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DEVELOPMENT OF SUSTAINABLE COMPETENCY EVALUATION CRITERIA FOR THE BUILDING SERVICES COURSE IN THE CONSTRUCTION TECHNOLOGY PROGRAMME

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Abstract:

Education for Sustainable Development (ESD) is receiving increasing emphasis in higher education to produce graduates capable of addressing sustainability challenges holistically. Nevertheless, a scarcity persists regarding standardized, systematic, and valid assessment criteria to measure students' sustainable competencies within Construction Technology programs at Vocational Colleges. Accordingly, this study was conducted to develop sustainable competency assessment criteria for implementation within Construction Technology programs. The objective of this study is assessing the validity and reliability of sustainable competency evaluation criteria through the Fuzzy Delphi Method (FDM). The research design employs a quantitative approach utilizing a survey method, conducted among Vocational College lecturers involving ten expert panelists selected via purposive sampling. The research instrument comprises a Fuzzy Delphi questionnaire developed based on the UNESCO sustainable competency framework encompassing eight primary constructs, whereas data analysis is performed using triangular fuzzy numbers through the determination of the threshold value ($d \leq 0.2$), expert consensus percentage ($\geq 75\%$), and defuzzification value (α-cut ≥ 0.5). The developed assessment criteria were found to possess a high level of content validity and reliability, rendering them suitable for application within the context of Construction Technology programs. This study

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contributes to the development of standardized and systematic sustainable competency assessment instruments to support the implementation of ESD, while serving as a reference for higher education institutions in assessing sustainable competencies with enhanced validity, consistency, and efficacy.

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Keyword:

Sustainable Development (ESD), Construction Technology, Fuzzy Delphi Method (FDM), Vocational College

Introduction

The Malaysia Education Blueprint (MEB), introduced in 2013, concluded in 2025. Educational and training development is guided by the National Education Philosophy (NEP), which emphasizes cultivating holistic and balanced graduates to support the nation's social, economic, and political development. In an increasingly critical era of globalization, the concept of sustainable development has emerged as a new focal point across various fields, including education. The United Nations (UN), through the Sustainable Development Goals (SDGs), emphasizes the importance of SDG 4: Quality Education, which outlines the need to ensure that education fosters the values, skills, and attitudes that drive universal sustainability (Brockwell et al., 2024). Consequently, the Ministry of Education Malaysia (MOE) has formulated the Malaysian Education Plan (MEP and METP 2026–2035) and the National TVET Policy 2030, which provide strategic directions, action plans, and key performance indicators encompassing ministries, institutions, and relevant agencies within a national education direction framework that is increasingly aligned with future demands.

Aligned with the Malaysian Qualifications Framework (MQF), program development in Vocational Colleges (KV) must emphasize a balance among knowledge, skills, values, and attitudes. KV also offer education up to the diploma level for students; consequently, they must align with the principles outlined by the Malaysian Qualifications Agency (MQA). This requires KV to ensure that the vocational education system contributes to the development of balanced human capital that is proficient academically and practically while possessing noble values. Cultivating values among KV students is a complex yet crucial aspect of education. It requires a comprehensive approach that encompasses curriculum design and experiential learning. By focusing on core values, skills, emotional intelligence, and social competencies, educational institutions can contribute effectively to holistic development.

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Objective Of the Study

Assessing the validity and reliability of sustainable competency evaluation criteria through the Fuzzy Delphi Method (FDM)

Literature Review

The escalating global significance of sustainable development has driven extensive research into the concept of sustainability competency, particularly within the realm of higher education. Sustainability competency is defined as an integrated combination of knowledge, skills, values, and attitudes required for individuals to act effectively in real-world situations and contexts related to sustainability. To comprehensively examine this issue, this literature review focuses on five key dimensions: Education for Sustainable Development (ESD), building services, sustainable competency frameworks, the importance of assessing sustainability competencies, and the identification of existing research gaps.

Education for Sustainable Development (ESD)

According to Cebrián et al. (2020) and Brundiers et al. (2020), Education for Sustainable Development (ESD) is regarded as a holistic and transformative education that addresses learning content, outcomes, pedagogies, and learning environments. UNESCO explains that ESD empowers learners with the knowledge, skills, values, and attitudes required to make informed decisions and act responsibly for environmental integrity, economic viability, and social justice, for both present and future generations, while respecting cultural diversity. Education for Sustainable Development represents a transformative approach in education aimed at producing global citizens capable of shaping a sustainable global future. The growing importance of sustainable development at the global level has driven in-depth research into the concept of sustainable competencies, particularly within the field of higher education.

Building Services

The Technical and Vocational Education and Training Division (BPLTV) defines the Building Services course as being designed to provide fundamental knowledge and skills related to building services. It encompasses building service practices and regulations, water supply systems, plumbing and waste management systems, ventilation and lighting systems, air conditioning systems, electrical supply systems, gas installation systems, fire prevention systems, mechanical building systems, communication and security systems, energy efficiency, and green buildings. The selection and use of equipment and materials, alongside relevant safety aspects, will also be emphasized.

According to Abd Rahiman and Abdul Rahman (2024), implementing green technology fosters a more sustainable, healthy, and prosperous future for construction, while ensuring that the environment is preserved and protected for future generations. Integrating sustainable

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development into the Building Services course helps students learn how to design and operate energy-efficient electrical, lighting, and air conditioning systems. Knowledge of water supply and sanitation systems encourages the use of water-efficient fixtures, rainwater harvesting systems, and water recycling to prevent waste. Students also learn about building systems designed to reduce air pollution and waste generation, thereby supporting environmental sustainability. The knowledge acquired from the Building Services course contributes to sustainable urban development, energy efficiency, and climate action. Studying the Building Services course is essential for sustainable development as it produces a workforce capable of designing, installing, and maintaining building systems that are energy-efficient, resource-saving, environmentally friendly, and safe. This knowledge not only benefits the construction industry but also helps create more sustainable and high-quality buildings for society and future generations.

Sustainable Competency Framework

The United Nations Educational, Scientific and Cultural Organization (UNESCO) delineates eight core competencies deemed critical for advancing Education for Sustainable Development (ESD) across all educational tiers, particularly within higher education. These transversal competencies transcend traditional disciplinary boundaries, engaging cognitive, affective, and psychomotor domains to navigate complex sustainability challenges:

1. Systems-thinking competency: The capacity to identify, analyse, and comprehend the intricate interdependencies among components within complex socio-ecological systems.
2. Anticipatory competency: The proficiency to conceptualize, evaluate, and model multiple alternative future scenarios.
3. Normative competency: The capability to critically examine and reflect upon the underlying norms, values, and ethical principles governing human actions and policy frameworks.
4. Strategic competency: The ability to collaboratively formulate, execute, and assess innovative strategies and systemic interventions geared toward sustainability transformations at local and global scales.
5. Collaboration competency: The aptitude to work constructively with heterogeneous stakeholders possessing diverse backgrounds and interests, underpinned by active listening, empathy, and effective conflict resolution.
6. Critical thinking competency: The analytical skill to question prevailing institutional norms, assumptions, and practices while critically evaluating empirical evidence and arguments.
7. Self-awareness competency: The reflective capacity to evaluate one's personal position, values, and agency within local communities and broader societal structures.
8. Integrated problem-solving competency: The overarching meta-competency that synthesizes preceding dimensions, empowering individuals to apply holistic frameworks to complex sustainability problems spanning social, economic, environmental, and cultural dimensions.

The Importance of Assessing Sustainable Competencies

Academic programmes need to design clear and explicit learning outcomes to reflect the sustainable competencies expected to be achieved by graduates (Annelin et al., 2023). These

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learning outcomes should not be limited solely to cognitive knowledge dimensions, but should also encompass the development of values, attitudes, and behaviors that support sustainable development. To ensure the achievement of these learning outcomes, the teaching and learning process must employ transformative pedagogies that encourage students to critically evaluate existing values and assumptions, envision a more sustainable future, and actively engage in transformative actions. The assessment of sustainable competencies is vital to ensuring that higher education institutions fulfill their commitment to sustainable development (Padmanabhan, 2025).

Research Gap

According to the report issued by the Technical and Vocational Education and Training Division (BPLTV, 2026), the Building Services course has been mapped against the ESD (Education for Sustainable Development) competency evaluation. Consequently, this study focuses exclusively on the ESD competency evaluation framework. The construction of evaluation criteria is a rigorous endeavour that necessitates a systematic approach to ensure the precise measurement of the targeted constructs.

Constructing evaluation criteria requires meticulousness and a systematic approach to ensure the targeted construct is measured accurately. A critical initial step involves formulating criterion items with clear, unambiguous, and study-relevant language, utilizing a Likert scale for systematic measurement. This process is followed by expert panel evaluations to assess the content and face validity of the criteria, incorporating feedback for refinement. Despite a robust methodology for developing criteria, challenges in achieving solid validity and reliability still persist, particularly within the context of sustainable competencies. Therefore, a more systematic and quantitative approach, such as the Fuzzy Delphi Method (FDM), is necessary to guarantee content validity and expert consensus, a practice that is increasingly gaining popularity in educational research in Malaysia.

Methodology

Research Design

This study employed a quantitative developmental validation design using the Fuzzy Delphi Method (FDM) to validate the proposed sustainable competency evaluation criteria for the Building Services course in the Construction Technology Program. FDM was selected because it provides a systematic procedure for obtaining and quantifying expert consensus regarding the relevance, clarity, and suitability of proposed evaluation criteria. The method combines the structured judgment process of the conventional Delphi technique with fuzzy set theory, allowing variations in expert judgment to be represented more precisely through triangular fuzzy numbers.

The study focused on determining content-related validity, expert consensus, item acceptance, and item priority rather than establishing psychometric reliability. The proposed constructs and items were initially developed based on the sustainable competency framework and the context of the Building Services course. These items were subsequently evaluated by experts with relevant knowledge and experience in Construction Technology and related areas.

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The methodological process consisted of four main stages: development of the initial evaluation criteria, selection of the expert panel, expert evaluation using a structured questionnaire, and analysis of expert consensus using FDM. Items meeting all predetermined FDM acceptance criteria were retained, whereas items failing to meet the required criteria were considered for revision or removal.

Table 1: Summary of the Research Design

Component	Description
Research approach	Quantitative
Research purpose	Development and expert validation of sustainable competency evaluation criteria
Validation method	Fuzzy Delphi Method (FDM)
Sampling technique	Purposive sampling
Expert panel	10 experts
Data collection instrument	Structured Fuzzy Delphi questionnaire
Response scale	5-point Likert scale converted into triangular fuzzy numbers
Main analysis	Threshold value, expert consensus percentage, defuzzification value, and item ranking
Main outcome	Expert-validated evaluation criteria based on FDM acceptance requirements

The use of FDM was therefore intended to establish whether the proposed evaluation criteria achieved an acceptable level of agreement among experts before further empirical testing or implementation.

Participants and Expert Sampling

Participants in this study consisted of 10 experts selected through purposive sampling. Purposive sampling was considered appropriate because FDM requires individuals with relevant expertise and experience in the area being evaluated, rather than respondents selected randomly from a general population.

Previous FDM studies indicate that an expert panel of approximately 10 to 15 participants can be sufficient when the selected individuals have relevant professional or academic expertise (Yaakub et al., 2020; Yin et al., 2024). Accordingly, ten experts were selected for the present study.

The expert selection process focused on individuals with relevant involvement in Construction Technology, Building Services, vocational education, industry practice, or related stakeholder roles. Their professional knowledge enabled them to evaluate whether the proposed criteria were relevant and appropriate for assessing sustainable competencies within the Building Services course.

Table 2: Expert Selection Framework

Selection Aspect	Requirement in the Present Study
Sampling approach	Purposive sampling
Number of experts	10
Primary field	Construction Technology and related areas
Relevant context	Building Services, vocational education, industry practice, or related stakeholder involvement
Role of experts	Evaluate relevance, suitability, clarity, and importance of proposed competency criteria
Purpose of selection	Establish expert consensus and content-related validation of the proposed items

Detailed demographic information such as academic qualifications, professional positions, years of experience, and areas of specialisation should be reported in the Results section to demonstrate the credibility and suitability of the expert panel.

Research Instrument

Data were collected using a structured Fuzzy Delphi questionnaire developed from the initial sustainable competency constructs and proposed evaluation items. The questionnaire was designed to allow experts to evaluate the suitability of each criterion within the context of the Building Services course. Each item was evaluated using a 5-point Likert scale, ranging from 1 (*Strongly Disagree*) to 5 (*Strongly Agree*). The conventional Likert scores were subsequently transformed into triangular fuzzy numbers for FDM analysis. The mapping of the Likert scale to triangular fuzzy numbers is presented in Table 3.

Table 3: Mapping of the Likert Scale to Triangular Fuzzy Numbers

Likert Scale	Evaluation	Triangular Fuzzy Number
1	Strongly Disagree	(0.00, 0.00, 0.20)
2	Disagree	(0.00, 0.20, 0.40)
3	Neutral	(0.20, 0.40, 0.60)
4	Agree	(0.40, 0.60, 0.80)
5	Strongly Agree	(0.60, 0.80, 1.00)

Source: Ridhuan et al. (2020).

A triangular fuzzy number is represented by three values, m_1, m_2, and m_3, corresponding respectively to the minimum, most plausible, and maximum values of an expert judgment. These values range from 0 to 1 and enable the uncertainty and variation inherent in expert responses to be incorporated into the consensus analysis.

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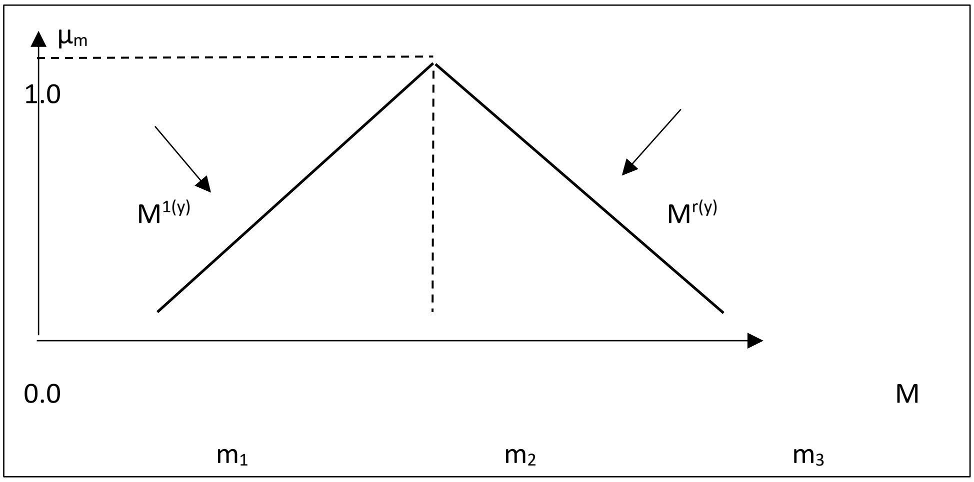

Figure 1. Representation of a Triangular Fuzzy Number (m_1, m_2, m_3)
Source: Ridhuan and Nurtulrabihah (2020).

Data Collection Procedure

Data were collected directly from the selected expert panel using the structured Fuzzy Delphi questionnaire. The questionnaire was administered face-to-face, allowing the researcher to provide clarification regarding the purpose of the evaluation and the meaning of the proposed criteria when necessary. Experts were asked to evaluate each proposed item according to its suitability for assessing sustainable competency within the Building Services course. Their responses were recorded using the five-point Likert scale and subsequently converted into triangular fuzzy numbers for analysis. Participation was based on expert judgement, and the collected responses were used solely to determine the level of consensus regarding the proposed evaluation criteria.

Item Acceptance Criteria

To improve methodological transparency, an item was retained only when it satisfied the predetermined FDM criteria presented in Table 4.

Table 4: Fuzzy Delphi Item Acceptance Criteria

Criterion	Acceptance Requirement	Interpretation
Threshold value, *d*	≤ 0.20	Acceptable distance among expert judgments
Expert consensus	$\geq 75\%$	Sufficient agreement among experts
Defuzzification value, *A*	≥ 0.50	Item achieves acceptable level of expert acceptance
Final decision	Must satisfy all criteria	Item retained
Item priority	Based on defuzzification value	Higher value indicates higher priority

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An item was therefore retained only when it met all three major FDM requirements. Items failing to satisfy one or more criteria were identified for reconsideration, revision, or removal.

Ranking of Accepted Items

After determining item acceptance, the defuzzification values were used to establish the relative priority of the retained criteria. Items with higher defuzzification values were assigned higher rankings, indicating stronger endorsement by the expert panel. Where two or more items obtained identical defuzzification values, the items could be reported as sharing the same ranking unless an additional predetermined ranking criterion was applied.

The ranking procedure was intended to identify which sustainable competency criteria were regarded by experts as particularly important within the Building Services course. However, ranking should not be interpreted as evidence of psychometric reliability or predictive validity.

Summary of the Fuzzy Delphi Analysis Process

The complete FDM procedure used in the study is summarised in Table 5.

Table 5: Stages of the Fuzzy Delphi Analysis

Stage	Procedure	Output
1	Experts evaluate each item using a 5-point Likert scale	Expert ratings
2	Likert scores are converted into triangular fuzzy numbers	Fuzzy values (m_1, m_2, m_3)
3	Expert fuzzy values are aggregated	Group fuzzy value
4	Threshold value (d) is calculated	Degree of expert agreement
5	Expert consensus percentage is calculated	Percentage agreement
6	Defuzzification value (A) is calculated	Crisp item score
7	FDM acceptance criteria are applied	Accepted, revised, or rejected item
8	Accepted items are ranked according to defuzzification values	Final item priority

Overall, the Fuzzy Delphi Method provided a systematic mechanism for determining whether the proposed sustainable competency evaluation criteria achieved sufficient content-related validity and expert consensus. The present validation phase should therefore be interpreted as an expert-validation stage. Further field testing with the intended student population would be required before broader claims concerning psychometric reliability, construct validity, or standardisation of the assessment criteria can be established.

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Finding

Collaboration Competency Items

The expert evaluation focused on eight proposed items under the Collaboration Competency construct. As presented in Table 6, the items represent key aspects of sustainable collaboration, including active participation in group discussions, consideration of diverse perspectives, ethical communication, mutual support, responsibility, flexibility in group roles, inclusive decision-making, and constructive conflict resolution. The expert panel subsequently evaluated these items using the Fuzzy Delphi Method (FDM).

Table 6: Collaboration Competency Items

No.	Collaboration Competency Items
1	Students actively engage in group discussions by considering social, economic, and environmental impacts to achieve common goals.
2	Students put forward proposals while considering diverse perspectives, including sustainability and community well-being.
3	Students communicate clearly and ethically in sharing information related to sustainability issues and social responsibility.
4	Students demonstrate mutual support within groups by considering shared interests and long-term well-being.
5	Students fulfil responsibilities by ensuring that group work outcomes do not cause negative impacts on the environment or society.
6	Students adapt their roles flexibly to support sustainable and inclusive solutions.
7	Students value and integrate diverse viewpoints, including aspects of social justice and sustainability, in decision-making.
8	Students resolve conflicts constructively by considering long-term implications for humanity and the environment.

Threshold Values and Expert Consensus

Table 7 presents the threshold values (*d*) obtained from the evaluation of the ten experts for each Collaboration Competency item. The individual threshold values were used to determine the level of agreement between each expert and the overall expert group.

Table 7: Threshold Values for the Collaboration Competency Items

Item	E1	E2	E3	E4	E5	E6	E7	E8	E9	E10
K1	0.020	0.020	0.180	0.180	0.220	0.020	0.020	0.180	0.020	0.220
K2	0.020	0.020	0.180	0.180	0.220	0.020	0.020	0.180	0.020	0.220
K3	0.020	0.020	0.180	0.180	0.220	0.020	0.020	0.180	0.020	0.220
K4	0.020	0.020	0.180	0.180	0.220	0.020	0.020	0.180	0.020	0.220
K5	0.020	0.020	0.180	0.180	0.220	0.020	0.020	0.180	0.020	0.220
K6	0.160	0.160	0.040	0.240	0.160	0.040	0.040	0.240	0.040	0.160

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K7	0.000	0.000	0.200	0.000	0.200	0.000	0.000	0.200	0.000	0.200
K8	0.410	0.110	0.090	0.090	0.110	0.090	0.090	0.290	0.090	0.110

The summary of the FDM analysis is presented in Table 4. The threshold values for the eight items ranged from 0.080 to 0.148, while the overall threshold value for the Collaboration Competency construct was 0.112. These values were below the established threshold of 0.20, indicating a satisfactory level of agreement among the expert panel.

Table 8: Summary of Fuzzy Delphi Analysis for Collaboration Competency

Statistics	**K1**	**K2**	**K3**	**K4**	**K5**	**K6**	**K7**	**K8**
Threshold value (*d*)	0.108	0.108	0.108	0.108	0.108	0.128	0.080	0.148
Construct threshold value (*d*)	0.112							
Expert consensus (%)	80	80	80	80	80	80	80	80
Average expert consensus (%)	**80**							
Defuzzification value	0.620	0.620	0.620	0.620	0.620	0.560	0.600	0.510
Ranking	1	1	1	1	1	7	6	8
Decision	Accepted	Accepted	Accepted	Accepted	Accepted	Accepted	Accepted	Accepted

As shown in Table 8, all eight Collaboration Competency items achieved threshold values below 0.20. The overall construct threshold value of 0.112 also fulfilled the FDM acceptance criterion. According to Cheng and Lin (2002), a threshold value below 0.20 indicates an acceptable level of agreement among experts. The reported expert consensus for all eight items was 80%, with an overall average consensus of 80%. This exceeded the minimum FDM requirement of 75%, indicating that the expert panel generally agreed on the suitability of the proposed Collaboration Competency items.

The defuzzification values ranged from 0.510 to 0.620, with all items exceeding the minimum α-cut value of 0.50. Items K1 to K5 obtained the highest defuzzification value of 0.620 and were jointly ranked first. Item K7 obtained a value of 0.600, followed by K6 with 0.560, while K8 obtained the lowest value of 0.510. Despite differences in ranking, all items exceeded the minimum acceptance value and were therefore retained.

Overall, the findings indicate that the eight proposed Collaboration Competency items achieved the required FDM criteria in terms of threshold value, reported expert consensus, and defuzzification value. The expert panel therefore supported the inclusion of these items as evaluation criteria for Collaboration Competency within the Building Services course in the Construction Technology Program.

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Conclusion

This study developed and validated a set of Collaboration Competency evaluation criteria for the Building Services course in the Construction Technology Program using the Fuzzy Delphi Method. The findings showed that all proposed items met the required FDM acceptance criteria based on threshold values, expert consensus, and defuzzification values. These results indicate that the criteria are considered relevant and suitable by the expert panel for assessing collaboration-related sustainable competencies within the course.

The validated criteria may serve as a practical reference for lecturers in planning teaching strategies, learning activities, and assessment tasks that incorporate sustainability-related collaboration skills. They may also support the review of program learning outcomes by helping to ensure that elements such as teamwork, ethical communication, shared responsibility, inclusive decision-making, and consideration of social and environmental impacts are explicitly addressed in the curriculum.

However, the criteria should be regarded as a preliminary expert-validated framework rather than a fully standardised assessment instrument. Further studies are required to test the criteria with actual students and across different Vocational Colleges. Future research should examine psychometric reliability, construct validity, usability, and consistency of assessment before broader implementation is considered.

It is also recommended that lecturers receive appropriate training on integrating Education for Sustainable Development (ESD) into teaching, learning, and assessment. With further empirical validation, the proposed criteria have the potential to contribute to a more systematic approach for assessing sustainable competencies in Construction Technology e

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The authors confirm contribution to the paper as follows: study conception, project administration and supervision: Nurfirdawati Muhamad Hanafi; literature review, data collection, analysis, interpretation of results, validation and draft manuscript: Alwani Adnan and Fatin Syahira Othman. All authors reviewed the results and approved the final version of the manuscript

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