DEVELOPMENT AND VALIDATION OF ONLINE MICRO-CREDENTIAL EDUCATIONAL FRAMEWORK AND EVALUATION OF FIRE SAFETY ESSENTIALS COURSE AMONG HEALTH SCIENCE STUDENTS

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by

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LIST OF SYMBOLS

SE	Standard error
SD	Standard deviation
t	*t*-statistics
n	sample size
p	*p*-value
Mdn	Median

LIST OF ABBREVIATIONS

CDAE	Centre for Development of Academic Excellence
CMF	Common Microcredential Framework
COVID-19	Coronavirus disease
CVI	Content Validation Index
DB	Digital badge
DS	Diploma Supplement
ECTS	European Credit Transfer and Accumulation System
EQF	European Qualification Framework
F2F	Face-to-Face
HE	Higher Education
HEI	Higher Education Institution
HEP	Higher Education Providers
MC	Micro-credential
MOOC	Massive Open Online Course
MQA	Malaysian Qualification Agency
QC	Quality Assurance
TEI	Training Evalution Inventory
RB	Rozita Baharudin
NSR	Nurhanis Syazni Roslan (Main Supervisor)
US	Urooj Saleem (Postgraduate student)

LIST OF APPENDICES

PEMBANGUNAN DAN PENGESAHAN KERANGKA PENDIDIKAN KELAYAKAN MIKRO DALAM TALIAN DAN PENILAIAN KURSUS ASAS KESELAMATAN KEBAKARAN DALAM KALANGAN PELAJAR SAINS KESIHATAN

ABSTRAK

Kelayakan mikro semakin diiktiraf sebagai pendekatan pembelajaran yang pendek, fleksibel, dan berfokus kepada kompetensi, yang dipercepatkan oleh pandemik COVID-19 dan peningkatan penggunaan kecerdasan buatan. Kelayakan mikro menyediakan platform berstruktur yang sesuai untuk graduan dan pembangunan profesional, termasuk peningkatan kemahiran semula dan peningkatan kemahiran. Walaupun mempunyai potensi yang besar, kelayakan mikro masih kurang dikaji, dengan kekurangan kerangka kerja yang setaraf dimana membimbing pembangunan kelayakan mikro. Kajian ini bertujuan untuk membangunkan dan mengesahkan kerangka pendidikan bagi kelayakan mikro serta menilai keberkesanannya sebagai alat latihan, menggunakan kelayakan mikro *Fire Safety Essentials MC* sebagai kajian kes. Kajian dijalankan dalam tiga fasa. Fasa pertama melibatkan ulasan skop untuk mengenal pasti elemen utama pembangunan MC, yang dianalisis secara tematik untuk menghasilkan domain dan item. Penilaian pakar oleh sepuluh pendidik dan pakar MC serta pendidikan mengesahkan kesesuaian dan kebolehgunaan kerangka ini. Fasa kedua membangunkan *Fire Safety Essentials MC* berdasarkan kerangka yang dibangunkan. Fasa ketiga menilai keberkesanannya dengan membandingkan dua kumpulan pelajar sains kesihatan: pembelajaran bersemuka (F2F) dan pembelajaran dalam talian menggunakan kelayakan mikro dan pengalaman latihan yang diukur melalui *Training Evaluation Inventory (TEI).* Jumlah sampel adalah 92 peserta (46

bagi setiap kumpulan), dengan penilaian merangkumi pengetahuan, kemahiran, dan pengalaman latihan. Kerangka ini terdiri daripada lapan domain dan 66 item: (1) hasil pembelajaran, (2) reka bentuk instruksional, (3) aktiviti pembelajaran, (4) peta kursus, (5) penilaian, (6) maklum balas, (7) lencana digital, dan (8) faktor institusi. Penemuan menunjukkan bahawa pelajar MC mencapai skor pengetahuan yang lebih tinggi, manakala pelajar F2F menunjukkan prestasi lebih baik dalam penilaian kemahiran. Bagaimanapun, kedua-dua kumpulan menilai pengalaman latihan dan reka bentuk instruksional secara setara, tanpa perbezaan yang signifikan. Kajian ini menyokong penggunaan MC sebagai alternatif atau pelengkap kepada pembelajaran F2F bagi graduan sains kesihatan dan profesional lain. Kerangka yang disahkan menyediakan panduan untuk mereka bentuk MC yang berkesan, manakala kursus kelayakan mikro *Fire Safety Essentials* menunjukkan penerapannya secara praktikal. Kerangka ini juga berpotensi untuk dijadikan senarai semak bagi proses jaminan kualiti kelayakan mikro.

DEVELOPMENT AND VALIDATION OF ONLINE MICRO-CREDENTIAL EDUCATIONAL FRAMEWORK AND EVALUATION OF FIRE SAFETY ESSENTIALS COURSE AMONG HEALTH SCIENCE STUDENTS

ABSTRACT

Micro-credentials (MCs) are increasingly recognized as short, flexible, and competency-focused learning approaches, accelerated by the COVID-19 pandemic and the rise of artificial intelligence. They provide structured platforms suitable for graduates and professional development, including reskilling and upskilling. Despite their potential, MCs remain under-researched, with limited standardized frameworks guiding their development. This study aims to develop and validate an educational framework for micro-credentials and to evaluate its effectiveness as a training tool, using the Fire Safety Essentials MC as a case study. The study was conducted in three phases. Phase one involved a scoping review to identify key elements for MC development, which were analysed thematically to generate domains and items. An expert evaluation by ten educators and MC specialists and educationist confirmed the framework's relevance and usability. Phase two developed the Fire Safety Essentials MC based on this framework. The third phase evaluated its effectiveness by comparing two groups of health science students: face-to-face (F2F) learning and online learning using the micro-credential and training experiences were measured using the Training Evaluation Inventory. The total sample included 92 participants (46 per group), and assessments measured knowledge, skills, and training experience. The framework consisted of eight domains and 66 items: (1) learning outcomes, (2) instructional design, (3) learning activities, (4) course maps, (5) assessment, (6) feedback (7) digital badge and (8) institutional factors. Findings indicated that MC learners achieved higher knowledge scores, whereas F2F learners performed better in skills assessments.

However, both groups rated the training experience and instructional design comparably, with no significant differences. This study supports the use of MCs as an alternative or complement to F2F learning for health sciences graduates and other professionals. The validated framework provides guidance for designing effective MCs, while the Fire Safety Essentials course demonstrates its practical application. The framework also had the potential to serve as a checklist for the quality assurance process of micro-credential.

CHAPTER 1

INTRODUCTION

1.1 Background of study

Micro-credentials (MC) are short, flexible courses designed to provide learners with specific skills, competencies, or knowledge aligned with industry or professional needs. MC is also defined as a digital certification that verifies assessed knowledge, skills, and competencies in a specific area or field, which can be a component of an accredited programme or stand-alone courses supporting the professional, technical, academic, and personal development of the learners [1,2]. Similarly, the European Union (EU) defined MC as documented evidence of learning outcomes acquired through a short and focused learning experience, targeted knowledge, skills, and competencies designed to address specific societal, personal, cultural, or labour market needs [3].

MCs have gained significant traction in public and private universities worldwide since the COVID-19 pandemic. It is an innovative way to support self-directed learning that could provide employees with added value to their current skill sets and knowledge [4]. More importantly, MCs are online digital courses that can be accessed remotely. Although MCs have been used in higher education and professional development [5], there are limited studies to assess its efficacy as a training tool.

1.1.1 Micro-credentials in higher education

Higher education institutions (HEI) are introducing more online courses to prepare the graduates work preparedness. The HEI needs to equip graduates with more than just skills and knowledge specific to their chosen field; they must also develop broader transferable capabilities that enable graduates to gain employment, contribute

to society, and adapt to change and uncertainty [6]. Massive Open Online Courses (MOOC) and MC are common types of online course that has given learners an advantage in meeting education and professional development needs [1,7,8].

In comparison with MOOC, MC breaks existing content into smaller chunks [9,10], to enable learners to access it more easily despite their commitments as students or working adults [11]. The flexibility of MC offers accessible learning opportunities that promotes professional development through upskilling and reskilling medium of specific skills and competencies [10]. Currently, HEI often develops two types of MC as providers, namely stackable MC and stand-alone MC.

Some online MC offers industry-recognized credentials. However, several challenges remained in imparting competence compared to the conventional F2F courses. First, there is lack of an educational framework to guide developers in designing an online MC for industrial skills. Second, there is a lack of studies that have explored whether online micro-credentialing produces comparable competency attainment (as per industry standards) to the conventional F2F course. Third, while students pursue online MC at their own pace, it is necessary to explore whether it provides the comparable learning experience to the learners especially in terms of engagement and feedback. These critical fundamentals need to be explored, as a poorly designed online micro-credential may not lead to competency attainment.

While local work is done to create a general framework for a wide implementation of MC [12], a comprehensive education framework for MC development informed by educational theories is necessary. This is to ensure that MC is able to impart relevant knowledge and skills, while possessing the efficacy required by industry and professional standards.

1.1.2 Micro-credentials in professional development

Employers expect employees to apply their knowledge to real-world settings, analysed, and solve problems [13]. Hence, MC are becoming increasingly popular not just in HEI but also in the employment sector. During the COVID-19 pandemic, MC began to open up opportunities not only for students but also at the professional development level where it allows employers to reskill and upskill their current competency level to meet expanding job requirements [14–16].

Although HEIs are pioneers in most MCs, some MCs are developed by ministries or national companies. In Malaysia, as of April 2022, the Human Resource Development Corporation (HRD Corp), in collaboration with the Ministry of Higher Education, has launched the nation first industry-based microcredit initiative for Malaysians, where their MC contains 24 skill areas focused on upskilling and reskilling, reflecting a national commitment to cultivating workforce-ready competencies that meet real employer demands in Malaysia. This action is also emphasized [17] where employers can provide qualifications internally or in collaboration with other organizations in professional development.

However, the lack of constructive alignment (mismatch between outcome and skills attainment) in the implementation of MC has caused many employees to feel insecure, especially when the employer does not acknowledge the acquired skills. stated that lack the of evidence and criteria used to award specific grades and categories causes employers to be unable to determine the exact knowledge, skills, and achievements achieved by employees.

1.1.3 Development of micro-credential

Several countries and stakeholders have taken various steps to establish guidelines and model development policies for MC development. These guidelines

have similarities in outlining the basic principles of good practice and developing MC. It also outlines the necessary elements in MC: name of holder, name of recipient, level in national, sectoral, or international qualification framework (preferably all three), learning outcomes, assessment methods, assessment results, and quality assurance [2,18–20].

It is essential to regulate and define micro-qualifications and integrate them into a regulatory framework or quality assurance system. Without a single, standardized, and precise policy and practice, key stakeholders such as students, employers, and providers, such as higher education institutions, face uncertainty about their value and micro-qualifications' role in education and employment [21].

Most of existing studies on MC focus on. Unfortunately, there is lack of a consensus on the effectiveness, design, or implementation of MC.

1.2 Problem statement

1.2.1 Framework on MC development and their effectiveness

Regardless of their backgrounds, employees across various industries often require professional development to upskill and reskill their competencies according to evolving employer expectations. While MC has emerged as an accessible training tool for employees [22], designing MC can be challenging, primarily due to the lack of a comprehensive guideline. Key issues include aligning learning and assessment objectives, with elements such as badge-enhancing appeal and linking badges to evidence of learning activities [14].

Poor quality of course design and content could hinder the effectiveness of MC [7]. Currently, many scholarly publications put more emphasis on learners’ awareness and motivation, acceptance of HEI and employers and use of blockchain technology

[23]. Much of the existing research has also concentrated on policy development and the role of stakeholders in MC implementation within HEIs [24], rather than evaluating how well MCs achieve their intended learning outcomes. This situation has created a gap in the effectiveness of MC, as previous studies focused more on the implementation of MC and the development of policies [24,25]. A systematic review [7] reported that out of the examined studies, thirteen demonstrated positive outcomes and one indicated a negative outcome. However, the outcomes were constructive learning environment, enjoyable way of learning, high peer support and beneficial teaching method. There is paucity of literature that proposed effectiveness of MC in terms of imparting knowledge or skills to the learners.

To address these gaps, this study aims to develop an educational framework for online MC and evaluate its efficacy compared to traditional F2F training methods. Having more MC developed with a comprehensive educational framework will support a cost-effective professional development strategy that reduces training costs and time while enhancing employees' skills and knowledge, not just Malaysia but globally [26].

1.2.2 Fire safety gaps among graduate students in terms of knowledge and skill

Fire safety remains a critical concern for graduate students, whose residence halls, laboratories, and campus facilities are particularly vulnerable to fire risks. In 2023, the Fire and Rescue Department of Malaysia (BOMBA) recorded 34,389 fire-related distress calls, with over 4,900 involving buildings and losses of RM 2.6 billion [27,28]. Yet, fire safety management in Malaysian universities has been inconsistently implemented, with emergency preparedness and response described as “not sufficiently explored” [29].

Current approaches by using generic briefings or one-off drills shows that are inadequate for sustained preparedness [30,31]. Although the Malaysia Education Blueprint (2015–2025) promotes digital learning and DOSH guidelines stress safety training, structured online fire safety modules remain underutilized [32]. Studies highlight low-to-moderate knowledge among students, limited awareness of institutional protocols, and poor practical skills (e.g., extinguisher use, evacuation) [30,33]. Training is often infrequent, narrowly scoped, and not tailored to the graduate student context, leaving them underprepared for real emergencies. These gaps point to the need for a structured, competency-based micro-credential in fire safety that integrates knowledge, skills, and preparedness into the graduate student learning environment.

1.3 Operational definition

1.3.1 Micro-credential (MC)

Micro-credentials are online courses in various certification forms, such as digital badges, credentials, and certifications that validate evaluated knowledge, skills, and competencies [2,12,34]. The contents are often delivered in chunks or short bites to accommodate students and working adults [9,17,34–37]. This course can be a stackable or stand-alone course that higher education institutions or stakeholders may offer to aid in professional development and academics [2,38–41]. In this study, the Fire Safety Essentials MC was used to assess the efficacy of MC as a training tool.

1.3.2 Massive Open Online Course (MOOC)

MOOC refers to a large volume of learning. This course is designed to offer a comprehensive learning experience at no cost and may require payment for additional

credentials [42,43]. While MOOC and MC can sometimes be used interchangeably in literature, the current study focuses on MC.

1.3.3 Fire Safety Essentials MC

The Fire Safety Essentials Micro-credential (MC) is a short, competency-based course adapted from the F2F GTK241: Fire Safety and Design. It is delivered online using learning4life.com.my and structured into three modules covering fundamentals of fire safety, fire prevention and control, and portable fire extinguishers. The course integrates knowledge outcomes (fire science, hazard identification, prevention strategies, and response protocols) with skill outcomes (fire hazard assessment). Competency is assessed through quizzes as continuous assessment and executive summary as summative assessment and successful learners are awarded a digital badge as recognition of achievement in essential fire safety practices. The course is not considered blended learning because less than 30% of the course content is online. Only the materials are uploaded on e-learning, while the instruction is delivered physically [44].

1.3.4 Educational framework in MC development

The educational framework in micro-credentials development is a structured guideline developed through a scoping review and thematic analysis to support systematic MC design. It consists of four domains operationalized by eight components: (1) learning outcomes, (2) instructional design, (3) learning activities, (4) course maps, (5) assessment, (6) feedback, (7) digital badge and (8) institutional factors. The framework ensures constructive alignment between knowledge, skills, teaching strategies, and assessment methods while maintaining flexibility across delivery modes. It functions as a validated tool for educators, institutions, and industry

stakeholders to design competency-based micro-credentials that are pedagogically sound and digitally recognized.

1.3.5 Training Efficacy

Training efficacy can be defined as the extent to which a specific training or educational measures produces the desired effect under ideal conditions [45]. It is different to training effectiveness which measure the effect under ordinary or uncontrolled environment. In this study, efficacy was measured using knowledge and skills assessment score, consistent with the Course Learning Outcome that emphasizes on these two domains.

1.3.6 Training Evaluation

Training evaluation can be done using a widely used model - Kirkpatricks four-level evaluation model. An evaluation can be done by examining one or combination of the following four levels: Level 1 Reaction, Level 2 Learning, Level 3, Behavioral and Level 4 Results or Effect on Organisation [46].

The study measured Level 1 (learners' reaction) through Training Evaluation Inventory (TEI) that measures learners' perception on training outcome and training design [47]. Through knowledge and skill scores assessment, the study also measured Level 2 (learners' learning).

1.4 Research Question

a. What is the education framework to guide the development of an MC?
b. Is the student performance in an MC comparable to F2F teaching in terms of knowledge?
c. Is the student performance in an MC comparable to F2F teaching in terms of skills?

d. Is MC training comparable to F2F training in terms of training outcomes and designs?

1.5 Research aims and objectives

In general, this study aimed to develop an educational framework for MC and assess the efficacy of the Fire Safety Essentials MC developed by the educational framework compared to F2F teaching.

1.5.1 Specific Objectives

a. To develop and validate an educational framework for MC development.

b. To develop an MC for health science graduates on Fire Safety Essentials based on the developed educational framework.

c. To evaluate the efficacy of the Fire Safety Essentials MC in comparison to F2F teaching in terms of knowledge and skill.

d. To evaluate the Fire Safety Essentials MC training outcome and design compared to F2F teaching.

1.6 Research hypothesis

a. Students' performance in MC is comparable to students' performance from F2F teaching in terms of knowledge.

b. Students' performance in MC is comparable to students' performance from F2F teaching in terms of skill.

c. Training outcomes in MC are comparable to those of F2F teaching.

d. Training design in MC is comparable to F2F teaching.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter begins by examining the concept and principles of MC, available framework and summarising literature focusing on the development and implementation of MC. Finally, the gaps in the literature were discussing, illustrated in a conceptual framework at the end of the chapter.

2.2 Overview of Micro-credentials

MCs is defined as a digital certification that verifies assessed knowledge, skills, and competencies in a specific area or field [1,18,23]. Similarly, MC is recognized as certified learners' documents from a short duration of educational or training activities [24].

MC offers various functionalities that has garnered interests in the field of education as well as the employment sector. In education, MCs gained prominence as an alternative to traditional education pathways featuring flexibility, affordability, and skill-oriented learning [9]. Students view MC as an attractive option to enhance their competence and skills, while educators or developers view that MC as a formal or informal qualification that is focused and can be delivered within a short timeframe [18]. From the industry perspective, MCs were considered equivalent to certificates obtained from attending professional development programs that foster lifelong learning and can fulfill upskilling needs for career advancement and supply industries with adaptable, skilled workers [18,25,26].

2.3 Micro-credentials concept

The use of terminology related to MC is still confusing and non-standard. Many definitions for MC exist. While the concept has gained recognition in HEI and industry, the terms "micro-credentials" and "digital badges" are often used interchangeably [8,48]. The definition of MC remains unclear, and the appropriate terminology is not consistently used [49–51]. The lack of standardization has impacted not only locally in Malaysia but globally, where MC is sometimes referred to other terms such as online certificates, alternative qualifications, nano degrees and micro masters [43,48]. A study in Malaysia found that 64% of tech-related personnel in Malaysia claim to be aware of the term, indicating the varied understanding of MCs [38]. The lack of consistent definitions or theoretical foundations in many studies poses challenges for the development of micro-credentials.

2.4 Micro-credentials

Developing a coherent, robust, and innovative quality framework is essential to support the validity, credibility, and recognition of MC. This is a challenging for HEI, whose operation has been focused on larger volumes of learning for major or minor qualification [52]. The Common Microcredential Framework (CMF), derived from the European Qualifications Framework, is currently the sole established framework for MC development across Europe that provides guidelines for credit transfer [53]. Additionally, the national qualification frameworks differ across countries, and the EQF and CMF, may not be suitable for Malaysian HEIs.

In Malaysia, the MQA introduced the first guideline on MC for HEP and relevant stakeholders on principles and good practices in the implementation of MCs in 2020 [2] and stand-alone MC in 2023 [54]. These frameworks and guidelines

collectively serve as quality assurance mechanisms, ensuring that MCs carry the same credibility as traditional qualifications, particularly in cross-border education and workforce mobility. The guideline outlines key principles in conceptualisation, development, design, implementation, assessment and credentialling of these short courses [46]. The principles consist of outcome/competency-centred (1), demand/industry-driven (2), personalisation (3), digital credential (4), secure and shareable credential (5), transparency (6), stackable (7), learning on demand (8), flexible learning pathway (9), self-directed learning (10), assessment of outcome (11) and verification/authentication (12). This guideline is set to serve as a reference for all stakeholders involved in MC development in Malaysia. Despite this, gaps remain in terms of educational approach, curriculum design, assessment strategies, and delivery methods; these areas require further investigation to ensure the effective implementation and recognition of MC [55].

While MC are still in the early stages globally, the European Commission, through projects like MICROBOL, is working to align them with existing qualification frameworks and strengthen their integration into the Bologna Process by supporting ministries and stakeholders in exploring new credentialing approaches [43]. The relevance of MCs within vocational education highlights persistent uncertainties that must be addressed in future policy development, such as formal certification and acceptance of MC achievements [19,56].

Although various large bodies such as UNESCO, MQA, and CMF introduced frameworks for the development of MC and implement them in the practice of education and industry, the limited empirical validation of the framework or the lack of a standard model across sectors against the existing framework has not yet been widely

studied. The need for standardization and quality assurance to ensure the MCs are rigorous and provide value to learners requires attention from the expert bodies [57].

Ultimately, a standardized and robust framework needs to be streamlined to ensure that the development and implementation of MC is of high quality and covers all aspects of both credit transfer and professional development. Therefore, it is essential to strategize MC by promoting their adaptation in HEI, through coherent policies and frameworks. This would address barriers in some universities to obtaining fully recognized micro qualifications, questioning the academic rigour of the learning outcomes and the amount of learning [34].

2.5 Micro-credentials as a training tool

There is an increasing demand for flexible and targeted training solutions in today's rapidly evolving work competencies [43]. MC has been developed to equip various workforce [58], for example geriatric nursing professionals, which to a certain extent, can help to alleviate the widening gap between the growing demand in healthcare [56]. With the self-directed learning concepts, MCs are enablers for higher education and training ecosystems as they provide learners with flexible, targeted training that is aligned with the growing needs of employers, fast-evolving job market, and increasingly accepted by companies as a way to validate a job candidate's skills and knowledge [57,59].

MC is one of the training tools used by gig workers, employees, and employers [60]. Therefore, it is crucial for HEIs to not only develop MCs for graduation but to ensure that MC meet the demands of the future workforce [53]. Similarly, employers seek entry-level employees with better skills and capacity to learn, giving companies a competitive advantage [61].

Robust student assessment is crucial for ensuring the accuracy and credibility of micro-credentials for employers. Evaluating learners' achievement through high-quality assessments can validate the content and rigor of the credential, enhancing its value and recognition in the job market. Previous study proposed that faculty members require assistance in incorporating high-quality assessment, such as aligning assessment with the delivery mode and embedding equity-focused assessment strategies when developing MCs [62].

These gaps further support the need for a more unified and evidence-based approach to develop MC as a training tool that aligns with pedagogical best practices and labor market requirements. MCs have significant potential in the future of education and training, and it is vital to continue to explore their effectiveness and impact from a training tool perspective [58].

2.6 Micro-credentials in health sciences graduate's context

Micro-credentials (MCs) have become increasingly integrated into undergraduate and postgraduate education, a trend accelerated by the digitalization of learning during the COVID-19 pandemic. Within the healthcare context, MCs offer a flexible, competency-based approach that allows health sciences students and professionals to acquire targeted skills efficiently, bridging gaps between academic learning and industry requirements [7,50]. By focusing on key competencies such as analytical thinking, technological literacy, and clinical preparedness, MCs can enhance employability and professional readiness.

Despite their potential, MCs in health sciences face challenges, particularly regarding quality assurance, transparency, and recognition by regulatory bodies and employers [50]. Critical reflection from policy and scholarly literature highlights the

need to address these issues to ensure MCs are both credible and effective in preparing graduates for professional practice. Integrating MCs into health sciences curricula, either as formal components or recognized supplementary pathways, can strengthen alignment between educational outcomes and the evolving demands of the healthcare sector [63].

Moreover, MCs promote inclusivity by providing accessible learning pathways for learners from diverse backgrounds, enabling upskilling or reskilling in response to emerging technologies, treatments, and public health challenges [64,65]. Their modular and flexible nature allows rapid acquisition of competencies that traditional degree programs may not deliver efficiently, making MCs a strategic tool for developing a skilled, adaptable, and globally competitive healthcare workforce.

2.7 Measuring effectiveness of micro-credentials

To ensure the effectiveness of MCs as an innovative tool for delivering focused, flexible learning experiences, it is crucial to pay attention to MC development and implementation. Strategies in the development of MC, such as integrating gamified learning tools, adaptive learning technologies, and increasing peer interaction may enhance engagement and learning outcomes, thereby determining the effectiveness of MC [10].

Existing study findings suggest that emphasizing flexibility, accessibility, and sustainability as central to the success and contributes significantly to perceived effectiveness in MC [59]. Importantly, findings indicated that course quality and design are the most influential factors on the efficacy of MCs, compared to other factors such as learners, educators, and social media [7,66]. It shows that MC structural features, particularly the design and delivery, play a critical role in their overall impact. Despite

the growth of MCs, there is still a lack of clarity regarding the design practices and quality standards that affect the overall effectiveness of MC [62].

2.8 Fire safety

Fire safety was selected as the case study due to its critical importance in occupational health and safety. Fire-related incidents continue to threaten lives, property, and organizational continuity. The International Labour Organization identifies fires and explosions as major workplace hazards worldwide [67]. In Malaysia, the Fire and Rescue Department (BOMBA) records thousands of incidents annually [27,28], underscoring the need for stronger public and workplace awareness.

Currently, fire safety education relies on face-to-face briefings, mandatory fire drills, printed manuals, and short workshops delivered by agencies such as BOMBA. While these methods raise awareness, they are resource-intensive, episodic, and limited in scalability for lifelong learning.

Globally, professional bodies such as the National Fire Protection Association (NFPA) provide flexible training and modular certifications, including online and self-study formats [68,69]. Online platforms such as Coursera and Udemy also offer short courses in fire safety. However, in Malaysia, while micro-credentials in occupational safety are emerging, targeted offerings specifically in fire safety remain limited. The MQA has issued guidelines for standalone micro-credentials, yet these have not been widely applied to fire safety domains [54].

This gap presents a significant opportunity: developing a structured, competency-based micro-credential framework for fire safety could provide accessible, flexible learning pathways while aligning with national quality assurance standards.

2.9 Training Evaluation Inventory (TEI)

The review of literature demonstrates that Kirkpatrick's four-level model remains a cornerstone of training evaluation, offering a comprehensive framework for assessing learner outcomes and organizational impact. The model evaluates training across four levels: reaction (how learners respond to the training), learning (the knowledge, skills, and attitudes gained), behaviour (the transfer and application of learning in practice), and results (the broader impact on organizational or institutional goals). Building upon this foundation, the TEI developed by [47], provides a validated and structured tool that operationalizes Kirkpatrick's principles while extending evaluation to include instructional design quality. Compared to other evaluation approaches such as post-training tests, satisfaction surveys, or ROI analysis, the TEI offers a more holistic perspective by integrating both learner outcomes and pedagogical processes.

In the context of this study, which focuses on the development and evaluation of an online fire safety micro-credential for graduate students, the TEI is particularly relevant. It allows for the systematic assessment of knowledge acquisition, learner attitudes, and perceived usefulness of the training, while also capturing the effectiveness of instructional design features such as problem-based learning, demonstration, and application. This alignment ensures that evaluation is not limited to immediate reactions but also considers the instructional strategies necessary for competency-based learning.

Therefore, the TEI serves as a suitable and robust instrument for evaluating the effectiveness of the fire safety micro-credential in achieving both individual learning goals and broader institutional safety priorities.

2.10 Summary of literature review on MC

Current research on MC reveals several significant gaps. Firstly, there is no standardization or unified framework in the development and implementation of MC guiding all stakeholders; instead, fragmented models dominate the landscape, with little agreement on standard criteria for assessing quality or outcomes. Secondly, the role of MCs as a training tool remains underexplored. While often promoted as flexible learning options, their specific use in targeted skill development for industry needs lacks rigorous study. Lastly, evidence on their effectiveness is limited. Most existing studies are short-term, lack robust methodological designs (such as control groups), and often prioritize learner satisfaction over measurable learning outcomes.

The conceptual framework of this study (Figure 2.1) is structured around four main objectives that collectively guide the development, implementation, and evaluation of MC as a training delivery tool. The first objective focuses on the development and validation of an educational framework for MC design, incorporating studies input from developers, learners, and HEI. This input will be used to develop and validate an educational framework with practical components such as creative content design, assessment strategies, and the use of digital badges to recognize learning achievements. The second objective operationalizes this framework by developing a specific MC course on Fire Safety Essentials for health science graduates, ensuring that the content is both knowledge-based and skill-based to meet professional training needs.

The third and fourth objectives shift towards evaluation, assessing the efficacy of the Fire Safety Essentials MC compared to F2F teaching. These evaluations focus on learning outcomes in terms of knowledge and skills, as well as the training design itself. Fire safety was chosen as the course because it is a critical but often underemphasized competency for health sciences graduates. In clinical, laboratory, and community

settings, graduates face fire hazards from equipment, chemicals, and crowded facilities. Current training, usually limited to briefings or drills, raises awareness but does not ensure sustained competence.

At the same time, micro-credentials are gaining recognition as flexible, competency-based pathways for professional development, yet targeted offerings in fire safety remain scarce in Malaysia. Positioning fire safety within a micro-credential framework addresses this gap by equipping health sciences graduates with essential workplace safety skills while supporting lifelong professional development.

The outcomes of the study aim to inform future applications across multiple levels: providing practical guidelines for HEIs and developers, informing policymaking and stakeholder, and supporting professional development for both employers and employees.

2.11 Conceptual framework of the study

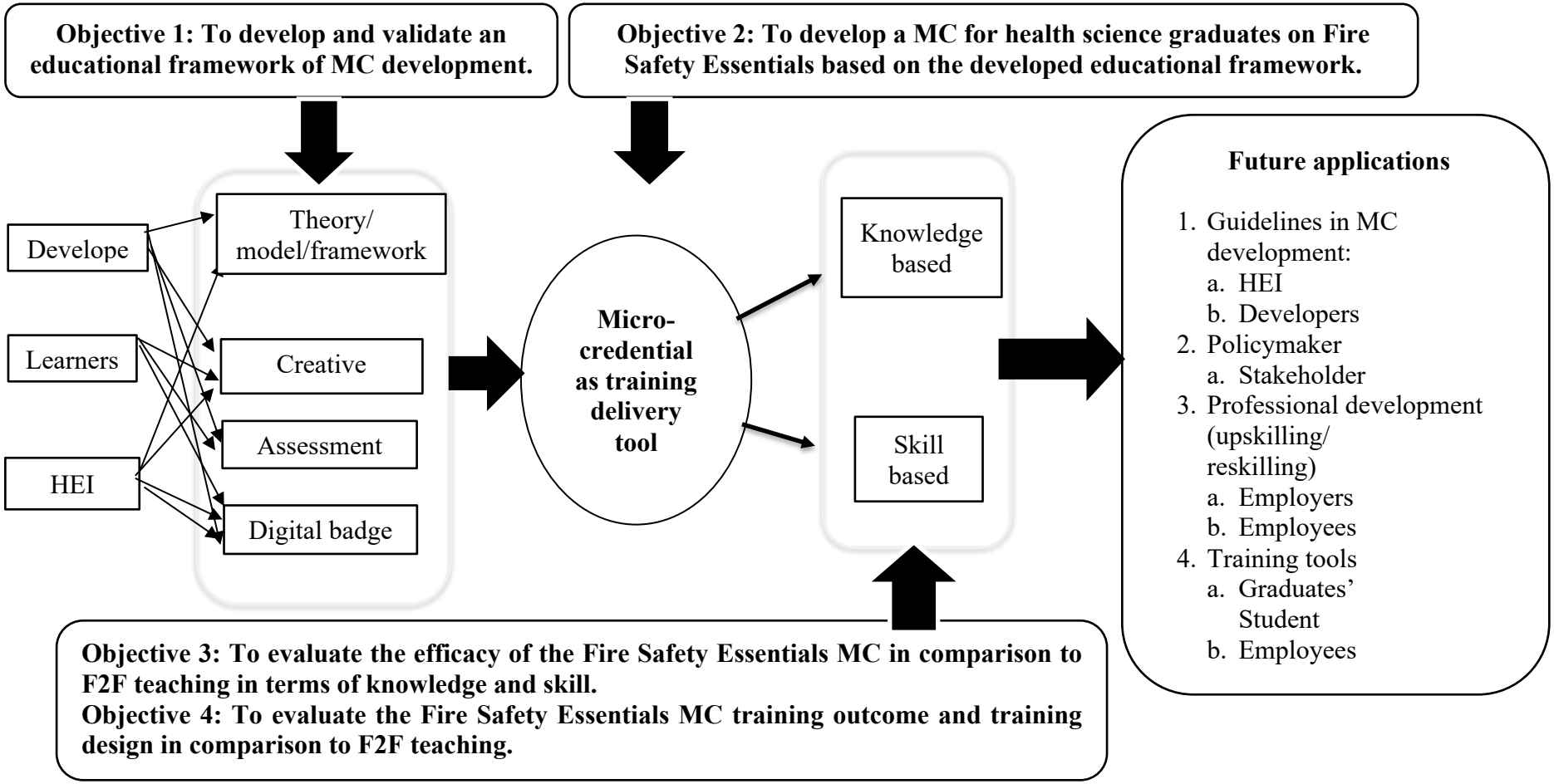

Figure 2.1 Conceptual framework of this study

CHAPTER 3

METHODOLOGY

3.1 Introduction

This section discusses the methodology of the study. Phase 1 of the study describes objective 1 (development and validation of an educational framework of MC development). Phase 2 expands on methods to develop an MC for health science graduates on Fire Safety Essentials based on the developed and validated educational framework. Phase 3 describes objectives 3-4 (efficacy testing and training evaluation of Fire Safety Essentials MC).

3.2 Study design

The study utilized the exploratory mixed methods design which is particularly appropriate when the research domain is novel and requires in-depth exploration before moving towards quantitative testing [70]. The design allows for research to begin with qualitative inquiry to identify key content areas, namely theories, models, frameworks and elements in MC development, followed by expert validation for content validation which involved in phase 1 and then quantitative evaluation of the developed educational intervention on the phase 3.

First, a scoping review was conducted to systematically map existing literature and identify key concepts, frameworks, and gaps [71] focusing on MC development. This approach was considered most suitable with research objectives aimed to explore, identify, map, report, or examine characteristics or concepts of development MC across a wide range of evidence sources [72].

The insights gained from the scoping review were used to inform the development and design of Fire Safety Essentials MC. Using a quantitative method

provides several advantages, such as the ability to reach larger sample sizes, efficient data collection, and enhanced generalizability of the findings in this study [73]. Then, a quantitative efficacy study was conducted to test learners' performance in MC compared to F2F teaching in terms of knowledge and skill. On top of that, the MC training outcome and design were evaluated using a validated tool.

3.3 Phase I: Development and validation of an educational framework for MC development

3.3.1 Stage I: Scoping Review

A scoping review was conducted to identify the aspects, elements, models, or theories of the educational framework relevant to MC development. The scoping review followed the Joanna Briggs Institute's (JBI) methodology for scoping reviews [74,75]. The review process will involve five key steps: 1 - formulating the review questions, 2 - searching for relevant studies, 3 - selecting eligible studies, 4 - extracting and charting the data, and 5 - analysing and reporting the findings [76,77]. The report was constructed based on the Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for scoping reviews (PRISMA-ScR) checklist [43]. The study protocol has been registered with the Open Science Framework (https:// osf.io/stf43) and has been accepted for publication in the Education in Medicine Journal (Appendix T).

3.3.1(a) Search Strategy

The search strategy included published studies from citation databases (Scopus and EBSCOhost) and a subject database (Education Resource Information Centre or ERIC). The following search string: ("micro*credential" OR "nano*degree" OR "micro*master" OR "digital*credential" OR "online*certification" OR "digital*badge")

AND (theory OR model OR design OR framework OR principle OR strategy OR develop*) was used to identify relevant studies. Eligible studies from 2013 until July 2024 were included to ensure important studies on micro-credentials are captured. This search string was piloted on selected databases and yielded around 30 to 974 records from each database (Appendix B).

Table 3.1 Inclusion and exclusion for articles screening in the scoping review

	Inclusion	**Exclusion**
Participants	• General population, undergraduate and postgraduate students • Age: 19 years and above • Learners, developers, and policymakers' perspectives	• School children • Specialized or highly advanced digital literacy level • Participants with cognitive and physical disabilities
Concept	• Pedagogical theory, model, design, framework, principle, or strategy in developing micro-credentials • Description of planning, development, implementation, evaluation, or continuous quality improvement of micro-credentials	
Context	• Online micro-credential, digital badge, digital credential, nano degree, micro-master, or online certification. • Knowledge-based, skill-based, or competency-based micro-credential	• Micro-credentials offered in a F2F setting • MOOC • Mobile applications, e-books, websites, or podcast-based courses
Types of sources	• Primary research (quantitative, qualitative, or mixed method study design, irrespective of methodological approach) • Secondary research (not limited to systematic review, scoping review, and meta-analysis) • Other published resources (limited to commentary, guideline, government document, policy paper, and conference proceedings) • English and Malay languages	• Grey literature (unpublished report, white paper, and training document) • Book or book chapter • Website or blogs • Not a full article