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Developing a Micro-Credential Curriculum in IoT for Malaysian Community Colleges: Key Topics and Projects

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Abstract

The Internet of Things (IoT) is a crucial course in Information Technology programs, merging electronic circuit concepts with programming skills to create interconnected devices. This study aimed to design a Malaysian Community College micro-credential curriculum for IoT by identifying relevant theoretical and practical topics and mini-projects. A need for a micro-credential module with suitable instructional materials was identified, enabling learners to apply theoretical concepts through mini-projects. Using the Fuzzy Delphi (FD) method, data from 19 experts via semi-structured interviews were analyzed to design the Fuzzy Delphi instrument. This instrument was distributed to 30 industry experts and academic practitioners, who ranked the elements on a five-point Likert scale. Fuzzy evaluation to establish consensus for inclusion requires an average expert agreement of 75%, a d-construct threshold of 0.2, and an average fuzzy number of 0.5. Consensus was reached for six out of nine theoretical topics and nine out of 13 practical topics. "Fundamental concepts of IoT" was deemed the most critical theoretical topic with 97% consensus, while "basic connectivity of IoT hardware" was the top practical topic with 100% consensus. For mini-projects, experts accepted two out of nine theoretical topics and nine out of 13 hands-on topics. The top authentic projects were "Air Quality Monitoring" and "Smart Home Security", with 83% and 80% consensus, respectively. This study lays the groundwork for developing learning outcomes and assessment strategies for a micro-credential course on IoT at Community Colleges to equip TVET students with industry-relevant competencies, thus making them more employable.

1. Introduction

Since 2002, Malaysia has set up 12 community colleges, and by 2024, this number has increased to 106 to cater to the growing population in different regions of the country. Community colleges in Malaysia play a crucial role in the nation’s educational landscape by providing post-secondary education that is more accessible and hands-on than traditional higher education institutions such as universities. Community Colleges focus on preparing students for employment through Technical and Vocational Education and Training (TVET) courses, catering to a range of learners, including recent school leavers, adults seeking additional qualifications or re-skilling, and members of the community interested in personal development. Thus, TVET courses are expected to equip the future workforce with essential skills to address immediate job market demands and contribute to the nation’s economic development goals.

The COVID-19 pandemic has altered how people teach and learn, offering flexibility and cost-effectiveness. Traditional in-person teaching and learning are losing popularity as more learners embrace hybrid or online education (Navanitha et al., 2022). Specialised skills for niche roles are in high demand in today’s dynamic business world and gig economy. In order to remain relevant in a workforce undergoing constant change due to the fourth industrial revolution (4IR), ongoing upskilling and reskilling are crucial but in more manageable time chunks (Selvaratnam & Sankey, 2020). Higher education institutions are adapting to offer more agile and faster forms of instruction. Micro-credentials, like nanodegrees or bite-sized qualifications, certify skills and knowledge in specific areas. Upon successful completion of a micro-credential program, individuals are typically awarded a digital badge to demonstrate their achievement (Varadarajan et al., 2023). These badges can be shared across different digital platforms, such as LinkedIn and social media, validating the accomplishment (Varadarajan et al., 2023). In Malaysia, the Malaysian Qualifications Agency (MQA) has defined micro-credential as “a digital certification of 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 and personal development of the learners” (MQA,2020).

1.1 Teaching and Learning of IoT using Micro-credentials

Micro-credentials can provide flexible higher education learning opportunities for students, a core component of the national aspiration for Community Colleges in Malaysia. Micro-credentials break down formal education programs higher education institutions offer into smaller, more manageable parts. This makes these educational opportunities more accessible to people who may not follow the traditional path of going straight to college after high school. Additionally, this approach supports the idea that learning can continue throughout one's life and across a wide range of experiences and environments, aligning with the national aim of encouraging lifelong and diverse learning experiences. Moreover, micro-credentials allow learners to gain skills and knowledge in specific areas without the time and financial investment required for a full-fledged certificate or diploma programs. Besides, micro-credentials may also include a sequence of modules or project-oriented units focused on cultivating distinct skills or competencies (Ralston, 2021). In addition, by offering micro-credentials, Community Colleges help enhance the employability of their students. These programs can provide proof of competency in particular skill sets those employers highly value. As a lifelong learning course hub, Community Colleges can also offer a pathway for working adults to pursue micro-credentials for career advancement or to pivot to new roles. Moreover, Community Colleges often have strong ties to local businesses and industries. By offering micro-credentials developed in collaboration with these partners, they ensure that the skills taught directly apply to the workforce. Thus, the offering of micro-credentials by Malaysian Community Colleges is a natural extension of their role in providing TVET education that meets the needs of learners and employers in a flexible and accessible manner. This trend towards micro-credentialing is part of a broader global shift in education towards more modular and competency-based learning outcomes.

Micro-credential courses in fields such as computing, robotics, 3D printing, data analytics, talent acquisition and supply chain logistics can be customized to specific industry sectors to enable their employees to improve their competencies and address the skills gap (Ralston, 2021). Internet of Things (IoT) is an important core course in Malaysia's Information Technology programs that integrates foundational concepts of electronic and electrical circuit concepts and programming skills into creating smart and interconnected devices. The Internet of Things (IoT) field is continually transforming as novel technologies and applications emerge, along with new challenges. As such, it's crucial to ensure that educational content remains updated and relevant, preparing students for real-world scenarios. Authentic tasks, which are real-world or realistic tasks, enhance the learning experience by providing context and practical application to theoretical knowledge. This not only aids in retention but also in developing problem-solving skills. By focusing on the most relevant topics and real-world projects, educational institutions can produce graduates ready to fill these gaps, driving innovation and growth in the sector. As the IoT field evolves, periodic reassessments will be needed to update and refine the curriculum. This ensures that education in the domain remains dynamic and responsive to changes. Therefore, it is imperative for community colleges to continuously review and update the IoT course content to align with the fast-paced advancements in the sector, ensuring that upcoming graduates possess the relevant knowledge and abilities. For effective instruction and understanding in IoT courses, both teachers and students need to possess knowledge in a range of topics. These include electricity, magnetism, circuits, electric motors, power system operations, control mechanisms, sensor technology, electro-optical systems, various communication protocols, both analog and digital electronics, microprocessor technology, digital control systems, programmable components, and coding principles (Ahmad et al., 2020; Burd et al., 2018). Furthermore, using the Arduino and Raspberry Pi platforms requires familiarity with programming in Java, including syntax, semantics, and the ability to debug compilation errors such as misspelled variables or misplaced semicolons for success (Ahmad et al., 2020). The Internet of Things (IoT) courses offered at community colleges cover only the fundamentals of IoT (Ahmad et al., 2020). This entails using Python to program Raspberry Pi devices for internet connectivity and employing affordable programmable Arduino microcontroller boards. Assessments of students are based on projects where they must program to interpret both digital and analogue signals, like those emitted by a light sensor, and to manipulate different outputs, for instance, switching an LED on or off or triggering a switch. These projects cover the fundamentals of electricity and electronics. The study revealed that instructors teaching IoT at community colleges were found to require appropriate teaching materials for their courses (Ahmad et al., 2020). It was also discovered that these instructors, especially those without an electric and electronics background, struggled to teach the theory and practical tasks required in the course (Ahmad et al., 2020). Instructors need to receive training in electronic and electrical circuit concepts used in IoT so that their students can better understand the content. Conversely, students were found to have a low-level understanding of electric and electronic concepts and low-level programming and logical thinking skills (Ahmad et al., 2020). A better grasp of IoT concepts would enable students to apply theoretical concepts to real-world applications, which might otherwise seem abstract. Inadequate training in IoT may also affect newly graduated IT students, given the significance of IoT in the field.

An ideal solution is to identify appropriate and up-to-date curriculum content to be implemented as a micro-credential course that contains a unit of study tailored to the needs of the industry, presenting a distinct and valuable offering within the education landscape (Parsons, 2023) to address the needs of both students and IoT instructors. Specifically, the objectives of the micro-credential course are to include fundamental concepts of the IoT and possible real-world applications of IoT using IoT mini-projects by applying the concepts learned. In addition, it was suggested that to add value, the design of the micro-credential module should be based on what is needed in the world of work by partnering with industry and organizations (Oliver, 2019). This ensures that learners will be equipped with the skills, knowledge and attitudes required to train workers in new skills and changing employment patterns (OECD,2019). Micro-credentials have the potential to significantly contribute to customized learning opportunities by enabling learners to enhance or acquire competencies that are relevant or anticipated to be highly sought after in the job market (Pirkkalainen et al., 2022). Building an industry-relevant unit of study with authentic tasks can be achieved by considering inputs and perspectives from various industry experts and stakeholders (Ajjawi et al., 2019). This move is also aligned with the Malaysian Education Blueprint 2015-2025 (Higher Education) by the Ministry of Higher Education of Malaysia (MOE) which highlights the role of the industry in leading curriculum design and delivery (MOE, 2015).

2. Using the Fuzzy Delphi Method to Achieve Expert Consensus

The Delphi method pioneered by Murray et al. (1985), which seeks convergence of opinion on a specific topic through iterative rounds of questioning and feedback, is deemed reliable (Jamil et al., 2023). Few studies have utilized the Delphi method in the field of Computer Science education, for example, in the development of a precise teaching evaluation system for programming courses (Yu et al.,2023) and developing curricula for computational thinking curriculum (Chuang et al., 2015). The Fuzzy Delphi method (FDM hereafter) extends the traditional Delphi method. It integrates fuzzy logic to handle the ambiguity and uncertainty in expert opinions, making it especially useful when opinions are diverse or lacking clarity (Linstone & Turoff, 2011). The FDM is an analytical decision-making process integrating fuzzy theory with the standard Delphi approach (Abdullah et al., 2021; Linstone & Turoff, 2011). The FDM represents an advanced version of the Delphi Method, designed to evaluate the consensus level among expert panels using triangulation statistics (Abdullah et al., 2021; Ishikawa et al., 1993). The FDM can save time and costs as the number of rounds of surveys can be reduced, and experts can fully express their opinions (Kadir et al., 2019). More importantly, this technique takes into account the fuzziness of the range, unlike the Delphi method, which disregards the typical range of fuzziness in a survey. The consensus of expert opinions in the Delphi method only applies to a specific range. This research used the cumulative frequency distribution and fuzzy scoring to collate the experts' opinions into fuzzy numbers (Ho et al., 2008). This means the opinions were described by linguistic terms expressed in triangular fuzzy numbers (Chen & Lin, 2002). To ensure consistency in expert consensus, the FDM was used to adjust the fuzzy rating of each expert. The aggregate fuzzy numbers were calculated by taking the product of the fuzzy decision matrix and the respective fuzzy attribute weight. This approach accurately captures experts' original opinions and does not distort the perspectives of the experts, ensuring their viewpoints are represented correctly.

In the context of the design and development of a micro-credential course, the FDM is deemed as a reliable approach to identifying the most relevant skills and knowledge areas (Kaufmann & Gupta, 1988), ensuring that the micro-credential course demonstrates both knowledge acquisition and competency (Ashcroft et al., 2021).

Thus, in this study, the FDM was used to discover the needs and gaps the IoT micro-credential should focus on by gathering input from experts in the field. This is to address the focal questions:
According to expert consensus,
(i) what foundational topics (both theory and practical) in IoT must be included in the micro-credential course?
(ii) what IoT mini-projects must be included in the micro-credential course?

In this study, the experts were carefully selected based on their expertise and practical experience in the subject under investigation (Nworie, 2011). They were chosen from reputable professional organizations (Holden & Wedman, 1993) and possessed at least ten years of dedicated practice in their respective fields (Ericsson & Charness, 1994). The identification of expert panelists for this study was based on sources that list professional organizations and experts associated with IoT Facebook Groups. The individuals were also selected using the snowball technique, relying on recommendations from professional contacts. This method ensured that only highly qualified panelists familiar with the topic under investigation were chosen. The diverse backgrounds of the experts were anticipated to offer a broader range of perspectives on the issue being studied (Nworie, 2011). The study successfully involved experts from diverse backgrounds and various social and professional levels, including IoT instructors and practitioners. The study aimed to blend theoretical understanding with practical experience by including academics and practitioners, ensuring a balanced insight (Hearnshaw et al., 2001). The diversification of expert groups facilitates the identification of significant topics that can be addressed using Fuzzy Decision Making (FDM), according to Glumac et al. (2011). It is recommended that the size of such panels ranges from 10 to 30 participants (Glumac et al., 2011; Jones & Twiss, 1978) to ensure a comprehensive representation of expertise. The panel size of 30 experts, who consented to contribute to this research, falls within the suggested range, indicating an optimal diversity for effective decision-making outcomes.

3. Data Collection

3.1 First Phase: Semi-structured Interviews to Develop the Fuzzy Delphi Instrument

A semi-structured interview was conducted with 19 experts to identify the relevant topics and tasks for teaching the Internet of Things (IoT). The experts were chosen based on their knowledge and competence in problem-solving, technology in education, IoT, Electrical and Electronics Engineering and Computing. Most of the experts had more than five years of experience in related fields and were a mix of academicians, both public and private sectors (*n*=10) and industry practitioners (*n*=9), which can help increase the study's validity. See Table 1.

Table 1 *Demographic background of experts in the first phase of the FDM*

Items	Respondent (*n*)
Field of expertise	
Problem-Solving	3
Technology in Education/ Instructional Technology	2
IoT Subject Matter Experts	18
Electrical & Electronics Engineering	3
Computing	5
Years of Experience	
Less than 5 years	7
5-10 years	5
10-15 years	2
More than 15 years	5
Affiliation	
Academician	8
Industry Practitioner	11
Total	19

After the appropriate objectives of the micro-credential course were identified, the experts were requested for some suggestions for key topics for inclusion into the micro-credential. Next, the experts were asked to "think out loud" about the authentic mini-projects, the sequence of problem-solving steps (how-to), and the problem constraints, requirements, and conditions for each mini-project.

3.1.1 First Phase: Development of the Fuzzy Delphi Instrument

The qualitative interview data with experts were coded using ATLAS.ti 8 software and then analyzed using thematic analysis (Braun & Clarke, 2006). This involved categorizing the data to identify relevant topics and authentic mini-projects. The final draft of the Fuzzy Delphi Instrument included a list of nine topics (theory) and 13 topics (practical), and 14 mini-project topics were administered to more experts using the Fuzzy Delphi method.

3.1.2 Second Phase: Distribution of the Fuzzy Delphi Instrument

The Fuzzy Delphi instrument was developed based on suggestions from a panel of 19 experts during interviews. Two experts conducted content validation to assess the comprehensiveness of the instrument, and no amendments were required. The instrument was then administered to 30 experts to determine their level of agreement with each item. The 19 experts interviewed to develop the Fuzzy Delphi instrument also participated in this phase to ensure the findings were consistent with the elements discovered. See Table 2.

Table 2 *Demographic background of experts in the second phase of the FDM*

Items	Respondent (*n*)
Field of expertise	
Problem-Solving	8
Technology in Education/ Instructional Technology	10
IoT Subject Matter Experts	23
Electrical & Electronics Engineering	6
Computing	13
TVET	
Years of Experience	
Less than 5 years	12
5-10 years	5
10-15 years	6
More than 15 years	7
Affiliation	
Academician	13
Industry Practitioner	17
Total	30

3.2 Data Analysis

The experts determined the importance of each item (topic and authentic tasks) anonymously and in isolation, without imposing ideas on each other. Each expert was required to rank each item based on the five-point Likert scales (1 = Unimportant, 2 = Of little importance, 3 = Moderately important, 4 = Important, 5 = Very Important) (Kardaras et al., 2013), which represents 5-point linguistic scale for the level of agreement. A linguistic scale similar to the Likert scale but with additional fuzzy numbers was provided to address the issue of fuzziness among the experts. See Table 3.

Table 3 *Fuzzy scale used in the study*

Likert Scale	Linguistic Variable	Fuzzy Scale
1	Unimportant	(0.0, 0.1, 0.2)
2	Of little importance	(0.0, 0.2, 0.4)
3	Moderately important	(0.2, 0.4, 0.6)
4	Important	(0.4, 0.6, 0.8)
5	Very Important	(0.0, 0.2, 0.4)

In this phase of the study, the Fuzzy Development Method (FDM) analysis was conducted by employing a triangular fuzzy number approach, accompanied by a defuzzification process to interpret the fuzzy data accurately. The condition for the triangular fuzzy number involves the threshold number (*d*). The percentage of expert consensus, which is the threshold (minimum requirement) value (d) for each item (component and element), must be less or equal to 0.2 (Cheng & Lin, 2002) and the expert consensus percentage must be equal to or more than 75.0% (Chang et al., 2011; Chu et al., 2008). If the distance between the average and the expert's evaluation data is less than the threshold value of 0.2, then all the experts are considered to have achieved a consensus (Cheng & Lin, 2002). For the defuzzification process, only one condition needs to be fulfilled; the fuzzy score (A) must be equal to or greater than the alpha-cut value of 0.5. as a threshold used to select the elements for developing the micro credential. The value of 0.5 was noted to be the median of the interval [0,1] (Tang & Wu, 2009). Based on logical reasoning, it signifies that only the elements with "sufficiently large" membership grades in a fuzzy set are included (Bodjanova, 2006; Tang & Wu, 2009).

Defuzzification involves classifying elements based on expert consensus and ranking. The fuzzy score was also analyzed using Microsoft Excel. The process involved the conversion of linguistic variables into fuzzy numbers. The outcome resulted in every response having three triangular fuzzy values: minimum value (m1), most plausible value (m2) and maximum value (m3). Thus, a triangular fuzzy number is symbolized as a triangle and contains the values of m1, m2 and m3. The m values indicate the probability of experts agreeing that IoT topics and authentic tasks are important. In defuzzification, each item was ranked to determine its level of relevance, and subsequent decisions were made regarding whether to retain or remove the item. Three criteria were applied for this purpose. Firstly, to determine whether the items were accepted, the experts were required to reach a consensus, with the difference between the average and expert evaluation data being less than or equal to the threshold value of 0.2 (Lin et al., 2023). If this condition was not met, a second round was necessary. To establish the threshold, the d-construct threshold value for each item was identified by determining the difference between each expert fuzzy number and the average fuzzy number (Lin et al., 2023). Secondly, the items were considered acceptable if the experts reached a consensus of more than 75%; otherwise, a second round needed to be conducted. Thirdly, an item with an average fuzzy number of 0.5 was accepted. Using the Fuzzy Delphi method, a framework of the topics and authentic tasks for designing an IoT micro-credential was modeled. This stage involved ranking the items based on expert consensus, with the most important topics and authentic tasks receiving the highest value.

4. Results

Thirty experts (response rate 100%) who met the inclusion criteria agreed to participate in the Fuzzy Delphi approach. Most of the experts were industrial practitioners with more than 10 years of experience in their fields of expertise. See Table 2. The results outline the key topics and authentic tasks that can help equip learners with industry-relevant competencies, fostering innovation and preparing students for modern, technology-driven workplaces aligned to the TVET system's objective.

4.1 Expert Consensus on the IoT Topics (Both Theory & Practical)

The topic element contains items to map out the content areas that can be used to develop authentic mini-projects in the micro-credential. Table 4 shows the threshold value (d), the percentage of expert consensus, the defuzzification value and the ranks for each item. Most experts agreed on the first topic with the defuzzification value of 0.709. This shows that all the experts strongly agree that the "Fundamental concepts of IoT (IoT ecosystem/architecture, function, importance, benefits, challenges, examples, advantages/disadvantages)" topic is the most important topic to develop real-world problems for the micro-credential. This was followed by Item 2, Introduction to sensors, devices/hardware capabilities, environment, and motion parameters, with the defuzzification value of 0.693, ranked second. Item 3 received a defuzzification value of 0.673. See Table 4. Experts rejected some items, which may have been considered too complex or advanced for the intended learners. Additionally, the practical relevance of certain topics might not align with the immediate goals of the micro-credential. For instance, soldering and analogue sensor usage might be viewed as less critical in IoT micro-credential development.

Table 4 *Experts' views on the theory topics in the micro-credential based on FDM*

No	Objective	Triangular Fuzzy Number Process		Defuzzification Process				Verdict	
		Threshold value (*d*)	Expert Consensus, %	mm_1	mm_2	mm_3	Threshold value (*d*)	Expert Consensus, %	Rank
1	Fundamental concepts of IoT *(IoT ecosystem/ architecture, function, importance, benefits, challenges, examples, advantages/disadv.)*	0.178	97%	0.513	0.707	0.907	0.709	ACCEPTED	1
2	Introduction to sensors, devices/hardware capabilities, environment and motion parameters	0.196	90%	0.493	0.693	0.893	0.693	ACCEPTED	2

No	Objective	Triangular Fuzzy Number Process		Defuzzification Process				Verdict	
		Threshold value (d)	Expert Consensus, %	mm_1	mm_2	mm_3	Threshold value (d)	Expert Consensus, %	Rank
3	Introduction to Programming Language (e.g. C, C++, Python basic syntax)	0.232	80%	0.473	0.673	0.873	0.673	ACCEPTED	3
4	Introduction to the realities of the IoT industry (job scope, trend, required skills of graduates, pillar of IR4.0)	0.177	93%	0.467	0.667	0.867	0.667	ACCEPTED	4
5	Basic Programming, Algorithm, Logic, Looping, Conditionals, Variables, Functions, Debugging	0.254	77%	0.453	0.653	0.853	0.653	ACCEPTED	5
6	Data processing using IoT dashboard (Use of IoT dashboard and types e.g. AdaFruit IO, Thingsboard IO)	0.254	83%	0.440	0.640	0.840	0.640	ACCEPTED	6
7	Introduction to Microcomputer / Microcontroller in IoT and basic usage and difference between Arduino, Raspberry Pi and Node MCU in programming and libraries by using GIT version control system.	0.291	30%	0.433	00.620	00.820	0.624	REJECTED	7
8	Networking and physical computing basics, Basic Electronic: Basic type of electronic parts, soldering, Basic Electrical Circuit: Serial communication, Pulse width modulation & analog to digital converse, Analog sensors - light sensor	0.212	43%	0.413	0.613	0.813	0.613	REJECTED	8
9	Introduction to mobile learning control for Android Application e.g. using Blynk IoT platform	0.234	40%	0.420	0.607	0.807	0.611	REJECTED	9

Experts have chosen item 1 until item 9 to be included in the micro-credential. The majority of the experts agreed that the first item with a defuzzification value of 0.713 is the most important to be included in the PSFC module. This was followed by Item 2, Selecting the right components for real-world IoT applications with the defuzzification value of 0.700, ranked second. Item 3 received a defuzzification value of 0.693. It was likely that the items that did not meet expert consensus were because they either exceeded the technical level expected of the target learners, didn't align closely enough with the course's primary goals, or provided insufficient depth in IoT-specific competencies that the course intended to foster.

Table 5 *Experts' views on the topics (practical) in the micro-credential based on FDM*

No	Practical Topic	Triangular Fuzzy Number Process		Defuzzification Process				Results	
		Threshold value (d)	Percentage of Expert Consensus, %	mm_1	mm_2	mm_3	*Fuzzy* Score (A)	Expert Consensus	Ranking
1	Practical of basic connectivity of IoT hardware	0.151	100%	0.513	0.713	0.913	0.713	ACCEPTED	1
2	Selecting the right components for real-world IoT applications	0.173	93%	0.500	0.700	0.900	0.700	ACCEPTED	2
3	Demonstrating the use of node/devices as environment or/and motion monitoring sensors (pH, temp, level, humidity etc.)	0.174	93%	0.493	0.693	0.893	0.693	ACCEPTED	3
4	How to do installation, configuration and integration of microcontroller using different sensors	0.169	93%	0.480	0.680	0.880	0.680	ACCEPTED	4
5	Mini projects using microcontroller focus on real IoT user cases	0.191	87%	0.480	0.680	0.880	0.680	ACCEPTED	4
6	Prepare the node / devices at the concerned area to read parameters pH, temp, level, humidity etc.) and later send to concentrator / gateway	0.183	93%	0.480	0.680	0.880	0.680	ACCEPTED	4
7	Demonstrate the use of Concentrator / Gateway as a tool for data collection and data forwarding	0.171	93%	0.480	0.680	0.880	0.680	ACCEPTED	4
8	Design and develop IoT prototype	0.199	90%	0.473	0.673	0.873	0.673	ACCEPTED	5
9	Demonstrate the use of PC and Network as tool for communication on wire / wireless ecosystem	0.193	87%	0.467	0.667	0.867	0.667	ACCEPTED	6
10	Data Collection: Build data server (simple) from cloud, data formatting/storage, designing data architecture/structure	0.235	43%	0.440	0.633	0.833	0.636	REJECTED	7
11	Data Processing: Using Spreadsheet (e.g. Excel), Statistics, Outliers, Reformatting data	0.231	30%	0.433	0.633	0.833	0.633	REJECTED	8
12	Logging data from IoT devices using IoT dashboards	0.197	47%	0.433	0.633	0.833	0.633	REJECTED	8

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No	Practical Topic	Triangular Fuzzy Number Process		Defuzzification Process				Results	
		Threshold value (*d*)	Percentage of Expert Consensus, %	mm_1	mm_2	mm_3	*Fuzzy* Score (A)	Expert Consensus	Ranking
13	Basic drag-and-drop programming	0.277	63%	0.340	0.527	0.727	0.531	REJECTED	9

4.2 Expert Consensus on the Authentic Mini Project Topics

The authentic mini projects that can be included in the micro-credential included 14 topics. The threshold value (d), the percentage of expert consensus, defuzzification value, and ranks for each item in the element based on expert consensus are presented in Table 6.

Table 6 *Experts' views on the authentic mini projects in the micro-credential based on FDM*

No	Authentic Mini Projects	Triangular Fuzzy Number Process		Defuzzification Process				Results	
		Threshold value (*d*)	Percentage of Expert Consensus %	mm_1	mm_2	mm_3	*Fuzzy* Score (A)	Expert Consensus	Ranking
1	Air Quality Monitoring	0.228	83%	0.460	0.660	0.860	0.660	**ACCEPTED**	1
2	Smart Home Security	0.206	80%	0.440	0.640	0.840	0.640	**ACCEPTED**	2
3	Water Quality Monitoring	0.265	23%	0.427	0.627	0.827	0.627	REJECTED	3
4	Disaster Monitoring System	0.238	33%	0.413	0.613	0.813	0.613	REJECTED	4
5	Smart Parking	0.251	33%	0.413	0.607	0.807	0.609	REJECTED	5
6	Smart Lighting System	0.226	40%	0.413	0.607	0.807	0.609	REJECTED	5
7	Smart Voice Assistant	0.217	37%	0.407	0.607	0.807	0.607	REJECTED	6
8	Smart Irrigation	0.214	47%	0.400	0.600	0.800	0.600	REJECTED	7
9	Smart Waste Management	0.214	47%	0.400	0.600	0.800	0.600	REJECTED	7
10	Smart Storage Device	0.242	43%	0.393	0.587	0.787	0.589	REJECTED	8
11	Weather Monitoring System	0.295	30%	0.393	0.587	0.787	0.589	REJECTED	8
12	Smart Pick-up Device	0.253	37%	0.387	0.580	0.780	0.582	REJECTED	9
13	Sensing Smart Ball	0.259	60%	0.367	0.553	0.753	0.558	REJECTED	10
14	Smart Restaurant/ Café	0.260	67%	0.353	0.540	0.740	0.544	REJECTED	11

Experts reached a consensus on accepting item 1 and item 2, rejecting the other items. The majority of experts agreed that the first item with a defuzzification value of 0.660 is the most suitable mini-project topic. This was followed by Item 2 with the defuzzification value of 0.640, which was ranked second. Air Quality Monitoring and Smart Home Security were likely accepted because they balance relevance, technical complexity, and clarity of learning outcomes. They provide foundational IoT experience, are highly applicable to current industry trends, and offer measurable, achievable outcomes suitable for students in a micro-credential course. The other items, while valuable, may have been rejected due to their complexity, niche applicability, or more challenging learning curves. See Table 6.

5. Discussion

The current study is centered on using FDM to collect expert opinions to identify relevant IoT topics (both theory and practical) and determine IoT mini-projects for an IoT micro-credential course. It is the first to model a framework for IoT micro-credential in Malaysia. Throughout the consensus building among 30 experts in the present study, the topic "Fundamental concepts of IoT (IoT ecosystem/architecture, function, importance, benefits, challenges, examples, advantages/disadvantages)" was ranked as the most relevant theoretical topic, whereas "Practical of basic connectivity of IoT hardware" was ranked the most relevant practical topic for the Malaysian IoT micro-credential curricula. Such a finding is consistent with previous studies (Abichandani et al., 2022; Gumina et al.,2023), highlighting that not only this topic is the foundation for IoT courses, but authentic tasks which allow students to solve real-world problems using IoT is the best approach to teach IoT (Abichandani et al., 2022). Based on the current findings, the highest-ranking IoT mini projects that reached expert consensus were "Air Quality Monitoring" and "Smart Home Security". Growing attention and research are focused on enhancing air quality and controlling air pollution due to the health problems caused by prolonged exposure to polluted environments (Anitha & Kumar, 2023; Varshitha et al., 2021). Besides, air quality monitoring IoT projects are one of the most popular IoT projects for beginners on online IoT communities, such as Hackster.io and *Instructables* can be built without needing heavy knowledge of signal processing or any other specific domains. Moreover, reports estimate the number of Internet of Things (IoT) devices worldwide is projected to nearly double from 15.9 billion in 2023 to over 32.1 billion IoT devices in 2030 (Vailshery, 2024). IoT is the key technology that enables smart homes. Smart home technology provides many facilities to users, like temperature monitoring, smoke detection, automatic light control, and smart locks, among others (Touqeer,2021). The key technology that enables smart homes is the Internet of Things (IoT).

The following practical topics, i.e. building data servers from the cloud, designing data architecture/structure, data processing, and logging data from IoT devices using IoT dashboards, might not have reached expert consensus for inclusion in a micro-credential curriculum as these topics may seem too specialised or technical for the intended audience of the micro-credential. Besides, practical exercises involving cloud servers, IoT dashboards and specific programming methods may not be easily accessible to all learners. Studies have shown that students prefer concise, practical and up-to-date courses tailored to their chosen career paths. Consequently, higher education institutions consider the 'unbundling' of their programs to provide only the components that align with market demands (Swinnerton et al., 2020; Varadarajan et al., 2023).

A significant impact of this study is its potential role as a benchmark for creating micro-credentials grounded in empirical evidence. The FDM, an updated version of the traditional Delphi method, seems more efficient because it does not need multiple feedback sessions, which can take a long time to gather expert opinions. Moreover, FDM is also less expensive than the traditional method, which often requires repeated surveys. This approach allows experts to share their opinions freely without being influenced by others. Additionally, FDM is effective with fewer survey responses, making achieving reliable and reasonable results easier. Although this study is valuable, it may have some limitations. For example, it does not address the measurement of information overload or the psychological disposition of the expert group. Additionally, it does not thoroughly investigate how varying levels of expertise or different communication modes between experts might influence consensus outcomes.

6. Conclusion

This study illustrates the utilization of the Fuzzy Delphi method to obtain consensus among experts for developing content and authentic tasks for the Internet of Things (IoT) curriculum. The experts accepted six out of nine potential theoretical topics and nine out of 13 practical topics. The "fundamental concepts of IoT" was ranked as the most important theoretical topic with 97% consensus, whereas the "practical of basic connectivity of IoT hardware" topic was ranked as the most important practical topic with 100% consensus. Regarding authentic tasks to design mini-projects, the experts accepted two out of nine potential theoretical topics and nine out of 13 hands-on topics. Regarding authentic tasks, experts accepted two out of 14 potential mini-project topics. The "Air Quality Monitoring" and "Smart Home Security" were ranked as the two most important authentic problems for simple IoT projects with 83% and 80% consensus, respectively. Thus, the present study has identified relevant IoT content areas and the appropriate authentic problems to design mini-projects when developing a micro-credential course on IoT using the Fuzzy Delphi approach. The subsequent phases in micro-credential

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development involve formulating suitable learning outcomes, instructional strategies, resources, and media and assessment. Subsequently, the full micro-credential course on IoT can be developed and piloted before being implemented across community colleges nationwide.

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Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of the paper.

Author Contribution

The authors confirm their contribution to the paper as follows: ***study conception and design:*** *Umawathy Techanamurthy, Zanariah Ahmad;* ***data collection:*** *Umawathy Techanamurthy, Fadhlina Ahmad;* ***analysis and interpretation of results:*** *Umawathy Techanamurthy, Ana Pataniah Salahuddin, Noorfadhilah Kahar;* ***draft manuscript preparation:*** *Umawathy Techanamurthy and Noorfadhilah Kahar. All authors reviewed the results and approved the final version of the manuscript.*

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