A Survey of Micro-Credentials and Competency-Based Education in Career Development and Workforce Training

Abstract

This survey paper explores the transformative role of micro-credentials and competency-based education (CBE) in modern career development and workforce training, emphasizing their capacity to address the skills gap and enhance employability. By providing structured, industry-aligned learning pathways, these educational frameworks support lifelong learning and adaptability in a rapidly evolving job market. The integration of digital badges and advanced technological tools offers flexible, personalized learning experiences, fostering skill acquisition and professional growth. Despite challenges in recognition and standardization, the collaboration between educational institutions and industry stakeholders is crucial for aligning micro-credentials with market demands. Technological advancements, such as adaptive learning algorithms and AI literacy, present significant opportunities for innovation, ensuring learners are equipped to navigate the complexities of AI-driven environments. The survey highlights the importance of creating inclusive educational practices that address equity and access issues, ensuring all learners can benefit from these innovations. By leveraging these opportunities, micro-credentials and CBE can effectively support lifelong learning and career advancement, equipping individuals with the competencies necessary to thrive in a dynamic global economy.

1 Introduction

1.1 Significance of Micro-Credentials and Competency-Based Education

Micro-credentials and competency-based education (CBE) are vital in contemporary career development and workforce training, providing innovative solutions to skill acquisition and validation challenges. These frameworks address the dynamic workforce needs by offering targeted and flexible learning opportunities aligned with industry standards. Micro-credentials facilitate a standardized approach to recognizing specific skills, thereby enhancing employability and career readiness [1]. By enabling learners to accumulate and demonstrate competencies modularly, they promote lifelong learning and professional development in an evolving job market [2].

CBE shifts the focus from time-based education to competency mastery, ensuring learners demonstrate proficiency in relevant areas [3]. This model is particularly effective in fields like healthcare and technology, where continuous assessment and skill validation are essential [4]. Implementing CBE systems highlights the need for personalized learning pathways that cater to individual student goals, enhancing educational outcomes and career prospects [5].

Digital badges as micro-credentials further document achievements and skills, providing a transparent and portable record of learning valued by employers. Emphasizing career adaptability resources—such as concern, control, curiosity, and confidence—underscores their positive correlation with well-being and career outcomes, essential for navigating complex career landscapes and sup-

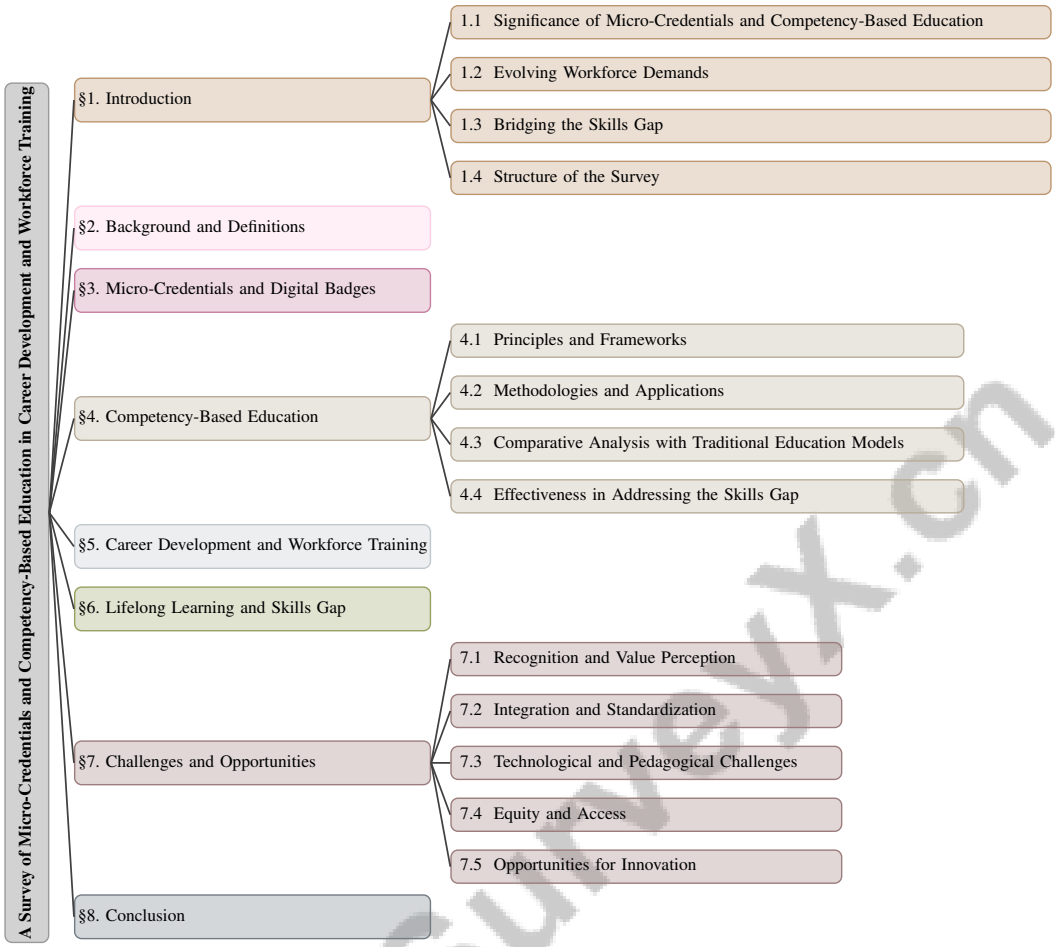


Figure 1: chapter structure

porting lifelong learning [6]. In the context of rapid AI advancements, AI literacy emerges as a critical competency for lifelong learning, preparing individuals for future challenges [7]. University students' perspectives on micro-credentials reveal their implications for higher education and career development, reflecting a growing recognition of the need for adaptable educational pathways [8].

The significance of micro-credentials and CBE in career development lies in their ability to bridge the skills gap, support lifelong learning, and enhance economic competitiveness. By integrating micro-credentials and lifelong learning initiatives, these frameworks cultivate a workforce that is highly skilled, adaptable, and equipped to navigate the evolving demands of the modern job market, especially following the shifts caused by the COVID-19 pandemic and the rise of Industry 4.0 and 5.0 [9, 10, 11].

1.2 Evolving Workforce Demands

The workforce's rapidly evolving demands, driven by technological advancements, digitalization, and globalization, necessitate innovative educational approaches emphasizing flexibility, adaptability, and lifelong learning. Traditional educational systems often struggle to efficiently retain and transfer knowledge across diverse tasks and contexts [2]. This gap is particularly pronounced in sectors like information technology, where a significant skills gap exists, as many graduates lack the necessary skills to meet industry demands [12]. The absence of assumptions regarding task generation distribution and the unknown number of instances for each task complicates learning in dynamic environments [13].

The misalignment between educational curricula and job requirements exacerbates the skills gap, as skills taught do not necessarily match those needed for jobs [3]. This disconnect highlights the

urgency for new educational paradigms closely aligned with industry standards. The integration of micro-credentials and CBE offers a promising solution by providing targeted, flexible learning opportunities that enhance employability and career readiness, directly addressing the skills mismatch [4].

In lifelong learning contexts, models enabling continuous learning and adaptation are crucial for dynamic job markets. The Lifelong Teacher-Student (LTS) framework exemplifies an educational approach designed to meet these demands by enhancing AI capabilities and facilitating continuous learning [6]. Such models equip learners with the competencies required to thrive in diverse career landscapes, emphasizing the necessity for critical and creative thinking for effective human-AI collaboration [7].

The COVID-19 pandemic accelerated interest in micro-credentials as a flexible educational option, emphasizing the need for effective online teaching methods and practical skills in the workforce [2]. The relevance of micro-credentials in a post-pandemic labor market, which demands rapid reskilling and upskilling, is increasingly recognized [14]. Understanding university students' perceptions of micro-credentials is crucial for tailoring these tools to meet evolving workforce needs [8]. As the workforce evolves, educational systems must adapt to equip learners with the necessary skills to navigate these challenges effectively.

1.3 Bridging the Skills Gap

Micro-credentials and competency-based education (CBE) are critical in addressing the persistent skills gap in the modern workforce, exacerbated by rapid technological advancements and evolving economic landscapes. These frameworks provide targeted, industry-aligned learning opportunities that enhance employability by focusing on specific skill sets, moving beyond traditional educational achievements [15]. Integrating digital badges within these frameworks further validates informal learning and enhances professional visibility, offering realistic training scenarios and adaptable learning pathways that contribute to developing a skilled and adaptable workforce.

Despite their potential, challenges remain in aligning skills acquired through education with those demanded by employers, particularly in sectors like information technology, where a significant skills mismatch exists [12]. While micro-credentials are perceived as beneficial for employability and skill verification, skepticism regarding their prestige and acceptance persists [8].

Innovative methodologies like the Continual Learning Analysis via a Model of Performance (CLAMP) enhance our understanding of lifelong learning systems, optimizing them to meet workforce demands without direct access to underlying algorithms [6]. Additionally, developing hybrid and networked educational approaches is essential for addressing the challenges posed by rapid AI evolution, catering to the needs of organizations and employees in advanced higher education levels [16].

The Micro-credential Value Framework aims to clarify the benefits and costs associated with micro-credentials, providing a structured approach to evaluate their role in bridging the skills gap [17]. However, significant hurdles remain, such as the inability to correlate assessment scores with actual performance and the lack of clarity in performance expectations [3].

1.4 Structure of the Survey

This survey is meticulously structured to comprehensively examine micro-credentials and competency-based education within career development and workforce training. It begins with an introduction that highlights the significance of these frameworks in addressing evolving workforce demands and bridging the skills gap. Following this, a detailed background section defines core concepts such as micro-credentials, competency-based education, digital badges, lifelong learning, and the skills gap, alongside their historical development and current trends.

The survey explores the role of micro-credentials and digital badges in recognizing and validating skills, discussing their implementation in educational and professional settings, and analyzing their impact on career development. A subsequent section delves into the principles and methodologies of competency-based education, comparing it with traditional education models and evaluating its effectiveness in addressing the skills gap.

The analysis examines the interconnected dynamics of competency-based education, micro-credentials, and career development, emphasizing how these frameworks enhance workforce training and equip individuals with skills necessary for career progression. Micro-credentials, recognized for their role in reskilling and professional development, serve as valuable supplements to traditional academic qualifications, responding to industry demands for practical skills and adaptability in a rapidly evolving job market. This relationship underscores the potential of micro-credentials to bridge gaps in formal education and empower learners in navigating their career paths effectively [18, 19, 8, 10]. The survey also addresses the importance of lifelong learning in maintaining and enhancing skills throughout an individual's career, exploring how micro-credentials and CBE can help bridge the skills gap.

The survey comprehensively addresses the multifaceted challenges and opportunities associated with implementing micro-credentials and competency-based education. It identifies critical issues such as recognition and standardization of micro-credentials, technological and pedagogical hurdles, and concerns related to equity and access. Additionally, it highlights potential avenues for innovation that could enhance the effectiveness and acceptance of these educational approaches, drawing on insights from a systematic review of literature spanning various educational contexts and stakeholder perspectives [19, 14]. The conclusion summarizes key findings, emphasizing the importance of these frameworks in modern career development and workforce training, and their potential to address the skills gap and support lifelong learning.The following sections are organized as shown in Figure 1.

2 Background and Definitions

2.1 Core Concepts and Definitions

Micro-credentials and competency-based education (CBE) are integral to modern educational frameworks, addressing workforce needs by emphasizing skill recognition and mastery. Micro-credentials, often in the form of digital badges, serve as verifiable records of skills acquired through various learning experiences [20]. They offer a flexible, targeted educational approach that benefits both learners and employers, providing a portable means to demonstrate qualifications [14]. In the gig economy and personalized professional development contexts, micro-credentials support tailored upskilling, though their integration into higher education is challenged by diverse interpretations and implementations [8].

CBE shifts focus from traditional time-based learning to the mastery of specific competencies, aligning educational outcomes with industry requirements [5]. This involves designing competencies in consultation with employers to ensure market relevance, especially in sectors like information technology, where both soft and hard skills are crucial for entry-level roles [12]. CBE emphasizes endpoint competencies derived from societal and workplace needs, allowing personalized learning experiences that enable learners to progress at their own pace while achieving essential competencies for career advancement.

Lifelong learning, defined as the continuous acquisition of new skills while retaining prior knowledge, is vital for adapting to workforce changes [7]. In an evolving job market where skills require constant updating, integrating computational thinking, critical thinking, and creativity as core competencies highlights the importance of lifelong learning in the AI era, necessitating educational strategies that support skill development and career progression.

2.2 Historical Development

The evolution of micro-credentials and CBE marks a transformative shift in educational paradigms, emphasizing flexibility, personalization, and alignment with industry demands. Micro-credentials emerged in response to digital transformation in education and the workforce, paralleling innovations like MOOCs. However, their widespread acceptance is hindered by a lack of global consensus on definitions and robust accreditation frameworks, alongside inconsistent terminology and limited institutional buy-in, which impede effective implementation and recognition [5].

The rise of micro-credentials reflects efforts to validate informal learning experiences, enhancing professional visibility and adaptability in a dynamic job market. Their integration into both formal and non-formal educational contexts highlights growing recognition among institutions and employers of the need for flexible, skill-based qualifications that align with industry demands [18, 14, 21, 19].

Despite potential benefits, challenges such as lack of market recognition and resistance to traditional educational practices persist, necessitating ongoing dialogue between academia and industry to adapt curricula to evolving skill demands.

CBE has a rich history of aligning educational outcomes with industry requirements, focusing on structured competencies that assess career readiness. The integration of technology in competency certification processes has facilitated efficient and scalable skill recognition methods. Misconceptions about CBE being merely flexible pacing persist, yet its frameworks continue to evolve, emphasizing personalized learning experiences that adapt to individual capabilities [5].

Incorporating a hybrid model that combines formal education with practical organizational development through collaborative modules marks a significant shift from traditional methods. This approach underscores the necessity of integrating theoretical knowledge with practical skills, as both students and industry professionals acknowledge this blend as essential for addressing the varied demands of learners and the evolving workforce, particularly in Information Technology and Artificial Intelligence [22, 23, 12, 24]. Although challenges in standardization and recognition persist, micro-credential frameworks present innovative solutions for enhancing workforce skills and adaptability, enabling individuals to navigate the evolving demands of a dynamic global economy, especially amid rapid technological advancements associated with Industry 4.0 and 5.0 [9, 25, 19, 11].

2.3 Current Trends in Education and Workforce Training

The contemporary landscape of education and workforce training is increasingly shaped by the integration of micro-credentials and CBE, driven by the need to align educational outcomes with the global economy's evolving demands. A significant trend is the accelerated adoption of micro-credentials, spurred by the COVID-19 pandemic, prompting shifts in higher education policy towards more flexible and accessible learning pathways [15]. This reflects a broader move towards digitalization, emphasizing micro-credentials' role in providing competency-based, personalized, and on-demand learning opportunities.

Micro-credentials are valued for their capacity to offer targeted skill validation, bridging the gap between academic learning and industry requirements. Industry endorsement and accreditation are crucial for enhancing the perceived value of micro-credentials, which is a key factor in their successful integration into educational frameworks [17]. However, challenges remain in fully integrating micro-credentials into traditional educational systems, as current studies often lack comprehensive perspectives on this integration [14].

CBE continues to gain traction by emphasizing mastery over time-based learning, enhancing student engagement and learning outcomes. This approach necessitates a paradigm shift in pedagogical practices to meet the dynamic needs of both educational institutions and the workforce [26]. The integration of AI literacy into educational frameworks is another emerging trend, equipping learners with necessary skills to navigate AI's implications in the workforce [7].

In the context of AI-related university courses and job advertisements in the UK, there is a growing need to map industry-required skills against those taught in university programs, emphasizing the importance of aligning educational content with labor market demands [23]. The CLAMP framework exemplifies innovative methodologies for estimating latent properties of lifelong learning systems, effectively separating task structure from algorithm performance [6].

Current trends in education and workforce training illustrate a complex interaction among digital innovation, personalized learning pathways, and strategic alignment of educational outcomes with labor market demands. This evolution is driven by the necessity for efficient workforce training that adapts to rapid technological changes across sectors, including manufacturing, construction, and healthcare. The rise of online learning platforms, accelerated by the COVID-19 pandemic, underscores the need for effective pedagogical strategies and resources to enhance skill development. Additionally, integrating digital badges and micro-credentials emerges as a transformative approach to making learning pathways more visible and equitable, supporting lifelong learning and addressing skills gaps in the workforce. Collaborative efforts among educational institutions, industry stakeholders, and researchers are essential to ensure training programs remain relevant and responsive to the evolving job market [27, 9, 28, 11]. As these trends evolve, the focus remains on developing frameworks that support lifelong learning and skill acquisition, ensuring learners are equipped to thrive in a rapidly changing global economy.

AI-generated, for reference only.

3 Micro-Credentials and Digital Badges

The evolution of education reflects a shift towards flexible skill recognition mechanisms, prominently seen in the adoption of micro-credentials and digital badges. These tools offer innovative solutions for documenting and validating competencies, crucial for both educational and professional settings. Understanding their role in skill recognition and validation is essential to grasp their broader implications. Figure 2 illustrates the hierarchical structure of micro-credentials and digital badges, focusing on their roles in skill recognition, implementation in educational settings, and contributions to professional development. Each section of the figure highlights key elements such as educational alignment, personalized learning tools, and industry relevance, while also addressing the challenges and opportunities associated with their adoption. This visual representation not only complements the discussion but also enhances our understanding of how these mechanisms function within the broader educational landscape.

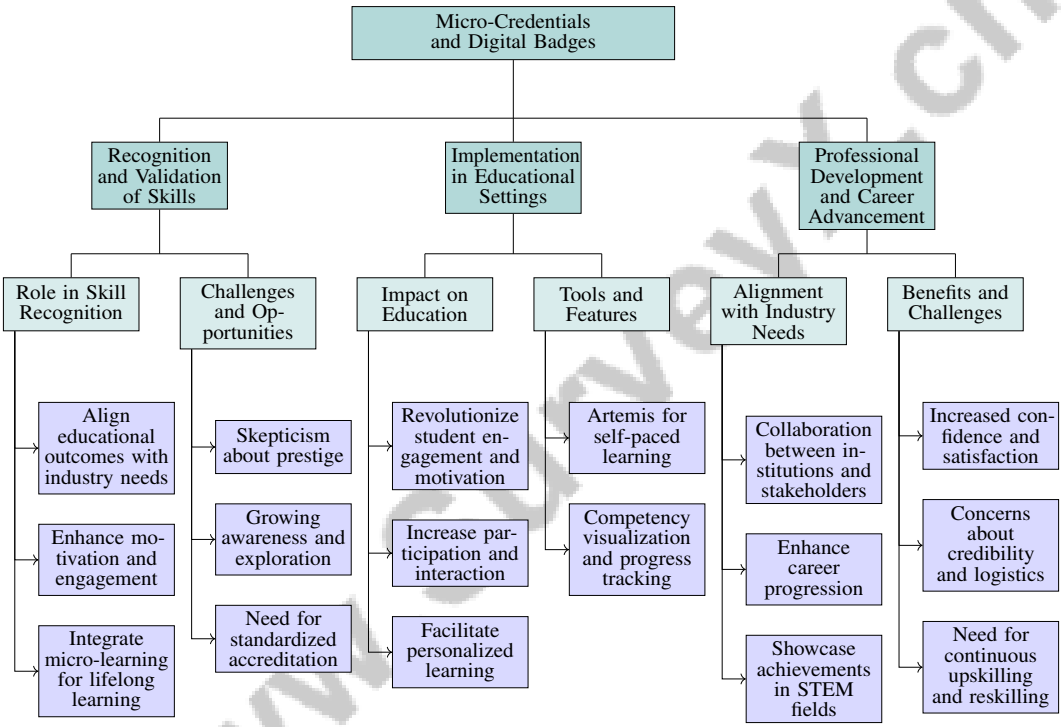


Figure 2: This figure illustrates the hierarchical structure of micro-credentials and digital badges, focusing on their roles in skill recognition, implementation in educational settings, and contributions to professional development. Each section highlights key elements such as educational alignment, personalized learning tools, and industry relevance, while addressing challenges and opportunities in their adoption.

3.1 Recognition and Validation of Skills

Micro-credentials and digital badges are critical for skill recognition and validation, providing a comprehensive framework that aligns educational outcomes with industry needs [14]. Digital badges, as visual representations of achievements, enhance motivation and engagement by offering a transparent record of competencies for potential employers [1]. Their motivational impact is well-supported, with evidence showing they encourage goal achievement and engagement [29].

Integrating micro-learning with digital badges further boosts engagement and retention, offering targeted learning experiences that support lifelong learning and improve employability by validating crucial skills [8]. Digital badges serve as effective extrinsic motivators in professional development, underscoring their educational value [20]. Despite skepticism about their prestige compared to traditional certificates, research highlights growing awareness and exploration of micro-credentials,

alongside frameworks that enhance employability and lifelong learning [30]. Standardized accreditation is vital for enhancing their perceived value across diverse settings.

3.2 Implementation in Educational Settings

The integration of micro-credentials and digital badges in educational settings revolutionizes student engagement, motivation, and skill acquisition. Their implementation follows structured stages, focusing on impacts on motivation and organizational skills [31]. Embedding badge systems in curricula aims to increase participation and interaction, offering a flexible framework for recognizing achievements [29].

Digital badges prove effective in professional development for online teaching, serving as motivational tools and growth documentation [20]. They provide educators with tangible means to showcase skills, enhancing profiles and encouraging continuous development, thus facilitating lifelong learning pathways.

Micro-credentials and digital badges also address the need for personalized learning. Tools like Artemis enable self-paced learning focused on specific competencies, aligning with academic and industry standards. Features such as competency visualization and progress tracking guide learners towards essential skills, recommending relevant resources [32, 33]. Such personalized approaches ensure learners acquire necessary skills for career advancement in a rapidly changing job market.

3.3 Professional Development and Career Advancement

In professional development and career advancement, micro-credentials and digital badges offer recognized skill validation aligned with industry needs. Collaboration between educational institutions and industry stakeholders ensures the relevance of micro-credentials, tailoring educational offerings to workforce demands [18]. This alignment enhances their value as effective tools for career progression.

Digital badges in professional development, especially in online teaching, yield benefits like high satisfaction, increased confidence, and improved knowledge of methodologies, underscoring their role in professional growth [20]. They serve as portable, transparent mediums for showcasing achievements, enhancing career opportunities by effectively communicating competencies to employers, particularly in STEM fields. Despite concerns about credibility and logistics, optimism prevails regarding their transformative potential in formal and informal learning environments [34, 28]. In dynamic job markets, continuous upskilling and reskilling are crucial for competitiveness. Micro-credentials provide targeted, industry-relevant learning experiences, enabling individuals to acquire and demonstrate specific skills needed for advancement.

4 Competency-Based Education

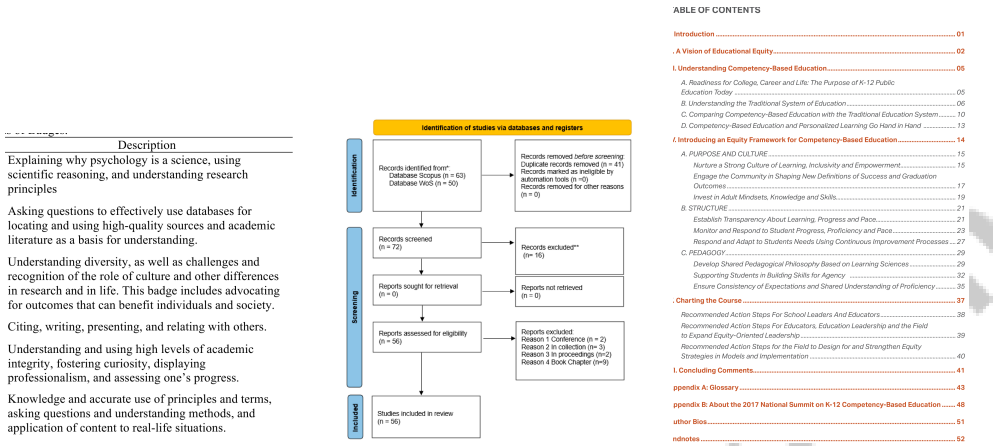
4.1 Principles and Frameworks

Competency-Based Education (CBE) is structured around aligning educational outcomes with industry demands, emphasizing mastery of competencies over traditional time-based progression. This model supports personalized learning experiences, enabling learners to advance upon demonstrating proficiency in essential skills, ensuring education is relevant to career objectives [5]. Continuous assessment and feedback are pivotal in CBE, providing insights for learners and educators to refine the educational process [5].

CBE frameworks encompass stages of educational design, teaching, learning, assessment, and administration, all aligned with desired outcomes [5]. These frameworks facilitate project-based learning, allowing practical skill application. Formative assessments guide personalized educational trajectories, ensuring competencies acquired are applicable to professional aspirations.

Hierarchical learning principles, exemplified by the Sketch-based Modular Architecture, enhance knowledge sharing and adaptation across diverse contexts, supporting development of critical competencies for emerging technologies, including AI [7]. The Lightweight Lifelong Learning (LLL) method exemplifies adaptability by employing a shared backbone for feature extraction, promoting efficient knowledge sharing among learners.

Technological advancements enhance CBE frameworks, with digital badges serving as boundary objects to communicate skills and competencies, thereby increasing student motivation and engagement [5]. Benchmark studies comparing digital badges with traditional token systems provide novel insights into incentivizing learning, an area previously underexplored [5].



(a) Psychology Skills Badge Description[35]

(b) Identification of studies via databases and registers[36]

(c) The image is a table of contents for a document or report.[37]

Figure 3: Examples of Principles and Frameworks

As shown in Figure 3, CBE emphasizes achieving specific skills and knowledge as the primary metric for success. Three illustrative examples elucidate how these principles are applied: the "Psychology Skills Badge Description" clearly defines competencies for psychology majors; the "Identification of studies via databases and registers" flowchart details a systematic research approach aligned with evidence-based learning; and the table of contents exemplifies the importance of organization for navigating complex information. Together, these examples showcase effective implementation of CBE principles and frameworks in educational settings [35, 36, 37].

4.2 Methodologies and Applications

CBE employs diverse methodologies to align educational outcomes with industry demands, focusing on mastering specific competencies. Key strategies include creating conducive learning environments, effective knowledge presentation, fostering peer learning, encouraging innovative approaches, and stimulating reflective practices [38]. Central to CBE are project-based learning and continuous feedback, ensuring active learner engagement and real-world skill application [35].

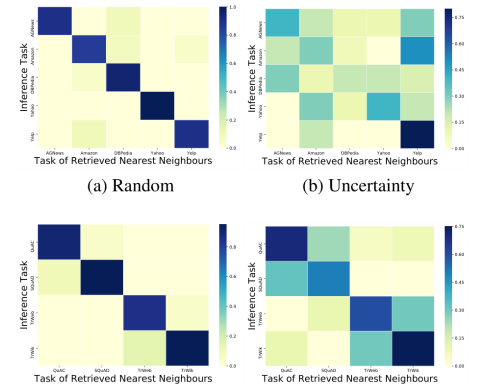
The Competency-Based Education Integration (CBEI) methodology emphasizes clear competency definitions, tracking learner participation, and visualizing progress to meet educational objectives effectively [33]. This approach aligns competencies with educational goals, facilitating systematic mapping to broader liberal education objectives [24].

Innovative methodologies incorporate advanced technological tools to enhance learning outcomes. The Dynamic Expandable Network (DEN) architecture in deep learning selectively retrains relevant network parts and dynamically expands its structure for new tasks, aligning with CBE principles. Similarly, the Lazy Weights Update algorithm optimizes memory management and adapts to expert performance with reduced weight update frequency, demonstrating an efficient lifelong learning approach [39].

The integration of learning sciences with data visualization techniques optimizes online course design by aligning learning objectives with assessments and learner engagement [27]. This framework supports online teaching methodologies that foster student engagement and collaboration, crucial for effective CBE [40].

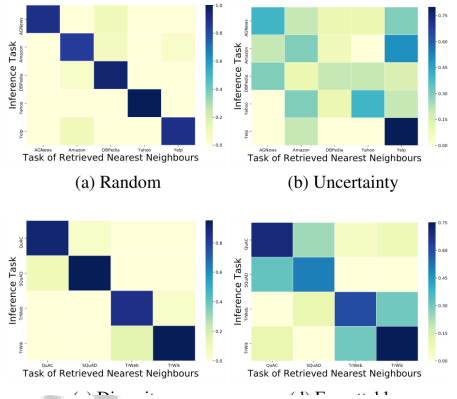
In machine learning, the Efficient Semi-Supervised Learning (ESSL) method enhances training efficiency and predictive accuracy by utilizing both labeled and unlabeled data, showcasing advanced algorithms supporting competency development [41].

CBE methodologies blend traditional teaching with innovative technological advancements, emphasizing mastery of knowledge and skills over conventional metrics like "seat time." This approach is being integrated into diverse educational settings, from secondary to higher education, including online and classroom environments. Recent studies highlight the importance of personalized learning, flexible assessment, and specific competency development, illustrating effective CBE implementation to enhance student outcomes and understanding of learning objectives [35, 42, 24]. These approaches equip learners with competencies necessary to thrive in a rapidly evolving job market, supporting lifelong learning and career advancement.



(a) Random (b) Uncertainty

(a) Comparison of Random and Uncertainty-Based Inference Task of Retrieved Nearest Neighbors[43]



(a) Random (b) Uncertainty

(b) The image shows a comparison of the performance of different models on the task of retrieving nearest neighbors for different datasets.[44]

Figure 4: Examples of Methodologies and Applications

As illustrated in Figure 4, CBE focuses on developing methodologies and applications that enhance learning outcomes through personalized strategies. The comparative analysis of random and uncertainty-based inference tasks in retrieving nearest neighbors is visually represented, highlighting performance disparities across datasets such as AGNews, Amazon, DBpedia, Yahoo, and Yelp. The heat map effectively showcases model performance in retrieving nearest neighbors, providing insights into the efficacy of these methodologies in diverse learning contexts. Such comparative studies are crucial for refining CBE approaches, ensuring educational strategies are data-informed and tailored to meet learners' specific needs, thereby enhancing the overall educational experience [43, 44].

4.3 Comparative Analysis with Traditional Education Models

CBE signifies a paradigm shift from traditional education models, emphasizing mastery of competencies over time-based progression. Unlike traditional methods relying on rote memorization and standardized testing, CBE focuses on knowledge application through projects and real-world scenarios, leading to greater student engagement and deeper learning outcomes [35]. This approach allows students to progress at their own pace, ensuring proficiency in essential skills before advancing, contrasting with conventional education's fixed timeframes.

Traditional education models typically adopt a one-size-fits-all approach, where curricula are designed for completion within set periods, measuring success primarily through recall during examinations. This method often overlooks individual learning needs and fails to equip students with essential soft and hard skills required for evolving workforce challenges, as indicated by research highlighting a significant skills gap perceived by IT students and industry professionals. With increasing technology integration across sectors, there is a pressing need for training approaches that facilitate continuous learning and adaptability, ensuring students are prepared for current roles and can thrive in rapidly changing environments [42, 12, 11]. In contrast, CBE offers a personalized learning experience, allowing students to focus on areas aligned with their career goals and industry needs.

Despite its advantages, CBE implementation faces challenges, particularly regarding conceptual clarity and establishing a cohesive framework for understanding its principles and methodologies. Current studies often lack a unified approach to defining and applying CBE, leading to varied interpretations and implementations across educational institutions [45]. This lack of standardization can hinder widespread adoption of CBE and its integration into existing educational systems.

CBE requires significant shifts in pedagogical practices, including developing new assessment methods that accurately measure competency attainment. The emphasis on continuous feedback and formative assessments necessitates moving away from traditional grading systems focused on summative evaluations. This transition can challenge institutions deeply rooted in conventional assessment methods, which may struggle to adapt to the dynamic, learner-centered approaches CBE necessitates. A clear understanding and agreement on competency definitions and practices among educators are essential for developing effective assessment processes aligned with CBE principles [22, 26, 35, 3, 45].

Competency-Based Education (CBE) presents a flexible and relevant framework for aligning educational outcomes with modern workforce demands; however, its effective implementation is hindered by challenges such as a lack of clarity regarding key terms like 'competence' and 'proficiency,' the need for standardized assessment practices, and significant pedagogical shifts among educators [22, 26, 35, 3, 45]. As educational institutions continue to explore and refine CBE frameworks, its potential to transform learning and skill development remains significant.

4.4 Effectiveness in Addressing the Skills Gap

Benchmark	Size	Domain	Task Format	Metric
TEP[46]	60	Human Resource Management	Performance Evaluation	Correlation Coefficient
HD-GD[47]	1,848	Youth Employment	Economic Outcome Measurement	Income, Asset Value
DBB[48]	21	Digital Badging	Correlational Analysis	Final Grade, Student Satisfaction
DBP[49]	120	English Learning	Behavior Observation	Post-test Scores, Behavior Observation Scores
IT-SG[12]	134	Information Technology	Skill Gap Analysis	Average Weighted Mean

Table 1: This table presents a comparative analysis of various benchmarks used to evaluate the effectiveness of competency-based education (CBE) in addressing the skills gap across different domains. It details the benchmark size, domain of application, task format, and the metrics used for assessment, providing a comprehensive overview of the methodologies employed in each study.

CBE has demonstrated significant potential in bridging the skills gap by aligning educational outcomes with workforce demands, ensuring learners acquire competencies directly applicable to their career paths. This alignment is facilitated by continuous assessment frameworks that enhance student engagement and learning outcomes, contrasting with traditional high-stakes assessments [5]. The implementation of decentralized learning systems within CBE minimizes the risk of catastrophic forgetting and enhances knowledge retention across various tasks [13]. Table 1 provides a detailed overview of representative benchmarks used to assess the effectiveness of competency-based education in bridging the skills gap across various domains.

Integrating micro-credentials within CBE frameworks enhances skill validation, improving employability and career readiness, particularly in rapidly evolving markets. Successful adoption of digital badges, when aligned with institutional values and communicated purposes, addresses the skills gap by providing structured means for skill verification [1]. However, challenges remain in integrating micro-credentials into traditional educational frameworks and ensuring employer acceptance [14].

Advanced methodologies like the Accumulating Knowledge Lifelong Online (AKLO) method demonstrate CBE's effectiveness in adapting to dynamic learning environments by balancing current task contributions with accumulated knowledge, improving predictions even in non-i.i.d. settings [13]. The A-GEM approach showcases superior performance in accuracy and efficiency, providing viable solutions for real-time applications and evaluating effectiveness in bridging the skills gap [2].

In specific fields, such as dental education, a shift towards competency and outcome-based models enhances education quality and patient care, further highlighting CBE's role in addressing sector-specific skills gaps [3]. Nonetheless, current research is limited by the nascent stage of micro-credentialing

systems and the need for robust frameworks to evaluate their effectiveness and integration into existing educational structures [4].

CBE offers a robust framework for addressing the skills gap by fostering a skilled and adaptable workforce. Through continuous assessment, interdisciplinary collaboration, and micro-credential integration, CBE supports lifelong learning and skill development, ensuring learners are equipped to meet evolving global economy demands. However, unanswered questions remain regarding the long-term impact of digital badges on professional development and their perception in various educational contexts, necessitating further exploration [20].

5 Career Development and Workforce Training

The evolving dynamics of the labor market necessitate a critical examination of how educational frameworks contribute to career development and workforce training. Lifelong learning emerges as a pivotal theme, emphasizing the need for continuous skill enhancement to meet changing job requirements. This section delves into the role of lifelong learning in career development, focusing on the integration of micro-credentials and competency-based education (CBE) in facilitating this process.

5.1 Integration of Lifelong Learning and Career Development

Micro-credentials and CBE are instrumental in integrating lifelong learning with career development, offering structured pathways for skill acquisition and professional growth. These tools provide flexible, targeted learning opportunities that align educational outcomes with individual career goals and market demands, thus enhancing employability in a dynamic job market [14, 8]. The adaptability of online courses and digital badges underscores their significance in career development, particularly highlighted by the increased adoption during the COVID-19 pandemic [8].

Educators now play a crucial role in facilitating student-centered learning experiences, promoting continuous skill development through structured pathways. CBE models support this shift by allowing students to progress based on skill mastery rather than traditional metrics, aligning educational practices with labor market demands and ensuring equitable access to lifelong learning opportunities [36, 50, 51, 52]. This approach caters to large learner populations, enabling individuals to adapt their skills to evolving job market requirements.

Moreover, integrating lifelong learning with career development must prioritize collaboration between educational institutions and businesses, breaking down traditional barriers. This collaboration enhances employee competencies and encourages universities to engage with organizations, creating a responsive educational framework that addresses real-world professional challenges [53, 16, 38, 54]. Such a holistic approach ensures that educational frameworks effectively meet the diverse needs of stakeholders, including learners, employers, and educational institutions.

5.2 Micro-Credentials and Digital Badges in Workforce Training

Micro-credentials and digital badges are integral to workforce training, offering a flexible approach to skill development and recognition. These tools validate competencies, aligning educational outcomes with industry demands and enhancing employability. Digital badges, as visual markers of achievement, effectively communicate skills and competencies to employers [55]. Their use in documenting research competencies exemplifies their role in workforce training [56].

The integration of micro-credentials into workforce training is further facilitated by decentralized learning methods, which support efficient skill validation and knowledge sharing [57]. Blockchain technology enhances credentialing processes by ensuring secure and verifiable records, maintaining the integrity and accessibility of credentials [58].

In higher education, digital badges significantly impact professional development by recognizing and validating skills acquired by instructors and graduate students [34]. The correlation between badge acquisition and improved grades and satisfaction highlights their effectiveness as assessment tools [48]. However, the recognition of micro-credentials varies across sectors, necessitating standardized frameworks and industry collaboration to enhance their acceptance [59]. Identifying common skills

in information systems micro-credentials emphasizes the need for targeted, industry-relevant training [21].

5.3 Competency-Based Education and Skill Development

Competency-Based Education (CBE) is crucial for skill development, aligning educational outcomes with industry demands and offering tailored learning paths. This approach enhances skill acquisition and career readiness by focusing on mastery of competencies applicable to professional aspirations [13]. By prioritizing competency mastery over time-based progression, CBE fosters deeper understanding and engagement, leading to positive employer feedback [12].

Implementing CBE involves comprehensive curricula that integrate diverse resources and methodologies, crucial for fields like information technology where both soft and hard skills are vital [12]. The emphasis on soft skills, such as communication and problem-solving, is essential for IT graduates to meet employer expectations.

Technological tools enhance CBE's effectiveness, with digital badges increasing student interaction and engagement in courses focused on reading and writing [29]. These tools validate competencies, supporting lifelong learning and career advancement by providing a transparent record of achievements.

Developing critical competencies such as computational and critical thinking is essential for navigating AI-driven environments and advancing careers in the modern workforce [7]. Innovative frameworks, like the A-GEM method, optimize learning processes by enhancing speed and reducing resource consumption, thereby supporting skill development [2].

6 Lifelong Learning and Skills Gap

6.1 Technological Advancements in Lifelong Learning

Technological advancements have significantly transformed lifelong learning frameworks, fostering continuous skill development and personal growth. Personal development is increasingly recognized as essential within lifelong learning, especially during crises [60]. Innovations have led to adaptive learning environments that cater to individual needs and resource constraints. Notably, neural network architectures like the LL0 model adapt dynamically to new information, exemplifying continuous learning through architectural modifications in response to incoming data [61]. The Plastic Support Structure further enhances lifelong learning in resource-constrained environments by optimizing network capacity [62].

In deep learning, the Hierarchical Deep Reinforcement Learning Network (H-DRLN) improves knowledge transfer and retention through temporal abstractions, demonstrating the effectiveness of hierarchical structures [63]. Complementary to this, Adaptation by Distillation allows models to adapt to new tasks while preserving past knowledge, ensuring efficient and scalable learning [64]. Meta-learning advances lifelong learning opportunities, as evidenced by the Meta-MbPA framework's state-of-the-art results in lifelong language learning, enhancing efficiency and reducing memory usage [44]. Research on mistake bounds in learning algorithms further underscores their effectiveness in lifelong learning scenarios [39].

These innovations create adaptable learning systems responsive to evolving educational and professional demands. Micro-credentials and competency-based education facilitate lifelong skill acquisition, offering tailored learning opportunities aligned with the global economy's shifting requirements. By promoting collaboration among learners, higher education institutions, and employers, these approaches equip individuals with competencies necessary to navigate Industry 4.0 and 5.0 complexities, enhancing adaptability and success in a rapidly changing job market [9, 24, 7, 51, 52].

6.2 Flexible Learning Pathways for Adult Learners

Flexible learning pathways for adult learners are increasingly supported by micro-credentials, offering personalized educational experiences aligned with career goals and industry demands. These pathways accommodate adult learners balancing educational pursuits with professional and personal commitments, requiring accessible learning options that integrate seamlessly into their lives

[14, 19, 50, 28, 65]. Micro-credentials enable targeted, time-efficient skill acquisition relevant to specific career trajectories.

Technological advancements play a crucial role in facilitating these pathways. The LL0 model exemplifies adaptive learning environments through rapid learning from new data, minimal energy consumption, and resilience against catastrophic forgetting [61]. These models offer efficient and scalable solutions for adult learners' continuous education. Hierarchical Deep Reinforcement Learning Networks (H-DRLN) enhance flexible pathways by incorporating reusable skills via Deep Skill Networks (DSNs), improving learning efficiency and aiding comprehensive skill set development across various contexts and industries [63]. Leveraging hierarchical structures allows adult learners to engage in structured learning processes, ensuring the acquisition of competencies necessary for career advancement.

The integration of micro-credentials and advanced technological frameworks establishes a robust foundation for adaptable learning pathways tailored to adult learners. This approach supports continuous education and skill enhancement in response to evolving job market demands and the necessity for lifelong learning. It bridges gaps between learners, higher education institutions, and employers, addressing skills shortages exacerbated by economic shifts, such as those due to the COVID-19 pandemic [14, 17, 19, 9, 21]. These pathways support lifelong learning by offering personalized, industry-aligned educational experiences that cater to adult learners' unique needs, ensuring their competitiveness and adaptability in a rapidly evolving job market.

6.3 Lifelong Learning in Different Contexts

Lifelong learning manifests across diverse contexts, each uniquely contributing to bridging the skills gap through continuous education and skill acquisition. In nursing, lifelong learning encompasses themes such as intellectual independence, collaborative learning, researcher thinking, persistence, and need-based learning, ensuring practitioners remain competent amidst evolving medical practices and technologies [66]. Beyond healthcare, lifelong learning is vital in domains requiring continuous skill refinement. For instance, in AI and machine learning, the Hierarchical Deep Reinforcement Learning Network (H-DRLN) architecture exemplifies lifelong learning systems' potential to enhance skill acquisition. Future research will focus on online skill learning, refining previously learned skills, and expanding H-DRLN's applicability to other complex domains, emphasizing adaptive learning frameworks' significance in lifelong education [63].

These varied contexts underscore lifelong learning's necessity as a strategic approach to addressing the skills gap. By fostering intellectual independence and collaborative learning, individuals enhance career adaptability—a crucial psychosocial resource for navigating vocational challenges and transitions. This adaptability prepares them to meet evolving job market demands and equips them with competencies needed for career advancement and professional growth, particularly amid rapid technological changes and the increasing importance of lifelong learning and micro-credentials in today's workforce [9, 67, 10, 24]. Integrating lifelong learning into educational and professional environments is crucial for developing a skilled and adaptable workforce capable of meeting the challenges of a rapidly evolving global economy.

7 Challenges and Opportunities

The exploration of challenges and opportunities in micro-credentials and competency-based education (CBE) demands a nuanced understanding of recognition and value perception issues. It is crucial to grasp how diverse stakeholders, including learners and employers, perceive micro-credentials, as this reflects their growing acceptance as valid skill indicators and highlights concerns about their recognition compared to traditional degrees. This understanding informs strategies for integrating micro-credentials into both formal and non-formal educational programs [18, 19, 14, 8]. Addressing these perceptions enhances comprehension of the complexities influencing the acceptance and implementation of micro-credentials in contemporary education.

7.1 Recognition and Value Perception

Micro-credentials encounter significant challenges related to recognition and perceived value, primarily due to inconsistencies in definitions and their relationship to traditional qualifications [15]. These

inconsistencies lead to varying stakeholder perceptions, affecting overall recognition [17]. Bridging the gap between educational institutions and organizations is crucial for aligning micro-credential offerings with industry needs [16].

A critical barrier is the limited understanding of CBE and outcomes-based education (OBE), alongside challenges in authentic assessment methods [3]. These factors hinder the establishment of a standardized framework for micro-credentials, impacting their credibility and market acceptance. Additionally, incentivizing educators to adopt and integrate micro-credentials into their teaching practices remains a challenge [4].

The usability of digital badges, a common form of micro-credential, is often undermined by increased faculty workload and unclear purposes [1]. Although they can enhance motivation, differing views on badge effectiveness raise concerns about diminishing intrinsic motivation [29]. Furthermore, assumptions underlying certain lifelong learning methodologies may not universally apply, complicating micro-credential recognition [6].

Strategic approaches are essential to address these challenges and elevate the perceived value of micro-credentials. Innovative learning methods like A-GEM, which reduce computational and memory costs while maintaining accuracy, highlight the importance of efficiency in recognizing new educational paradigms [2]. The trend towards online AI programs can enhance accessibility for diverse student backgrounds, potentially increasing micro-credential acceptance in digital learning environments [23].

7.2 Integration and Standardization

The integration and standardization of micro-credentials within educational systems face hurdles due to the absence of comprehensive frameworks encompassing all aspects of CBE. This lack of a unified approach contributes to fragmented implementations and misunderstandings, as current research often lacks a holistic view of CBE's principles [32]. Diversity in definitions and interpretations further complicates integration, leading to inconsistencies in perception and utilization across educational contexts.

A critical challenge in standardizing micro-credentials is aligning them with existing educational structures and industry requirements. Educational institutions must effectively incorporate micro-credentials into traditional curricula, requiring careful consideration of pedagogical strategies and employer recognition. This integration is vital for enhancing students' educational pathways and ensuring that micro-credentials are acknowledged by employers across industries. Research indicates that while micro-credentials can complement formal education and support professional development, their recognition and impact on employability warrant further exploration [14, 19, 18, 21, 65]. Establishing clear guidelines and standards defining the competencies associated with each micro-credential is crucial for their relevance in the job market.

Integrating micro-credentials into educational systems necessitates a shift in pedagogical practices, moving from traditional time-based learning models to more adaptive, competency-based approaches that emphasize skill acquisition and practical application [30, 21]. This transition requires new assessment methods to accurately measure skill attainment and provide meaningful feedback. Balancing innovative practices with established institutional frameworks poses a significant challenge.

Collaboration among educational institutions, industry stakeholders, and policymakers is essential to address these challenges. By fostering partnerships and ongoing dialogue among stakeholders—including learners, higher education institutions, and employers—there is an opportunity to develop standardized frameworks that facilitate the effective integration of micro-credentials into formal and non-formal educational systems. This integration is crucial for addressing workforce skills gaps and enhancing lifelong learning, especially in rapidly evolving industries characterized by Industry 4.0 and 5.0. Establishing a common language and taxonomy for micro-credentials will further facilitate their adoption and ensure they provide tangible value to all parties involved [9, 19, 14, 17].

7.3 Technological and Pedagogical Challenges

Implementing CBE involves technological and pedagogical challenges that must be addressed for success. Technologically, adapting digital tools to support the CBE framework is a major challenge.

The transition to online teaching has revealed difficulties in managing diverse student backgrounds and skill levels, hindering personalized learning experiences [40]. Advanced methods such as diversity-based memory selection in lifelong learning systems may become less efficient as memory size increases, complicating optimal performance [44].

While the A-GEM approach reduces computational and memory costs, it may struggle with complex tasks, impacting its applicability in dynamic learning environments [68]. Additionally, the quality of knowledge generated by systems like the Lifelong Teacher-Student Network may degrade over time when learning extended sequences of tasks, affecting learner performance [69].

Pedagogically, the shift towards CBE necessitates reevaluating traditional teaching methodologies and assessment practices. Developing flexible, competency-focused curricula that align with industry standards while accommodating diverse learner needs presents a significant challenge. The widespread adoption of technology in education is further complicated by the availability of skilled labor capable of effectively utilizing these tools, as current research highlights limitations in this area [70]. Ensuring that educators receive adequate training and support in these new pedagogical approaches is essential for the successful implementation of CBE.

7.4 Equity and Access

Equity and access present substantial challenges in adopting micro-credentials and CBE, as these innovations often exacerbate existing social inequalities. The focus on fragmented skills in micro-credentials can undermine the coherence and depth of traditional educational programs, potentially limiting access to comprehensive knowledge and contributing to educational inequities [15]. This fragmentation may hinder the development of a well-rounded skill set, crucial for equitable employment opportunities.

In employability skills training, equity and access issues are pronounced in sectors such as banking in Bangladesh, where disparities in training availability and quality can limit opportunities for marginalized groups [71]. These challenges underscore the need for inclusive educational practices that ensure equitable access to skill development initiatives for all learners, regardless of socio-economic background.

Integrating ethics and privacy into learning analytics solutions is vital for addressing equity issues in educational technology. By incorporating these considerations from the outset, institutions can create inclusive learning environments that respect learners' rights and promote equitable access to resources [72]. Addressing social inequalities in lifelong learning participation is crucial, as these disparities significantly impact individuals' ability to engage in continuous education and skill development [73].

Moreover, ongoing social inequity in access to postgraduate taught (PGT) study remains a significant limitation, potentially hindering the benefits of advanced education for all students [74]. This inequity emphasizes the need for targeted interventions and policies that promote access to higher education and professional development opportunities for underrepresented groups.

7.5 Opportunities for Innovation

The evolving landscape of micro-credentials and CBE presents significant opportunities for innovation, particularly in developing methodologies that address the dynamic needs of learners and the workforce. Enhancing digital badge systems, where future research should focus on improving badge design, user understanding, and exploring their long-term value in professional development, is a promising area [20]. Collaboration between higher education institutions and industry is crucial to ensure that micro-credentials align with market demands, fostering innovation that meets the needs of both learners and employers [12].

Technological advancements offer substantial potential for innovation in CBE. Developing adaptive learning algorithms can enhance the performance and adaptability of machine learning models, providing personalized learning experiences tailored to individual student needs [13]. Integrating visualization techniques for tracking student progress can facilitate more effective competency-based education by adapting to individual learning trajectories [5].

Integrating AI literacy into educational approaches and workforce training represents another opportunity for innovation, ensuring that learners are equipped with the competencies necessary to navigate AI-driven environments [7]. Future research should also explore developing incentives for districts to adopt micro-credential systems, integrating them into teacher certification processes, and assessing their long-term impact on teaching practices and student outcomes [4].

Furthermore, developing integrated talent management strategies that align with Industry 4.0 demands, including enhancing middle managers' capabilities, is essential for addressing skills gaps and supporting career development. Longitudinal studies involving employers' perspectives and integrating micro-credentials into career development frameworks within higher education should also be prioritized [8].

8 Conclusion

Micro-credentials and competency-based education (CBE) are pivotal in modernizing career development and workforce training. By aligning with industry needs, these frameworks effectively bridge the skills gap, enhancing employability and career readiness. The digitalization of education further extends their reach, offering flexible and personalized learning experiences tailored to diverse learner requirements.

Recent advancements in lifelong learning methodologies, such as the Lightweight Lifelong Learning (LLL) approach and decentralized learning models, have significantly improved learning outcomes while mitigating issues like catastrophic forgetting. Innovative frameworks, including the Dynamically Expandable Network (DEN), provide robust foundations for adaptive learning environments, showcasing the potential for optimal network structure estimation.

The integration of Adaptive Retention Correction (ARC) within continual learning paradigms has led to notable performance gains, highlighting the critical role of innovation in addressing the evolving needs of workforce training. Techniques like Distillation and Retrospection have consistently enhanced task performance, underscoring the necessity for continuous innovation in educational practices.

Addressing the gaps in teaching strategies for 21st-century competencies is crucial, emphasizing the ongoing need for research and curriculum development to improve educational quality and student skills. The transformative capabilities of Large Language Models (LLMs) in creating personalized lifelong learning environments further necessitate practical evaluations of these emerging frameworks.

References

[1] Jill Stefaniak and Kimberly Carey. Instilling purpose and value in the implementation of digital badges in higher education. *International Journal of Educational Technology in Higher Education*, 16(1):44, 2019.

[2] Arslan Chaudhry, Marc'Aurelio Ranzato, Marcus Rohrbach, and Mohamed Elhoseiny. Efficient lifelong learning with a-gem. *arXiv preprint arXiv:1812.00420*, 2018.

[3] Richa Khanna and Divya Mehrotra. The roadmap for quality improvement from traditional through competency based (cbe) towards outcome based education (obe) in dentistry. *Journal of oral biology and craniofacial research*, 9(2):139–142, 2019.

[4] Dan French and Barnett Berry. Teachers, micro-credentials, and the performance assessment movement. *Voices in Urban Education*, 46:37–43, 2017.

[5] Mark Kostin and Don Weafer. Competency-based education. *Portland, Great School Partnership*, 2017.

[6] Corban Rivera, Chace Ashcraft, Alexander New, James Schmidt, and Gautam Vallabha. Latent properties of lifelong learning systems, 2022.

[7] Margarida Romero. Lifelong learning challenges in the era of artificial intelligence: a computational thinking perspective, 2024.

[8] Mehmet Ali Yılık. Micro-credentials, higher education and career development: perspectives of university students. *Higher Education Governance and Policy*, 2(2):126–139, 2021.

[9] Breda Walsh Shanahan and John Organ. Harnessing the benefits of micro credentials for industry 4.0 and 5.0: skills training and lifelong learning. *IFAC-PapersOnLine*, 55(39):82–87, 2022.

[10] Maria Batool, Zohaib Islam, Muhammad Nawaz, Shahan Zeb Khan, et al. The role of micro-credentials in professional development of skills in employees: A qualitative study from an emerging economy. *Bulletin of Business and Economics (BBE)*, 12(2):220–227, 2023.

[11] Holly Rushmeier, Kapil Chalil Madathil, Jessica Hodgins, Beth Mynatt, Tony Derose, Blair Macintyre, and other workshop participants. Content generation for workforce training, 2019.

[12] Frederick F Patacsil and Christine Lourrine S Tablatin. Exploring the importance of soft and hard skills as perceived by it internship students and industry: A gap analysis. *Journal of Technology and Science education*, 7(3):347–368, 2017.

[13] Changjian Shui, Ihsen Hedhli, and Christian Gagné. Accumulating knowledge for lifelong online learning, 2018.

[14] Giedre Tamoliune, Rasa Greenspon, Margarita Tereseviciene, Airina Volungeviciene, Elena Trepule, and Estela Dauksiene. Exploring the potential of micro-credentials: A systematic literature review. In *Frontiers in Education*, volume 7, page 1006811. Frontiers Media SA, 2023.

[15] Leesa Wheelahan and Gavin Moodie. Analysing micro-credentials in higher education: a bernsteinian analysis. In *Towards Powerful Educational Knowledge*, pages 70–86. Routledge, 2024.

[16] Jimmy Jaldemark and Peter Öhman. Developing a hybrid and networked educational approach to lifelong learning for organisations and employees. In *Proceedings of the International Conference on Networked Learning*, volume 12, pages 47–50, 2020.

[17] Beverley Oliver. Micro-credentials: A learner value framework: Provocation. *Journal of Teaching and Learning for Graduate Employability*, 12(1):48–51, 2021.

[18] Rukiye Orman, Elif Şimşek, and Meryem Ayşegül Kozak Çakır. Micro-credentials and reflections on higher education. *Higher Education Evaluation and Development*, 17(2):96–112, 2023.

[19] Soovendran Varadarajan, Joyce Hwee Ling Koh, and Ben Kei Daniel. A systematic review of the opportunities and challenges of micro-credentials for multiple stakeholders: learners, employers, higher education institutions and government. *International Journal of Educational Technology in Higher Education*, 20(1):13, 2023.

[20] Angelica Risquez, Dara Cassidy, and Gearoid O'Suilleabhain. Badge of honour? an exploration of the use of digital badges to support a partnership approach to faculty development. *Australasian Journal of Educational Technology*, 36(5):18–29, 2020.

[21] Guido Lang and Jason H Sharp. Micro-credentials in us higher education: An empirical analysis. *Information Systems Education Journal*, 21(1):2–10, 2023.

[22] Andrew GD Holmes, Marc Polman Tuin, and Sophie L Turner. Competence and competency in higher education, simple terms yet with complex meanings: Theoretical and practical issues for university teachers and assessors implementing competency-based education (cbe). *Educational Process International Journal*, 10(3), 2021.

[23] Khushi Jaiswal, Ievgeniia Kuzminykh, and Sanjay Modgil. Understanding the skills gap between higher education and industry in the uk in artificial intelligence sector, 2024.

[24] , , , , and . Competency-based education and core competencies in higher education. *Korean Journal of General Education*, 15(1):11–30, 2021.

[25] Zara Whysall, Mike Owtram, and Simon Brittain. The new talent management challenges of industry 4.0. *Journal of management development*, 38(2):118–129, 2019.

[26] Lynn Curry and Marcia Docherty. Implementing competency-based education. *Collected Essays on Learning and Teaching*, 10:61–73, 2017.

[27] Kylie Peppler, Joey Huang, Michael C. Richey, Michael Ginda, Katy Börner, Haden Quinlan, and A. John Hart. Key principles for workforce upskilling via online learning: a learning analytics study of a professional course in additive manufacturing, 2020.

[28] Caroline R Pitt, Adam Bell, Rose Strickman, and Katie Davis. Supporting learners' stem-oriented career pathways with digital badges. *Information and Learning Sciences*, 120(1/2):87–107, 2018.

[29] Chientzu Candace Chou and Shi-Jen He. The effectiveness of digital badges on student online contributions. *Journal of Educational Computing Research*, 54(8):1092–1116, 2017.

[30] Mairéad Nic Giolla Mhichíl, Beverley Oliver, Conchúr Mac Lochlainn, and Mark Brown. A snapshot in time: the next new normal and micro-credentials. *International Journal of Educational Technology in Higher Education*, 20(1):44, 2023.

[31] Linda Dowling-Hetherington and Matt Glowatz. The usefulness of digital badges in higher education: Exploring the students' perspectives. *Irish Journal of Academic Practice*, 6(1):1, 2017.

[32] Eliot Levine and Susan Patrick. What is competency-based education? an updated definition. *Aurora Institute*, 2019.

[33] Maximilian Sölch, Moritz Aberle, and Stephan Krusche. Integrating competency-based education in interactive learning systems, 2023.

[34] Patti Dyjur and Gabrielle Lindstrom. Perceptions and uses of digital badges for professional learning development in higher education. *TechTrends*, 61(4):386–392, 2017.

[35] Jennifer Simonds, Ellen Behrens, and Jessica Holzbauer. Competency-based education in a traditional higher education setting: A case study of an introduction to psychology course. *International Journal of Teaching and Learning in Higher Education*, 29(2):412–428, 2017.

[36] Laura Icela González-Pérez and María Soledad Ramírez-Montoya. Components of education 4.0 in 21st century skills frameworks: systematic review. *Sustainability*, 14(3):1493, 2022.

[37] Chris Sturgis and Katherine Casey. Designing for equity: Leveraging competency-based education to ensure all students succeed. competencyworks final paper. *iNACOL*, 2018.

[38] Eva Cendon. Lifelong learning at universities: Future perspectives for teaching and learning. *Journal of New Approaches in Educational Research*, 7(2):81–87, 2018.

[39] Robi Bhattacharjee and Gaurav Mahajan. Learning what to remember, 2022.

[40] Beatrice Alex, Clare Llewellyn, Pawel Michal Orzechowski, and Maria Boutchkova. The online pivot: Lessons learned from teaching a text and data mining course in lockdown, enhancing online teaching with pair programming and digital badges, 2021.

[41] Doriane Olewicki, Sarra Habchi, Mathieu Nayrolles, Mojtaba Faramarzi, Sarath Chandar, and Bram Adams. On the costs and benefits of adopting lifelong learning for software analytics – empirical study on brown build and risk prediction, 2024.

[42] Sarah Ryan and Joshua D Cox. Investigating student exposure to competency-based education. *Education Policy Analysis Archives/Archivos Analíticos de Políticas Educativas*, 25:1–32, 2017.

[43] Zirui Wang, Sanket Vaibhav Mehta, Barnabás Póczos, and Jaime Carbonell. Efficient meta lifelong-learning with limited memory. *arXiv preprint arXiv:2010.02500*, 2020.

[44] Zirui Wang, Sanket Vaibhav Mehta, Barnabás Póczos, and Jaime Carbonell. Efficient meta lifelong-learning with limited memory, 2020.

[45] Tacettin Açıkgöz and Mustafa Cem Babadoğan. Competency-based education: Theory and practice. 2021.

[46] CL Kuruppu, CS Kavirathne, and N Karunarathna. The impact of training on employee performance in a selected apparel sector organization in sri lanka. 2021.

[47] Craig McIntosh and Andrew Zeitlin. Skills and liquidity barriers to youth employment: Medium-term evidence from a cash benchmarking experiment in rwanda, 2022.

[48] Joseph R Fanfarelli and Rudy McDaniel. Exploring digital badges in university courses: Relationships between quantity, engagement, and performance. *Online Learning*, 21(2):n2, 2017.

[49] Ryan Homer, Khe Foon Hew, and Cheng Yong Tan. Comparing digital badges-and-points with classroom token systems: Effects on elementary school esl students' classroom behavior and english learning. *Journal of Educational Technology & Society*, 21(1):137–151, 2018.

[50] Guoqing Zhu, Naga Anjaneyulu Kopalle, Yongzhen Wang, Xiaozhong Liu, Kemi Jona, and Katy Börner. Community-based data integration of course and job data in support of personalized career-education recommendations, 2020.

[51] Carlos Vargas. Lifelong learning from a social justice perspective 21. *Education Research and Foresght*, 21:83–105, 2017.

[52] Susan Patrick. Transforming learning through competency-based education. *State Education Standard*, 21(2):23–29, 2021.

[53] Rebeca P. Díaz-Redondo, Manuel Caeiro-Rodríguez, Juan José López-Escobar, and Ana Fernández-Vilas. Integrating micro-learning content in traditional e-learning platforms, 2023.

[54] Sahan Bulathwela, Maria Perez-Ortiz, Emine Yilmaz, and John Shawe-Taylor. Towards an integrative educational recommender for lifelong learners, 2019.

[55] How and why are digital badges b.

[56] Internationalconference the futu.

[57] Yunhao Ge, Yuecheng Li, Di Wu, Ao Xu, Adam M. Jones, Amanda Sofie Rios, Iordanis Fostiropoulos, Shixian Wen, Po-Hsuan Huang, Zachary William Murdock, Gozde Sahin, Shuo Ni, Kiran Lekkala, Sumedh Anand Sontakke, and Laurent Itti. Lightweight learner for shared knowledge lifelong learning, 2023.

[58] <div style="text-align: center;".

[59] Christoph Resei, Christian Friedl, Thomas Staubitz, and Tobias Rohloff. Micro-credentials in eu and global. *Corship, July*, 2019.

[60] Saskia Eschenbacher and Ted Fleming. Transformative dimensions of lifelong learning: Mezirow, rorty and covid-19. *International Review of Education*, 66(5):657–672, 2020.

[61] Claes Strannegård, Herman Carlström, Niklas Engsner, Fredrik Mäkeläinen, Filip Slottner Seholm, and Morteza Haghir Chehreghani. Lifelong learning starting from zero, 2019.

[62] Georges Kanaan, Kai Wen Zheng, and Lucas Fenaux. A novel approach to lifelong learning: The plastic support structure, 2021.

[63] Chen Tessler, Shahar Givony, Tom Zahavy, Daniel Mankowitz, and Shie Mannor. A deep hierarchical approach to lifelong learning in minecraft. In *Proceedings of the AAAI conference on artificial intelligence*, volume 31, 2017.

[64] Saihui Hou, Xinyu Pan, Chen Change Loy, Zilei Wang, and Dahua Lin. Lifelong learning via progressive distillation and retrospection. In *Proceedings of the European Conference on Computer Vision (ECCV)*, pages 437–452, 2018.

[65] Gavin Moodie and Leesa Wheelahan. Credentialing micro credentials. *Journal of Teaching and Learning for Graduate Employability*, 12(1):58–71, 2021.

[66] Mojtaba Qanbari Qalehsari, Morteza Khaghanizadeh, and Abbas Ebadi. Lifelong learning strategies in nursing: A systematic review. *Electronic physician*, 9(10):5541, 2017.

[67] Claire S Johnston. A systematic review of the career adaptability literature and future outlook. *Journal of career assessment*, 26(1):3–30, 2018.

[68] Arslan Chaudhry, Marc'Aurelio Ranzato, Marcus Rohrbach, and Mohamed Elhoseiny. Efficient lifelong learning with a-gem, 2019.

[69] Fei Ye and Adrian G. Bors. Lifelong teacher-student network learning, 2021.

[70] Wallace Camacho and Cristina Dias. Visoes da industria 4.0, 2021.

[71] ls gap of business graduates in.

[72] Arham Muslim, Mohamed Amine Chatti, and Mouadh Guesmi. Open learning analytics: A systematic literature review and future perspectives, 2023.

[73] Ellen Boeren. Understanding adult lifelong learning participation as a layered problem. *Studies in Continuing Education*, 39(2):161–175, 2017.

[74] Jane Artess and Tristram Hooley. Towards a new narrative of postgraduate career. 921y4, 2017.

Disclaimer:

SurveyX is an AI-powered system designed to automate the generation of surveys. While it aims to produce high-quality, coherent, and comprehensive surveys with accurate citations, the final output is derived from the AI's synthesis of pre-processed materials, which may contain limitations or inaccuracies. As such, the generated content should not be used for academic publication or formal submissions and must be independently reviewed and verified. The developers of SurveyX do not assume responsibility for any errors or consequences arising from the use of the generated surveys.