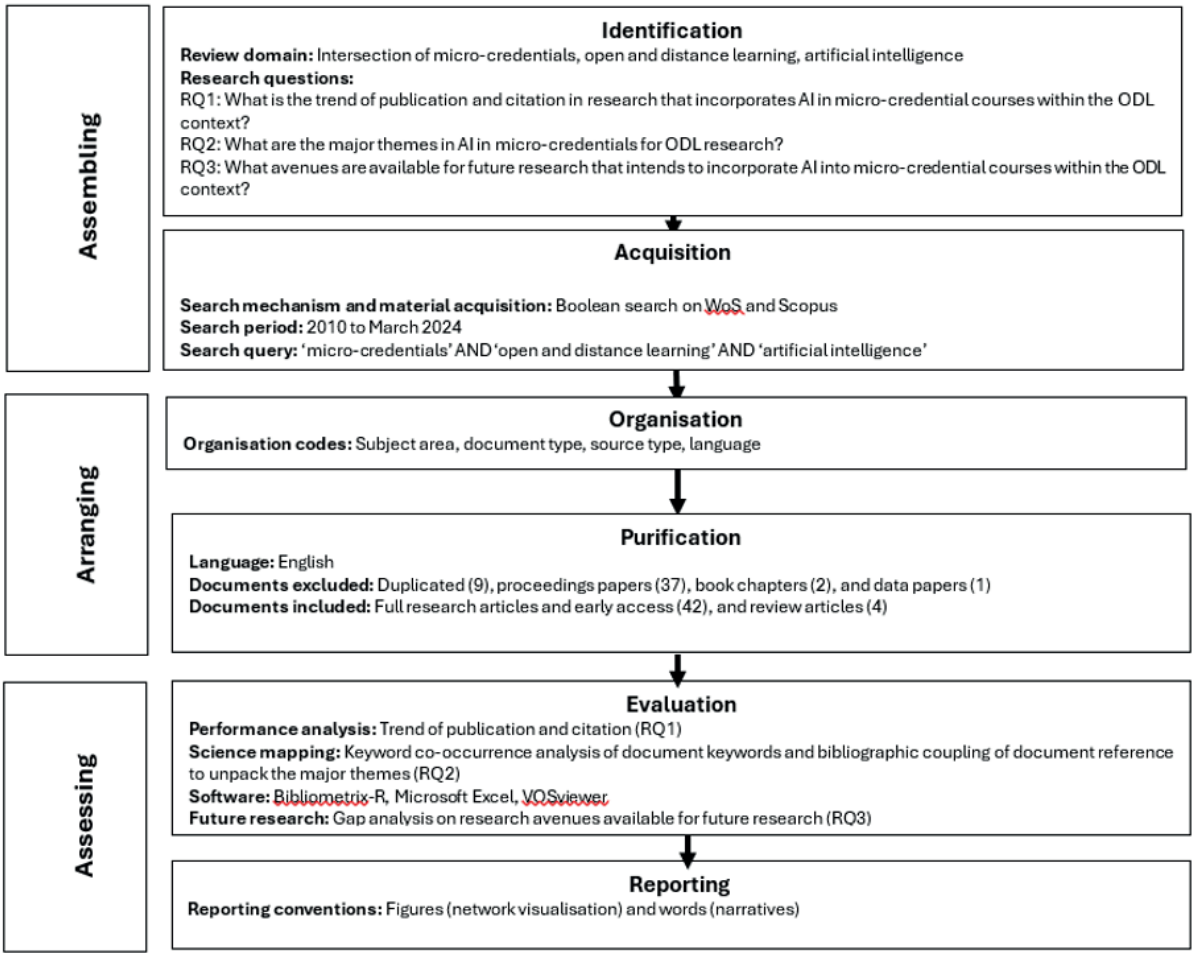

Figure 1. SPAR-4-SLR protocol

Source: Paul et al., (2021)

RESULTS AND FINDINGS

Trend of Publications and Citations (RQ1)

The body of knowledge focusing on AI in micro-credentials for ODL was published between 2010 and March 2024 (see Figure 2). The majority of the articles were published as full research articles (91.3%), while the remainder were review articles (8.75%). The annual publication growth rate was 8.16%, with an average of 4.63 citations per document. The total number of authors recorded was 333, out of which 30% of authors published single-authored documents, while international co-authorship was 20.31%. The average co-authorship per document is 2.82. A total of 4,014 references were used in composing the articles, with an average of 4.63 citations per document.

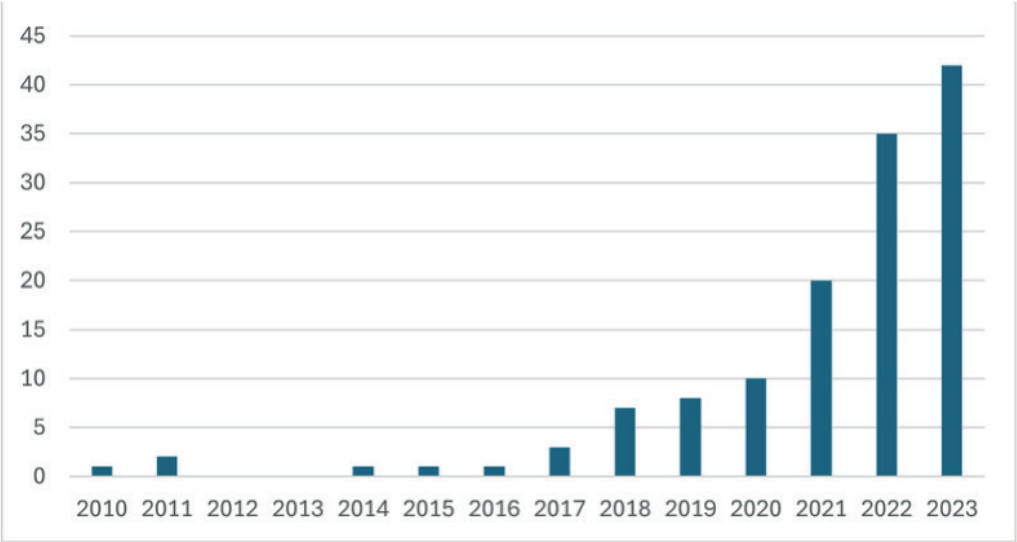

Figure 2. Number of articles published between 2010 and 2023

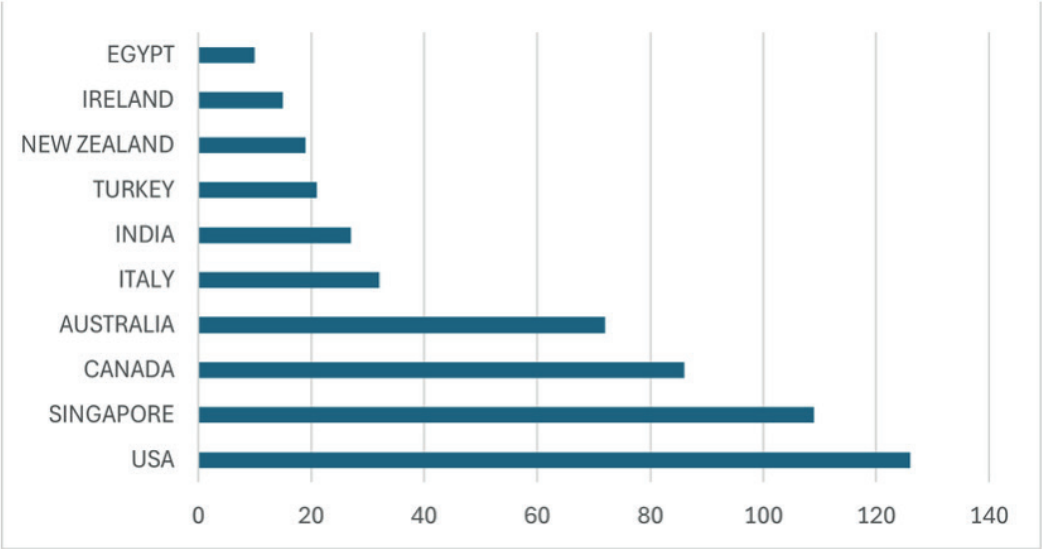

Figure 3. Country of citations (total article citations)

Figure 3 shows the countries of citations. The most cited country was the U.S. (126 citations), followed by Singapore (109 citations), Canada (86 citations), Australia (72 citations), Italy (32 citations), India (27 citations), Turkiye (21 citations), New Zealand (19 citations), Ireland (15 citations), and Egypt (10 citations).

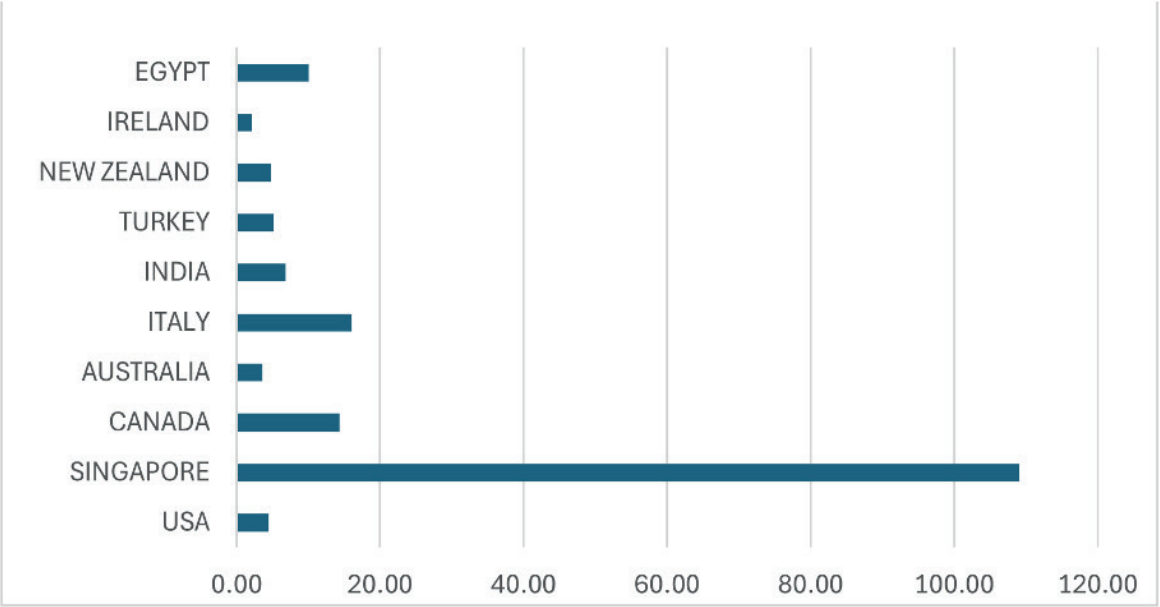

Figure 4. Average article citations by country

In terms of average article citations by country (see Figure 4), Singapore has the highest number of average article citations (109), followed by Italy (16 citations), Canada (14.3 citations), Egypt (10 citations), India (6.8 citations), Turkiye (5.2 citations), New Zealand (4.8 citations), the U.S. (4.5 citations), Australia (3.6 citations), and Ireland (2.1 citations).

Table 1. Most frequent keywords

Terms	Frequency
higher education	8
students	8
perception	6
digital badges	5
education	5
badges	4
motivation	4
achievement	3
curriculum	3
engagement	3

In Table 1, the most frequent keywords used in the publication are higher education (n=8) and students (n=8), followed by perceptions (n=6), digital badges (n=5), education (n=5), badges (n=4), motivation (n=4), achievement (n=3), curriculum (n=3), and engagement (n=3).

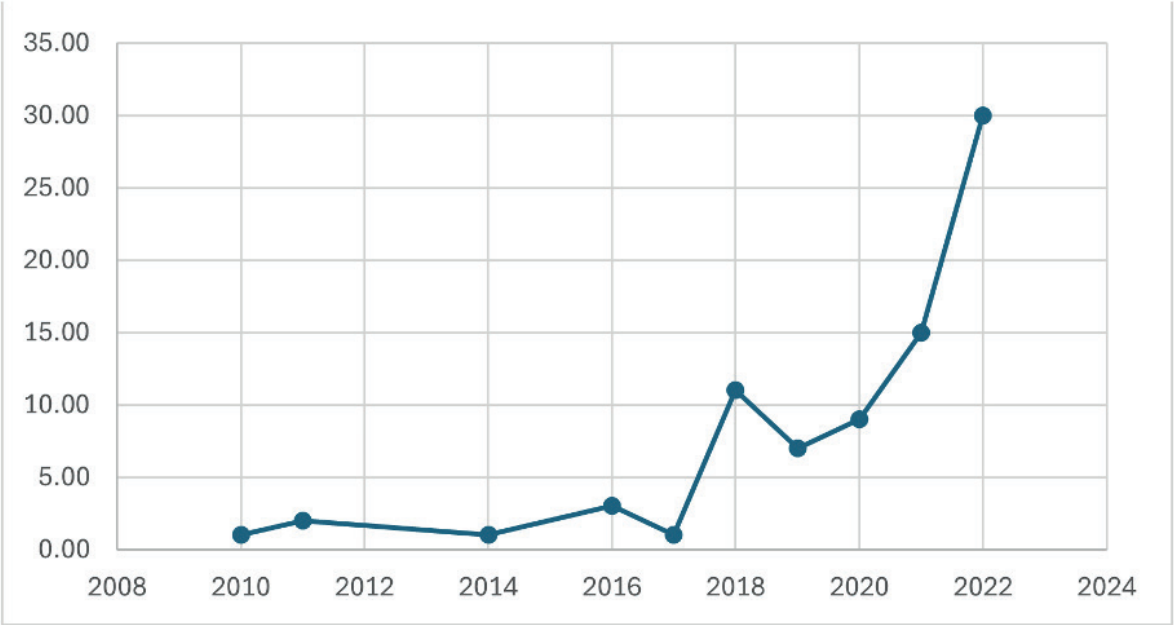

Figure 5. Annual total citations per year

There is an increasing trend in the annual total citations per year from 2010 to 2022 (see Figure 5). The humble trend started with one citation per year in 2010, followed by two citations in 2011, one citation in 2014, and three citations in 2016, which dropped to one citation in 2017 before spiking to 11 citations in 2018 and down to seven and nine citations in 2019 and 2020, respectively. The latter trend saw a dramatic increase of 15 annual total citations per year in 2021 to 30 citations in 2022. The 2023 and 2024 figures are not yet available.

Major Thematic Cluster (RQ2)

Keyword Co-occurrence Analysis

A keyword co-occurrence analysis was conducted to identify major emerging themes in the literature that integrate AI into micro-credentials within the ODL context. The resulting outcome of the keyword co-occurrence network uncovers major areas of interest via the mapping of keywords that have been enlisted by authors in their articles (Donthu et al., 2021). Figure 6. shows the keyword co-occurrence network of AI, micro-credentials, and ODL. This network was generated and visualised using VOSviewer apps. The distance between two keywords in the visualisation indicates the relatedness of the keywords in terms of co-citation links. In general, the closer two keywords are to each other, the stronger their relatedness. The strongest co-citation links between keywords are also represented by lines.

Six thematic clusters resulted from the keyword co-occurrence analysis. Each cluster is represented by different colours of the network (see Figure 6). Red networks denote motivational drives underlying micro-credentials, green networks represent alternative aspects of micro-credentials, blue networks manifest motives underlying lifelong learning, and yellow networks signify AI-based learning. Purple networks indicate micro-credentials for teacher education, while cyan networks exhibit equity and inclusivity of open education.

The keyword co-occurrence network supplements the bibliometric information that demonstrates the co-occurrences among all keywords in Table 2. The keyword co-occurrences and the relationships between topics in each cluster are explained in a logical sensemaking manner (Lim & Kumar, 2023), in which keywords are organised to logically present a coherent narrative of each cluster (Donthu et al., 2021).

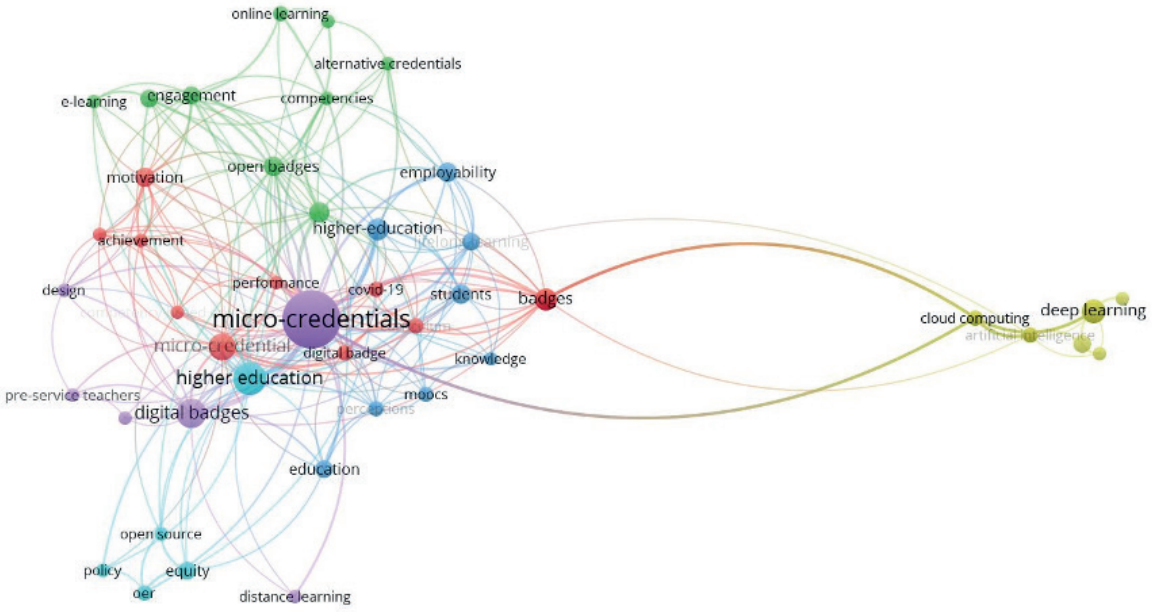

Figure 6. Keyword co-occurrence network between AI, micro-credentials, and ODL research

Table 2. Major keyword co-occurrence clusters in the research

Themes and keywords			
Co-word cluster 1: Motivational drives underlying micro-credentials (red network)		Co-word cluster 2: Alternative aspects of micro-credentials (green network)	
Achievement	Micro-credential	Alternative credentials	Open badges
Badges	Motivation	Competencies	Skills
Competency-based education	Performance	e-learning	
Covid-19	Self-efficacy	Engagement	
Curriculum		Massive open online course (MOOC)	
Digital badge		Online learning	
Co-word cluster 3: Motives underlying lifelong learning (blue network)		Co-word cluster 4: AI-based learning (yellow network)	
Education	Perceptions	Artificial intelligence	
Employability	Students	Classification	
Higher education		Cloud computing	
Knowledge		Deep learning	
Lifelong learning		Machine learning	
		Metaheuristics	

Co-word cluster 5: Micro-credentials for teacher education (purple network)	Co-word cluster 6: Equity and inclusivity of open education (cyan network)
Design	Equity
Digital badges	Higher education
Distance learning	Open Educational Resources (OER)
Micro-credentials	Open source
Pre-service teachers	policy
Teacher education	

Keyword co-occurrence cluster 1: Motivational drives underlying micro-credentials (red network)

The first keyword co-occurrence cluster focuses on the motivational factors that drive learners to undertake micro-credential courses. From the perspective of policymakers and higher educational institutions, this cluster represents the objectives of offering chunk-based micro-credential courses and programmes that utilise it. This cluster is formed by ten keywords: 'achievement', 'badges', 'competency-based education', 'Covid-19', 'curriculum', 'digital badge', 'micro-credentials', 'motivation', 'performance', and 'self-efficacy'. The motivational drive underlying micro-credentials is stimulated by the desire for achievement, enhanced self-efficacy, and the practical benefits of competency-based education. Digital badges serve as powerful motivators, providing visible recognition of skills and fostering a culture of continuous learning and improvement, especially in the context of the evolving educational landscape post-Covid-19. The motivational drives underlying micro-credentials are multi-faceted and deeply rooted in the pursuit of achievement, self-efficacy, and the need for competency-based education, particularly following the Covid-19 pandemic.

Keyword co-occurrence cluster 2: Alternative aspects of micro-credentials (green network)

The second keyword co-occurrence cluster deals with alternative aspects of micro-credentials. This cluster is formed by eight keywords: 'alternative credentials', 'competencies', 'e-learning', 'engagement', 'MOOC', 'online learning', 'open badges', and 'skills'. The alternative aspects transform education by fostering engagement, enhancing employability, and promoting lifelong learning. These credentials offer a practical and flexible approach to skill acquisition, preparing learners for the dynamic demands of the modern workforce. Micro-credentials provide a targeted approach to learning, focusing on the acquisition of discrete, job-relevant skills rather than traditional, time-bound degrees. This shift is particularly significant in the context of online learning, in which engagement and flexibility are paramount. By integrating micro-credentials into massive open online courses (MOOCs) and other e-learning environments, educators can create more personalised and interactive learning experiences that cater to the diverse needs of students.

Keyword co-occurrence cluster 3: Motives underlying lifelong learning (blue network)

The third keyword co-occurrence cluster encapsulates motives for lifelong learning, which comprises seven keywords: 'education', 'employability', 'higher education', 'knowledge', 'lifelong learning', 'perceptions', and 'students'. The motives underlying lifelong learning are deeply intertwined with the evolving demands of education, employability, and the pursuit of knowledge. These motives encompass a blend of practical and aspirational goals that are centred on the continuous pursuit of education, employability, and knowledge in an ever-changing world. In today's world, the concept of lifelong learning has gained significant importance, driven by the need to stay relevant in the workforce and adapt to new technologies and methodologies. Education is no longer confined to the traditional boundaries of primary, secondary, and higher education. It has expanded to encompass a continuous, self-directed process that extends throughout an individual's life. This shift is motivated by the recognition that knowledge and skills must be constantly updated to meet the demands of an ever-evolving job market.

Keyword co-occurrence cluster 4: AI-based learning (yellow network)

The fourth keyword co-occurrence cluster focuses on AI-based learning. This cluster is made up of six keywords: 'artificial intelligence', 'classification', 'cloud computing', 'deep learning', 'machine learning', and 'metaheuristics'. AI-based learning represents a significant leap forward in education driven by artificial intelligence, machine learning, deep learning, and cloud computing. Through classification algorithms, AI can assess a student's strengths and weaknesses, enabling more targeted interventions that optimise learning outcomes. Meanwhile, metaheuristics, which are the advanced optimisation algorithms used in AI, also contribute to educational advancements by solving complex problems related to resource allocation and curriculum planning. These algorithms help institutions optimise their operations, ensuring that resources are used efficiently and effectively to support student learning.

Keyword co-occurrence cluster 5: Micro-credentials for teacher education (purple network)

The fifth keyword co-occurrence cluster taps into micro-credentials for teacher education. This cluster is formed by six keywords: 'design', 'digital badges', 'distance learning', 'micro-credentials', 'pre-service teachers', and 'teacher education'. The integration of micro-credentials and digital badges into teacher education is a transformative development that supports the professional growth of pre-service teachers. By leveraging these innovative tools, teacher education programmes can better prepare educators for the dynamic and technologically advanced educational landscape, ultimately leading to improved teaching outcomes and student success.

Keyword co-occurrence cluster 6: Sustainable development goals (sdgs) – equity and inclusivity of open education (cyan network)

The sixth and last keyword co-occurrence cluster concentrates on the equity and inclusivity of open education. This cluster is made up of five keywords: 'equity', 'higher education', 'Open Educational Resources (OERs)', 'open source', and 'policy'. This cluster contains the least number of keywords, indicating possible future research avenues for educational policies and Sustainable Development Goal 4 (SDG4) studies. SDG4 is a commitment to 'ensure inclusive and equitable quality education and promote lifelong learning opportunities for all' (United Nations, n.d.).

In an increasingly interconnected world, the principles of equity and inclusivity are becoming paramount in the realm of the liberalisation of education. Thus, OERs and open-source policies play a pivotal role in democratising access to higher education. By providing free and openly licensed educational materials, OERs eliminate financial barriers that often prevent marginalised communities from accessing quality learning resources. This inclusivity ensures that students, regardless of their socio-economic background, have the opportunity to engage with high-quality educational content, fostering a more equitable learning environment. In short, the equity and inclusivity of open education, bolstered by OERs and open-source policies, represent a transformative approach to higher education. By championing these principles, educational institutions can create a more equitable and inclusive future in which knowledge is accessible to all, regardless of their background or circumstances.

Bibliographic Coupling of the Research

Bibliographic coupling was performed using data clustering techniques. Similar articles based on common referencing pattern coverage are categorised under the same cluster (Weinberg, 1974). Figure 7 shows the article network that was generated and visualised using VOSviewer. The six main thematic clusters that emerged from the bibliographic coupling analysis are indicated by the colours of the network constituting the body of knowledge. Each colour of the network represents each theme identical to those generated earlier in the keyword co-occurrence analysis. Motivational drives underlying micro-credentials are denoted by red networks, while alternative aspects of micro-credentials are represented by green networks. Motives underlying lifelong learning are denoted by blue networks, while AI-based learning is represented by yellow networks. Micro-credentials for teacher education are indicated by purple networks, while equity and

inclusivity of open education are expressed by cyan networks. The bibliographic coupling network detailing the authors and publications in Figure 7 distinguishes the semantic associations among the articles to identify and uncover latent research themes that may guide future research directions.

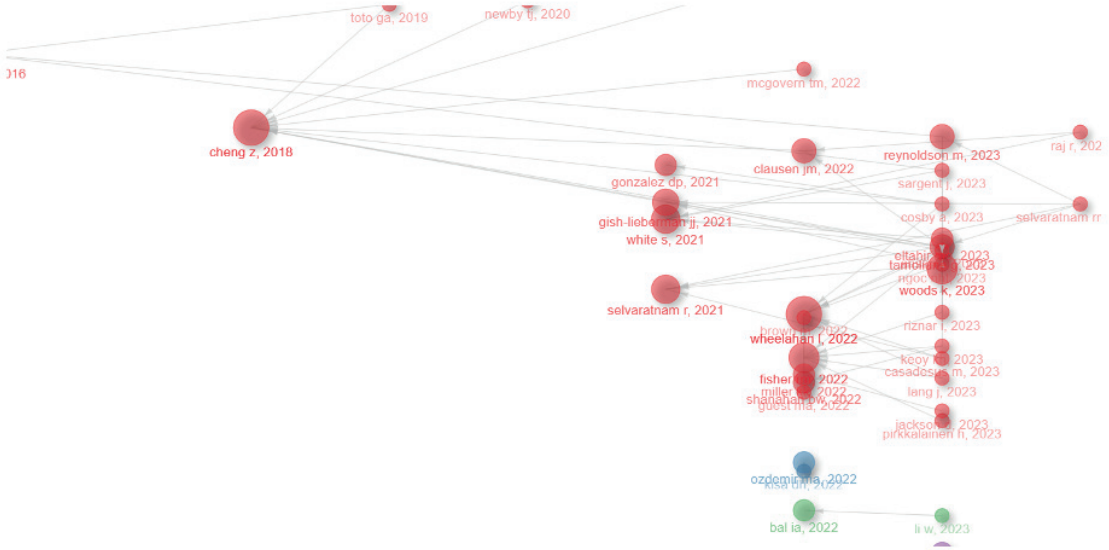

Figure 7. Bibliographic coupling networks between AI, micro-credentials, and open and distance learning research

Bibliographic cluster 1: Motivational drives underlying micro-credentials

The first bibliographic cluster focuses on the motivational drives underlying micro-credentials. Fourteen prolific studies formed this cluster. Wheelahan and Moodie (2021) asserted the importance of micro-credentials in higher education, arguing that this aligns curricula with labour market demands, employability, and 21st-century skills. Applying Basil Bernstein's sociological theory, the authors examined how micro-credentials shaped education through the lens of human capital theory, focusing on re-contextualisation and the market-oriented 'homo economicus'. In another study, Wheelahan and Moodie (2022) stressed that micro-credentials that are indeed aligned with the gig economy contribute to education privatisation, transferring employment preparation costs to individuals, and tightening higher educations' ties to immediate workplace demands, rather than broader occupational skills.

Cheng et al. (2018) argued for integrating open digital badges with a set goal – optimising learning – and provided design recommendations for incorporating open digital badges as technological tools. Newby and Cheng (2020) found that pre-service teachers who used digital badges with instructional scaffolding reported higher confidence and achieved better grades compared to those who used traditional instructional projects. This highlights the potential of these badges to enhance learning performance. McGovern and Gogan (2022) asserted that a stackable badged micro-credential system can enhance academic flexibility, helping students manage personal and societal crises by certifying mastery in modules of a graduate-level course. This also offers structure, temporal flexibility, and portability, thereby easing course interruptions and resumptions.

In 2018, the New Zealand Qualifications Authority (NZQA) recognised micro-credentials, defined their credit limits, and publicised this on the NZQA website. This framework applies to tertiary education organisations, while universities create their own recognition schemes (Fisher & Leder, 2022). The rules address international and non-university tertiary education organisations (TEO) providers and identify potential issues, such as qualification disaggregation and future recognition.

White (2021) critiqued the development of credit-bearing micro-credentials for Australian teachers' professional advancement, which are designed to support learning and create pathways to advanced education

by examining design stages, challenges, and benefits. Selvaratnam and Sankey (2021) reported that surveys conducted by the Australasian Council on Open, Distance, and eLearning revealed increased interest and policy work and that significant implementation efforts are required. Furthermore, Selvaratnam et al. (2024) suggested that as the demand for micro-credentials rises, education providers need guidance to enhance their capacity and capability for high-quality, profitable learning outcomes. The authors developed a maturity model to help providers assess and improve their micro-credential delivery. A survey of Australasian higher education providers validated the model. Technical infrastructure was the most mature model, while quality, resourcing, standards, and strategy were the least mature. In another study, Reynoldson (2023) emphasised neoliberal ideals in which students were viewed as independent consumers managing their employability; however, the study lacked students' perspectives. In this study, micro-credentials in Australian higher education are seen as innovative, industry-linked educational credits. Proponents include public institutions, private companies, and governments.

In the United States, Gonzalez and Villaire (2021) elaborated on the Healthy People 2030, which advocates for increasing organisational health literacy. To support this endeavour, the Institute for Healthcare Advancement offers the Health Literacy Specialist Certificate Program for professional development and the Health Literacy Solutions Center for networking. This specialist certificate includes seven micro-credentials developed by experts, and the solutions centre provides over 10,000 members with resources and education. Clausen (2022) highlighted the opportunities and challenges of a comprehensive micro-credentialing system aligned with the International Society for Technology in Education (ISTE) (standards that serve as a framework for innovation and excellence in learning, teaching, and leading adopted by the United States and many countries worldwide) to prepare teachers for technology integration. This system addresses the lack of a required educational technology course and receives feedback for further improvement. Given the current U.S. higher education climate, in which university faculty and staff are tasked with doing more with less, Woods and Woods (2023) explored the benefits of micro-credentials for students and universities, detailing the creation of graduate certificates within a master's programme and offering insights into design challenges and opportunities.

Gish-Lieberman et al. (2021) asserted that micro-credentials support self-directed learning by providing visible learning pathways with digital badges. Rooted in historical badge systems, self-regulated learning phases, which comprise forethought, performance, and self-reflection, were suggested for micro-credentials as an effective implementation process requires standards, best practices, and integration with feedback and collaborative learning. Raj et al. (2024) identified key barriers to micro-credential implementation that hinder the motivation to enrol, namely, unclear definitions, ambiguous courses, lack of accreditation, quality assurance, remuneration policies, coordination issues, inadequate learning volume, and low acceptance by individuals and organisations. The findings are derived from the literature, expert input, and ranking methods, which guide educational institutions and policymakers.

The following issues are covered by the prominent articles in this cluster: meeting the contemporary rapid labour market demand, facilitating the flexibility of 21st-century learning, integrating with the national education frameworks and systems, suitability with self-directed learning orientations, and overcoming barriers that hinder the motivations to undertake micro-credential courses.

Bibliographic cluster 2: Alternative aspects of micro-credentials

The second bibliographic cluster concentrates on the alternative aspects of micro-credentials. This cluster also includes MOOCs, which can be inferred from the near-similar characteristics of micro-credentials, innovations in current pedagogy, and ideal applicability for corporate training. This cluster comprises nine prominent studies. Traditional education systems inadequately prepare learners for the future of work through standardised and inequitable approaches. Based on this assumption, Laughlin (2021) envisioned the integration of emerging learner-centred paradigms into micro-credentialing to create relevant learner-focused educational experiences that would benefit future workforce preparations while addressing individual needs. West et al. (2020) reviewed societal, educational, employer, and learner needs for new alternative credentials, provided theoretical rationales for open micro-credentials, and examined their credentialing, motivational, and technological functions, including those of open badges. On a global scale,

Bean et al. (2023) highlighted the evolution and key developmental challenges of alternative credentials, and the opportunities arising therefrom. The researchers outlined the implications of using these credentials and badges for higher education, based on lessons learned from their extensive experience in credentialing initiatives across continents and sectors of North America, Europe, and Australasia.

Innovation in the current pedagogy is also emphasised. Tang and Qian (2022) proposed the LITTLE framework that emphasised learner-centred, inquiry-based, technology-enriched, trophy-driven, literature-guided, and evidence-based design strategies to enhance the effectiveness of existing micro-credentials and MOOCs, which have been promoted as disruptive, low-cost higher education options but face issues of low retention and forum participation rates. Examples and theoretical justifications were provided to illustrate these guidelines. Delivering blended-mode eLearning in Technical and Vocational Education and Training (TVET) is challenging due to motivational and engagement issues; therefore, Jayalath and Esichaikul (2022) proposed a gamified operational model to enhance learner success in TVET by embedding motivational (attention, relevance, confidence, and satisfaction) and engagement (behavioural, emotional, and cognitive) frameworks. Fifteen game dynamics, mechanics, and components were suggested and tested in a sample online course. Ruutmann (2023) outlined the psycho-didactical model of Engineering Pedagogy for effective science, technology, engineering, arts, and mathematics (STEAM) education. The author presented the attributes and skills of 21st-century engineering graduates and the International Society for Engineering Pedagogy (IGIP) competency model for educators and described a micro-credential programme for STEAM teachers that emphasised interconnecting learning activities to achieve specific educational goals.

In corporate training, Egloffstein and Ifenthaler (2017) investigated 119 employees' perspectives on MOOCs for workplace learning, focusing on motivation, credentials, and incentives. The findings showed a high interest in career development through MOOCs but a low acceptance of MOOC credentials among stakeholders. Implications for MOOC design and implementation in professional contexts were discussed. Subsequently, Egloffstein (2018) explored MOOCs for digital workplace learning, discussing basic designs, platform features, and current providers. The study highlighted the strengths, weaknesses, opportunities, and threats and offered insights into implementing MOOCs in corporate settings and future developments. In another study, Clements et al. (2020) provided a practical guide for organisations in designing and implementing open badging systems that cover key terms, past uses, and technologies for creating badges, including a framework with step-by-step implementation instructions to recognise diverse skills and experiences across various settings. Given that MOOCs are a growing trend in professional learning, the authors explored openSAP as an example of Enterprise MOOCs and found it valuable for global professional learning. However, it often does not focus on digital workplace learning in which alternative achievement metrics are required.

The increasing preferences for micro-credentials and MOOCs in organisational and corporate training through alternative credentials and open badges are among the issues highlighted in this cluster. Indeed, the expected outcomes are commonly shared, which consistently focus on enhancing the competencies, and skills, and better student engagement through innovative technology, including e-learning and online learning.

Bibliographic cluster 3: Motives underlying lifelong learning

The third bibliographic cluster encapsulates the motives underlying lifelong learning. It is known that the rise of digital micro-credentials in education has led to confusion among stakeholders, prompting global efforts to define the quality of learning and its beneficial impacts. Therefore, in response to the Fourth Industrial Revolution, Lang (2023) came out with commentary reviews of literature on micro-credentials that emphasised their role in lifelong learning and workforce upskilling. Keoy et al. (2023) examined the adoption of micro-credentials in Malaysia from the perspectives of higher education providers in which technological, organisational, and people-related challenges were identified, while proposing a framework for successful implementation. By addressing these recommendations, the study hoped to enhance student learning and transform higher education, thus meeting digital age demands. Jackson and Dean (2023) surveyed 84,000 Australian graduates' participation in employability related activities and the impact on work readiness and employment outcomes. Over half of them participated with notable differences in

age, gender, disability, citizenship, and socio-economic background. It was also found that graduates from disadvantaged backgrounds experienced significant benefits, particularly in leadership roles, awards, and mentoring programmes. In summary, this cluster wraps up the underlying factors that motivate lifelong learning. The important issue is the focus on the pursuit of lifelong learning through micro-credentials, and MOOCs are largely driven by the need to acquire higher education and knowledge about employability based on students' perceptions.

Bibliographic cluster 4: AI-based learning

In this cluster, AI-based learning is highlighted. This cluster illustrates the significance of AI in supporting student learning. With AI, online learning is conveniently accessible and flexible. Important studies underlying this cluster comprise Babu et al. (2023), Pence (2020), and Rajendran et al. (2022). Babu et al. (2023) used AI techniques to predict student performance by analysing large educational datasets. The study proposed the Metaheuristic Optimization-based Feature Subset Selection with an Optimal Deep Learning (MOFSS-ODL) model, which combined feature selection and deep learning to enhance predictive accuracy. Tested on University of California Irvine machine learning repository (UCI) dataset, the model achieved 96.49% accuracy, outperforming the recent methods of Educational Data Mining. Rajendran et al. (2022) highlighted the significance of edge computing for decentralised healthcare by leveraging wearable devices and mobile apps for immediate diagnosis and treatment, which are supported by scalable data privacy mechanisms. The study found that AI and edge computing could enhance medical care by integrating deep learning with medical technology, reducing latency, and improving real-time patient monitoring. Pence (2020) acknowledged that new instructional technologies, such as smartphones, cloud computing, AI, 3D printing, virtual reality, and augmented reality, are transforming chemistry education by extending learning beyond the classroom. However, it is important to note that these technologies can lead to student isolation and pose challenges for faculty in fostering essential social skills and managing individualised learning. AI-based learning forms an important catalyst for the future design and implementation of micro-credentials. Therefore, it is important to utilise and design the available AI tools and techniques to enhance the practicability and significance of micro-credentials in the ODL context.

Bibliographic cluster 5: Micro-credentials for teacher education

This cluster addresses the importance of designing and developing micro-credentials for teachers' training and curriculum. A Maryland university developed a micro-credential in Computational Thinking (CT) for K-8 pre-service and in-service teachers (Bal et al., 2022). The analysis of surveys, journal entries, and lesson plans showed growth in CT awareness and integration. Thus, the micro-credential effectively adds CT content to an already packed curriculum to enhance teachers' knowledge and implementation skills.

Given the effectiveness of digital badges and micro-credentials' unclear roles in improving learning, Newby and Cheng (2020) have found that pre-service teachers who used digital badges with instructional scaffolding reported higher confidence and achieved better grades compared to those who used traditional instructional projects. This outcome further recognises the effectiveness of micro-credentials in enhancing learning performance. Through a niche study, Ruutmann (2023) outlined the psycho-didactical model of Engineering Pedagogy for effective STEAM education (STEAM education is an approach to learning that uses science, technology, engineering, the arts, and mathematics) by presenting the attributes and skills of 21st-century engineering graduates, introducing the IGIP competency model for educators, and describing a micro-credentials programme for STEAM teachers. The model emphasises interconnected learning activities to achieve specific educational goals. Given the evidence of micro-credential development across various fields of teacher education, it is important to implement more micro-credentials for the educational sector to reap its benefits in facilitating teachers' training and enhancing their skills and competencies.

Bibliographic cluster 6: SDGs – equity and inclusivity of open education

This cluster centres on the equity and inclusivity of open education, despite niche focuses on AI, micro-credentials, and ODL aspects. Three important studies are elaborated upon. The Covid-19 pandemic, rising

education costs, and employer concerns about skills have driven universities, colleges, and credentialing agencies to refocus on open education and micro-credentials. By providing affordable flexible options for students and meeting employer needs for skilled employees, micro-credentials ensure acceptance, stackability, and secure digital records of skills while supporting Education for All (SDG4). Based on these findings, McGreal et al. (2022) encouraged institutions, governments, UNESCO, and NGOs to undertake and implement micro-credentials in their respective entities.

Lane and Goode (2021) detailed the cost-effective implementation of open-source technologies by highlighting the technological benefits of Open Education Resource universitas (OERu), an international consortium offering stackable micro-credentials. Through an open-source Next Generation Digital Learning Ecosystem (NGDLE) that supports hundreds of thousands of learners with an annual budget under US$10,000, technological autonomy, resilience, and educational opportunities are enhanced for learners and educators globally.

Furthermore, Ossiannilsson (2023) highlighted the UNESCO OER recommendations, which were adopted in 2019 and aligned with multiple UN SDGs, particularly SDG 4 (education), SDG 5 (gender equality), SDG 9 (industry, innovation, and infrastructure), SDG 10 (reducing inequalities), SDG 16 (peace, justice, and strong institutions), and SDG 17 (partnerships). The author also explored ways in which OERs support these goals, advocated for stakeholder involvement, and addressed accessibility and quality issues by highlighting the interconnectedness of OERs with universal values, such as equality and social justice, and proposed a model that links OER implementations with achieving these SDGs.

Open education significantly contributes to SDGs related to equity and inclusivity by providing accessible, affordable, and flexible learning opportunities for all individuals, regardless of their socio-economic status, geographic location, or background. By leveraging digital platforms and resources, open education reduces barriers to learning, enabling marginalised and underserved populations to acquire essential skills and knowledge. By aligning with SDGs, open education not only addresses immediate educational disparities but also contributes to long-term societal transformation by creating a more informed, skilled, and equitable global community.

Discussion, Gaps, and Future Research Avenue (RQ3)

This part of this review identifies and discusses notable knowledge gaps encountered that address and suggest future research that can be pursued.

Gap 1: Lack of Research in the Actual Implementation of Micro-credentials.

Although open digital badges are recognised as micro-credentials, their potential to enhance learning through goal setting is under-researched (Cheng et al., 2018), while their effectiveness in improving learning is unclear (Newby & Cheng, 2020). More research is needed to refine and assess the designs and effective implementation through standards, best practices, and integration with feedback and collaborative learning in micro-credentials (Gish-Lieberman et al., 2021). In Selvaratnam et al.'s (2024) study, future research was suggested to refine and extend a maturity model that helps providers assess and improve their micro-credential delivery.

Gap 2: Lack of Research in Measuring the Achievement of Micro-credentials in Workplace Settings

Gaps remained in adhering to the motivational and engagement issues, for example, Jayalath and Esichaikul (2022) suggested that game dynamics, mechanics, and components should be further tested in a sample online course. Enterprise MOOCs are found to be valuable for global professional learning. However, they do not focus on digital workplace learning (Egloffstein & Schwerer, 2019). Therefore, alternative achievement metrics are needed.

Gap 3: Lack of Research on Micro-credentials for Teacher Education

Despite the importance of teacher empowerment as far as their roles are concerned, there are limited studies on micro-credentials that are specifically designed for teachers' training and educational programmes. More studies should be undertaken to align the skills and competencies of teachers with the learning outcomes achievable through micro-credentialing. This provides teachers with more flexibility when engaging with the evolving learner generation, which is closely shaped by the latest technological trends.

Gap 4: Lack of Studies That Research Equity and Inclusivity of Open Education

Few research articles specifically tapped into the issues of equity and inclusivity of open education. To date, much attention has been paid to the role of OER in achieving SDGs (Ossiannilsson, 2023), recommendations for universities, colleges, and credentialing agencies to rethink credentials by focusing on open education and micro-credentials (McGreal et al., 2022), and cost-effective strategies in the implementation of open-source technologies (Lane & Goode, 2021). Insights from the operationality of micro-credentials in actual implementation have yet to be understood, particularly in developing countries where access to education is not always ideal.

Gap 5: Lack of Research in the Actual Integration of AI into Micro-credentials within ODL Settings

Despite its benefits, implementing micro-credentials faces challenges, such as ensuring quality assurance, integrating them into existing educational frameworks, and gaining recognition from employers. Addressing these challenges is crucial for the widespread adoption and success of micro-credentials in higher education. Although it is acknowledged that new instructional technologies, such as smartphones, cloud computing, AI, 3D printing, virtual reality, and augmented reality, are transforming chemistry education by extending learning beyond the classroom (Pence, 2020), these technologies can lead to student isolation and pose challenges for faculty in fostering essential social skills and managing individualised learning. Future research may delve into smoothening the impact of using AI on micro-credentials within the ODL context.

Gap 6: Lack of Research on the Ethical and Effective Use of AI in the Implementation of Micro-credentials in ODL Settings

Data privacy, ethical considerations, and the digital divide pose significant barriers to the widespread adoption of AI in education. Although there are concerns regarding the quality assurance and recognition of AI-enhanced micro-credentials, which are crucial for their acceptance and value in the job market, studies to date have yet to delve into these aspects, highlighting the importance of developing robust frameworks and standards to ensure the ethical and effective use of AI in the implementation of micro-credentials in ODL settings.

DISCUSSIONS AND CONCLUSION

Micro-credentials represent a significant innovation in education, offering flexible, accessible, and targeted learning opportunities that cater to the needs of modern learners and employers. While challenges remain, their potential to complement and enhance traditional education systems is substantial. The integration of AI in micro-credentials within ODL is deemed to significantly enhance the learning experience by providing personalised education, automating support systems, and improving accessibility. AI technologies make it possible to offer more flexible, efficient, and tailored learning experiences, thus meeting the diverse needs of learners in an ODL environment.

This review presents the trends of publications in the domains of AI integration into micro-credentials in the ODL context, namely publication years and countries, authors' affiliations, domain subtopics, and citation numbers over time. Major thematic clusters based on keyword co-occurrences and bibliographic coupling of research topics were also generated. The keyword co-occurrence analysis produced six thematic clusters on the integration of AI into micro-credentials in ODL. These clusters were well triangulated using two

bibliometric information sources, i.e. keywords and publication citations, which comprise motivational drives underlying micro-credentials (Cluster 1), alternative aspects of micro-credentials (Cluster 2), motives underlying lifelong learning (Cluster 3), AI-based learning (Cluster 4), micro-credentials for teacher education (Cluster 5), and SDGs' equity and inclusivity of open education (Cluster 6). A reflection on this bibliometric review reveals notable gaps that can be addressed in the current literature and makes suggestions for future research. The review provides a theoretical understanding for advancing the subject area while addressing its practical applications for future researchers, scholars, and practitioners. It also serves as a key and quick reference in providing state-of-the-art literature, while enabling industry practitioners to harnes the full benefits of bridging the theoretical and practical gap.

Integrating AI into micro-credentials is crucial in advancing lifelong learning, particularly within the framework of SDGs aimed at equity and inclusivity in education. Micro-credentials provide an alternative to traditional degrees by offering flexible, competency-based certifications that address the diverse needs and motivations of learners. For educators, micro-credentials facilitate continuous professional development, ensuring that teaching practices evolve to meet the demands of modern education systems. Through micro-credentials and the booming of AI, a progressive education system should offer meaningful qualifications valued in both labour markets and society, made possible via ODL settings.

Motivational drives for micro-credentials stem from the need for accessible, personalised learning paths that accommodate the varying schedules and learning preferences of students. AI-enhanced learning systems offer tailored educational experiences, providing real-time feedback and adaptive learning pathways that support individual progress. This approach not only enhances the learning experience but also ensures that education is inclusive, catering to all learners regardless of their socio-economic background or geographic location.

Micro-credentials play a significant role in teacher education. By leveraging AI, educators can engage in ongoing professional development, acquiring new skills and knowledge that are immediately applicable in the classroom. This continuous learning process is essential for maintaining high educational standards and adapting to new teaching methodologies. Furthermore, the focus on equity and inclusivity aligns with SDGs by removing traditional barriers to education, such as cost and accessibility. Open education initiatives supported by AI-driven micro-credentials provide flexible learning opportunities that are crucial for fostering a more equitable global education landscape.

In summary, the integration of AI in micro-credentials enhances lifelong learning, supports teacher education, and promotes the SDGs' goals of equity and inclusivity in open education. This comprehensive approach ensures that all learners have the opportunity to succeed in an increasingly digital and interconnected world. Despite its contributions and insights, the review has several methodological limitations. First, only articles published in the WoS and Scopus databases were considered. Second, other possible and relevant studies that are searchable using the same search query may have been overlooked. This may limit the scope of the insights provided by the review. Third, the review also included only articles strictly related to the integrated domains of AI, micro-credentials, and ODL. Other articles related to the domains might have been missed because of misalignment with the keyword entry or other technical aspects related to the metadata of the listings. New reviews that capture these alternative domains are welcome.

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