

Expert Consensus Validation of an Augmented Reality-Integrated Pedagogical Framework for Food Preparation and Production in Malaysian TVET: A Fuzzy Delphi Study

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ABSTRACT

Context: Augmented reality (AR) has been progressively considered as a digital instrument to enhance visualisation, engagement, and procedural comprehension in education. Nonetheless, in technical and vocational education and training (TVET), especially in Food Preparation and Production, the integration of augmented reality (AR) is inadequately embedded in established pedagogical frameworks. In competency-based vocational settings, instructional design must facilitate procedural ability, supervised practice, authentic task performance, and conformity with professional norms. This study intended to validate the pedagogical principles behind an augmented reality-integrated teaching framework for Food Preparation and Production in Malaysian Technical and Vocational Education and Training (TVET).

Approach: A quantitative expert consensus approach that uses the Fuzzy Delphi Method was implemented. Eleven experts from three fields Food Preparation and Production, module development, and educational technology, were chosen through purposive sampling. The instrument was created through a literature study, document analysis, and needs assessment, and was subsequently evaluated by three experts before implementation. Two constructs were assessed: AR-integrated instructional strategies and AR-integrated teaching activities. Data were analysed using threshold values, expert consensus percentages, and defuzzification techniques. Items were preserved based on the established Fuzzy Delphi criteria: threshold value $d < 0.2$, expert consensus $\geq 75\%$, and defuzzification value > 0.5 .

Findings: The results revealed significant and homogeneous expert agreement across all 14 items. The threshold values for the instructional strategies construct varied from 0.01718 to 0.02672, yielding an overall construct score of 0.02263. Defuzzification values varied between 0.93636 and 0.98182, with all items achieving complete expert consensus.

In the teaching activities construct, threshold values varied from 0.01718 to 0.04008, and defuzzification values ranged from 0.93636 to 0.98182, with all items reflecting a unanimous expert consensus of 100%. All items met the established Fuzzy Delphi criteria and were preserved. The results demonstrate that experts strongly supported both constructs as pedagogically suitable for incorporating augmented reality into competency-based culinary education.

Conclusion: The study contributes to VET research by validating pedagogical constructs for AR-integrated teaching in a competency-based culinary vocational context. The findings indicate that AR should be positioned as a scaffold for demonstration, guided practice, procedural clarity, feedback, and authentic task performance, not as a technological novelty. The validated constructs offer a defensible basis for subsequent module development and pedagogical suitability research in culinary TVET and may inform wider international discussions on how digital technologies can be aligned with occupationally oriented pedagogy.

Keywords: Vocational Education and Training, Educational technology, Instructional design, Learning activities, Competency based training

INTRODUCTION

Digital technologies are increasingly entering vocational classrooms, workshops, laboratories, and practice-based learning environments. Within technical and vocational education and training (TVET), however, the value of technology depends on whether it strengthens occupational competence, task performance, and pedagogical coherence. This distinction is important because vocational learning is not limited to conceptual understanding. It also involves the development of procedural accuracy, material judgement, safety awareness, timing, workplace habits, and the capacity to perform tasks according to explicit standards. For this reason, research on educational technology in TVET should be embedded in vocational pedagogy rather than framed only as technology adoption.

There has been a growing interest in educational research regarding augmented reality (AR) due to its ability to superimpose digital information onto real-world environments, thereby improving engagement and procedural comprehension [1]. In recent years, AR has been widely explored in science, engineering, and medical education, where it supports spatial visualisation and simulation-based learning. Nonetheless, in Technical and Vocational Education and Training (TVET), especially in the culinary arts, the pedagogical framework for augmented reality integration is rather underdeveloped [2, 3].

Food Preparation and Production provides a particularly relevant context for examining this issue. In culinary vocational education, learners must coordinate ingredients, tools, equipment, temperature, timing, sensory judgement, cleanliness, safety, teamwork, and presentation quality. These competencies are developed through demonstration, imitation, guided practice, repeated performance, feedback, and reflection. Traditional culinary instruction has often been associated with master-apprentice pedagogy, in which the teacher demonstrates and learners reproduce procedures [4, 5]. While this approach remains valuable for procedural skill acquisition and professional socialisation, contemporary TVET also requires more structured, learner-centred, and technology-supported pedagogies that maintain the authenticity of practical learning.

Against this background, the Malaysian Food Preparation and Production context is used in this study as a sector-specific example of competency-based TVET. In Malaysia, Technical and Vocational Education and Training (TVET) is structured to prepare learners with occupationally relevant knowledge, practical skills, and work-related competencies required by specific industry sectors. Within the school-based vocational pathway, the Upper Secondary Vocational Program (PVMA) provides vocational subjects at the upper secondary level, including Food Preparation and Production. This subject is competency-based in nature because learners are expected to demonstrate procedural accuracy, safe work practices, appropriate use of tools and equipment, and the ability to complete food production tasks according to specified performance standards. Teaching and learning in this context are therefore commonly organised around practical tasks, teacher demonstration, guided practice, and performance-based assessment. For an international readership, the Malaysian context examined in this study should be understood not merely as a local educational setting, but as an example of school-based vocational training where digital technology must be aligned with competency standards, occupational procedures, and authentic practical instruction.

Existing studies on AR in education often focus on student engagement, pedagogical suitability, motivation, or learning outcomes [2, 6]. Fewer studies examine the expert validation of pedagogical constructs that guide AR integration in a specific vocational domain. This gap is significant because TVET requires strong alignment between instructional design and the practical requirements of the occupation. In culinary education, AR should therefore be justified not by novelty, but by its capacity to support demonstration, sequencing, guided practice, feedback, and authentic task performance.

Accordingly, this study was designed as an expert consensus study, not as a programme evaluation or political analysis. Its purpose was to validate and prioritise pedagogical constructs for AR-integrated teaching in Food Preparation and Production using the Fuzzy Delphi Method. The study is guided by the following research questions:

- RQ1: What level of expert consensus is obtained for AR-integrated instructional strategies in a competency-based Food Preparation and Production TVET context?
- RQ2: What level of expert consensus is obtained for AR-integrated teaching activities in a competency-based Food Preparation and Production TVET context?
- RQ3: Which AR-integrated pedagogical items are prioritised by experts for inclusion in the proposed framework?

By answering these questions, the study contributes to international VET research by showing how emerging educational technologies can be pedagogically validated within a specific occupational learning context before they are translated into teaching modules or classroom interventions.

LITERATURE REVIEW

In Technical and Vocational Education and Training (TVET), effective classroom instruction is closely associated with the development of vocational competence through structured, practice-based, and performance-oriented learning. This is particularly evident in Food Preparation and Production, where learners are expected to demonstrate procedural accuracy, task sequencing, time management, safety awareness, and authentic task performance in practical settings. Culinary education has historically been influenced by a master-apprentice tradition, in which learning is often organised around teacher demonstration, modelling, and learner imitation. Although this tradition remains important for practical skill development, contemporary vocational pedagogy increasingly emphasises the need for learner-centred, systematically structured, and pedagogically coherent approaches that support competence development.

From this perspective, Augmented Reality (AR) should be regarded not solely as a technological advancement, but as an educational support instrument that can improve visualisation, guided practice, procedural comprehension, and task-oriented learning. This literature review, therefore examines two interconnected components that are central to AR-integrated culinary TVET: instructional strategies and teaching activities. These components are discussed to show how pedagogical structure, rather than technological affordance alone, can support the design of AR-integrated instruction in Food Preparation and Production.

Global viewpoints on vocational education and skills Enhancement

The acquisition of isolated technical skills is not the sole focus of vocational learning; international VET scholarship underscores this important point. The integration of professional identity, occupational judgement, attitudes, skills, and knowledge within practice-oriented learning environments is necessary. Sauli et al. [7]; Schaap et al. [8] argues that in both school-based and workplace-based learning situations, vocational learners must combine their knowledge, abilities, and attitudes while creating a professional identity. Additionally, Al-Jamea & Shatnawi [9]; Mark [10] mentioned that learning outcomes frameworks in vocational education and training underscore the knowledge, comprehension, and skills learners are supposed to acquire, while enhancing coherence across curriculum, assessment, and labour market demands.

These viewpoints are essential for Food Preparation and Production, as culinary proficiency necessitates procedural precision, adherence to safety protocols, sensory evaluation, timing, and execution in accordance with professional standards[11]. Consequently, the incorporation of augmented reality in culinary technical and vocational education and training should not be validated solely by participation or technological innovation. It should be evaluated on its educational contribution to vocational proficiency, supervised practice, genuine task execution, and assessment coherence[12].

Augmented reality and vocational pedagogy

Within vocational education, the significance of AR lies less in its technical capacity to overlay digital information and more in its potential to support procedural visibility, guided practice, and task-based learning. This is particularly relevant in practice-intensive domains where learners must connect visual cues, embodied action, and occupational standard [1]. In education, this feature is often associated with improved visualisation, engagement, and access to complex phenomena. In TVET, the relevance of AR is more specific. Vocational

learning requires learners to connect conceptual knowledge with embodied practice, tools, workplace materials, and performance standards. Therefore, AR is pedagogically meaningful only when it supports the development of occupational competence. Bacca et al. [2] emphasised the need for careful design frameworks when AR is used in vocational education. This argument is important because technological affordances alone do not guarantee meaningful learning. If AR is introduced without pedagogical sequencing, teacher mediation, and task alignment, it may function merely as visual novelty. Conversely, when AR is integrated into demonstration, practice, feedback, and reflection, it can operate as a scaffold that helps learners interpret procedures and quality indicators. This study adopts the latter position by treating AR as a component of vocational instructional design.

Food Preparation and Production as competency-based vocational learning

Food Preparation and Production is a practice-based vocational field in which learners are expected to perform tasks with accuracy, safety, timing, and quality. Practical culinary lessons require students to manage multiple forms of knowledge simultaneously: ingredients, measurements, equipment, techniques, sequencing, sensory cues, hygiene, and presentation standards. Such learning cannot be reduced to theoretical explanation. It requires demonstration, repeated practice, feedback, and judgement in authentic or near-authentic settings. The master-apprentice tradition remains influential in culinary education because it reflects the practical and relational nature of skill formation [4, 5]. However, recent scholars have also problematised an overreliance on demonstration and imitation alone. Culinary education increasingly needs approaches that encourage student agency, reflection, collaboration, and flexible problem solving while still preserving the discipline-specific importance of teacher guidance and procedural accuracy. This creates a need for instructional strategies that can connect teacher demonstration with learner-centred activity and structured competence development.

Instructional strategies for AR-integrated culinary TVET

Instructional strategies refer to the overall pedagogical approaches used to organise teaching, guide learning, and support competence development. In TVET, strategies such as guided demonstration, problem-based learning, project-based learning, and scaffolded practice are appropriate since they engage learners as active participants in vocational tasks. Rafiq et al. [13] argued that technology-supported vocational learning can enhance engagement when it is connected to active learning conditions. Similarly, project-based and learner-centred approaches in vocational contexts are valuable when they are aligned with authentic tasks and clear performance expectations. In culinary education, instructional strategies must also respond to the complexity of practical lessons. Students often need to interpret teacher demonstrations while managing tools, ingredients, time, and sensory cues. Woodhouse & Rodgers [5] showed that digital resources can support culinary learning but do not replace the role of the chef-educator. Saem & Kyun [14], similarly reported that digital and flipped approaches in cooking practice require teacher demonstration and systematic instructional design to help students interpret procedures. These studies indicate that AR-supported strategies should not remove the teacher from the learning process. Instead, AR should strengthen the teacher's capacity to show processes clearly, sequence tasks, prompt attention to critical features, and provide timely feedback. From this perspective, AR-integrated instructional strategies should be evaluated according to their pedagogical fit with vocational competence development. The central question is whether AR can help teachers structure practical learning more effectively, not whether AR is visually impressive. This distinction directly supports the present study's focus on expert consensus regarding the suitability of AR-integrated strategies for Food Preparation and Production teaching.

Teaching activities for AR-integrated culinary TVET

Teaching activities are the enacted forms of instructional strategies. In Food Preparation and Production, activities are often organised around recipes, demonstrations, practice tasks, peer interaction, safety routines, and performance evaluation. Recipe-based activities can be pedagogically useful when each recipe is connected to learning objectives, ingredients, equipment, preparation methods, safety requirements, and quality criteria [15]. Task analysis in culinary-related teaching also suggests that complex cooking processes are easier to learn when broken into sequential steps supported by demonstrations, repeated practice, and visual aids [16].

AR can support these activities by visualising processes that are difficult to observe directly, such as internal changes in food structure, ingredient transformation, or critical texture indicators. It can also provide step-by-step prompts during practice, reinforce teacher explanations, and support reflection after task completion. Chen et al. [17] found that multimedia-supported dessert instruction could improve learning outcomes when technology was embedded within the task design. In a similar way, AR-integrated activities in culinary TVET should be designed as supports for practical learning rather than as separate media experiences. Therefore the effective use of AR in Food Preparation and Production depends on the coherence between activity design, teacher guidance, and vocational performance requirements. Demonstration, recipe-based training, interactive practice, peer learning, and reflection remain central. AR becomes educationally meaningful when it strengthens these activities by improving procedural visibility, learner attention, and feedback.

Expert consensus as pedagogical validation

Before a teaching framework is implemented, its underlying constructs should be examined for relevance and representativeness. Expert consensus methods are suitable for this purpose because they allow researchers to determine whether proposed components are considered appropriate by people with relevant professional knowledge. The Delphi method has been widely used for structured expert judgement [18, 19, 20]. The Fuzzy Delphi Method extends this logic by combining expert judgement with fuzzy set theory, allowing linguistic responses to be converted into numerical values while preserving uncertainty in expert opinion [21].

FDM is particularly suitable for pedagogical validation because instructional constructs are often interpretive rather than directly measurable at the design stage. It allows expert agreement to be assessed using threshold values, consensus percentages, and defuzzification scores. In the present study, FDM was used to validate two pedagogical constructs: AR-integrated instructional strategies and AR-integrated teaching activities. This method supports transparent decision making about which items should be retained in the proposed framework.

METHODOLOGY

This study applied a quantitative expert consensus approach through the Fuzzy Delphi Method (FDM) to validate a pedagogical construct for a food preparation and production vocational teaching framework integrated with Augmented Reality (AR). FDM was chosen to achieve expert consensus regarding the suitability of AR-supported instructional strategy and teaching activities for competency-based food preparation and production education. This technique is appropriate for research involving expert opinion as it integrates linguistic expert judgements into quantifiable fuzzy values, enabling systematic consensus determination. In comparison to the traditional Delphi technique, FDM is more efficient as it minimises the need for many questionnaire rounds, optimises time and resources, and allows experts to present cohesive perspectives within a systematic evaluation framework [22, 23].

Instrument Development

This study's design of the Fuzzy Delphi instrument had three primary stages. Initially, questionnaire items were generated by a review of relevant literature, document analysis, and insights obtained from the needs assessment phase. This process allowed the identification and enhancement of constructs and items pertinent to AR-integrated instructional strategy and teaching activities in the competency-based food preparation and production subject [24]. First, an initial pool of items was generated from three sources: relevant literature on vocational pedagogy, augmented reality in education, and culinary teaching; document analysis of competency-based Food Preparation and Production materials; and findings from the preliminary needs analysis involving vocational teachers. The literature studies shaped the pedagogical framework of the instrument, specifically highlighting teacher-driven demonstration, scaffolded practice, active learning, feedback, and competency-based training. The document analysis confirmed that the proposed items conformed to the practical requirements of Food Preparation and Production, encompassing work procedures, performance standards, safety practices, and task-oriented learning. The needs analysis facilitated the identification of pedagogical challenges and practical classroom necessities to be addressed when using AR in culinary vocational education.

Next, the initial items were categorised into two primary constructs: AR-integrated instructional strategies and AR-integrated teaching activities. The items about the instructional strategies construct emphasised the primary pedagogical methodologies employed to facilitate competency-based culinary education, including project-based learning, problem-based learning, teacher-guided demonstrations, collaborative learning, procedural scaffolding, feedback, and reflection. Elements within the teaching activities framework emphasised the practical implementation of strategies, encompassing AR-assisted demonstrations, recipe-driven practical tasks, procedural videos, supervised hands-on practice, interactive visual resources, inquiry, corrective feedback, and post-activity reflection.

Lastly, the draft questionnaire was next validated by three experts to confirm its clarity, relevance, and conformity with the intended constructions before advancing to the Fuzzy Delphi phase[25]. The experts were selected for their relevance to the study domains, specifically vocational culinary education, instructional design, and educational technology. This assessment aimed to assess the clarity, relevance, phrasing, construct alignment, and appropriateness of the questionnaire items, rather than to produce Fuzzy Delphi data. The experts were requested to pinpoint ambiguous phrasing, redundant elements, unsuitable terminology, and discrepancies between items and constructs. Subsequent revisions were executed in accordance with their comments before the administration of the final instrument to the Fuzzy Delphi panel. The three validation experts were set apart from the eleven experts involved in the Fuzzy Delphi analysis. This separation was implemented to reduce potential bias and to guarantee that the instrument initially underwent content and linguistic improvement before expert consensus evaluation. The final instrument comprised 14 items divided into two constructs: seven items of AR-integrated instructional strategies and seven items related to AR-integrated teaching activities.

Participants

A total of 11 experts were chosen via purposive sampling. This figure is considered suitable as FDM studies typically necessitate a minimum of 10 experts to achieve satisfactory consistency and homogeneity in expert assessment [26, 27]. The expert group comprised specialists in culinary arts vocational education, instructional design, and educational technology. The selected disciplines aimed to examine the constructs from the viewpoints of vocational subject knowledge, instructional design, and technological integration. An expert panel was formed based on certain selection criteria to assure the suitability of participants for the study. According to Jamil et al. [28]; Mokhtar & Yasin [29] experts were required to have a minimum of five years of experience, a clearly defined specialisation in the relevant field, and current involvement in teaching or management-related responsibilities.

They were also expected to possess suitable academic qualifications and professional experience aligned with their area of expertise. This selection criterion aligns with Berliner [30] statement that expertise originates through significant field experience, and with Gambatese et al. [31], who highlighted the relevance of academic and professional qualifications in the selection of experts. The experts participating are presented in Table 1:

Table 1: Composition of the Fuzzy Delphi Expert Panel

Expert	Field of Specialisation	Current Role	Professional Experience (Years)
1	Food Preparation and Production	Senior Subject Instructor	15
2	Food Preparation and Production	Subject Teacher	9
3	Food Preparation and Production	University Subject Lecturer	10
4	Food Preparation and Production	University Subject Lecturer	7

5	Food Preparation and Production	Private College Subject Lecturer	5
6	Food Preparation and Production	Private College Subject Lecturer	20
7	Instructional Module Design	Institute of Teacher Education Lecturer	5
8	Instructional Module Design	Institute of Teacher Education Lecturer	7
9	Educational Technology	Advanced Technology Training Centre Lecturer	5
10	Educational Technology	National Leadership Training Institute Officer (IAB)	10
11	Educational Technology	Institute of Teacher Education Lecturer	7

Data collection and analysis

Data were gathered on a seven-point linguistic scale, ranging from strongly disagree to strongly agree. Each response category was transformed into a triangular fuzzy number to quantitatively represent expert assessment while maintaining the uncertainty associated with linguistic responses. The seven-point scale was chosen as it enabled experts to articulate varying degrees of agreement with adequate sensitivity, suitable for assessing educational elements requiring professional judgement. The Fuzzy Delphi analysis comprised four primary methods. Initially, the verbal responses of each expert were transformed into a triangular fuzzy number denoted as (m_1, m_2, m_3) , where m_1 denotes the minimal value, m_2 denotes the most probable value, and m_3 denotes the uppermost value. Second, the fuzzy values were aggregated to obtain the group response for each item. Third, the threshold value (d) was calculated to determine the distance between expert responses and the group fuzzy value. A threshold value of $d \leq 0.2$ was used to indicate acceptable expert consensus. Fourth, defuzzification was conducted to convert the fuzzy value into a single crisp score (A), which was used to determine item priority and ranking.

Three criteria were utilised to find out the retention of each item: the threshold value must be $d \leq 0.2$, the expert consensus percentage must be no less than 75%, and the defuzzification value is required to exceed 0.5. The expert consensus percentage was determined by calculating the ratio of experts whose individual threshold value for an item satisfied the requirement of $d \leq 0.2$. The formula applied was:

$$\text{Expert consensus percentage} = \frac{\text{Number of experts with } d \leq 0.2}{\text{Total number of experts}} \times 100$$

The percentage of expert consensus was calculated by dividing the number of experts whose responses met the threshold criterion ($d \leq 0.2$) by the total number of experts and multiplying the result by 100. In this study, a consensus value of 100% indicates that all 11 experts' responses were within the acceptable threshold range. It does not indicate identical scoring, but rather sufficient convergence of expert judgement according to the Fuzzy Delphi criteria.

The retained items were then prioritised based on their defuzzification ratings. Items with elevated defuzzification scores were regarded as of greater expert priority within the proposed AR-integrated pedagogical framework.

Each response category was converted into a triangular fuzzy number to represent expert judgement quantitatively while preserving the uncertainty associated with linguistic responses. The scale used in this study is shown in Table 2.

Table 2:7 Point Linguistic Scale and Triangular Fuzzy Numbers

Scale	Linguistic Variable	Triangular Fuzzy Number
1	Strongly Disagree	(0.0, 0.0, 0.1)
2	Disagree	(0.0, 0.1, 0.3)
3	Slightly Disagree	(0.1, 0.3, 0.5)
4	Neither Agree nor Disagree	(0.3, 0.5, 0.7)
5	Slightly Agree	(0.5, 0.7, 0.9)
6	Agree	(0.7, 0.9, 1.0)
7	Strongly Agree	(0.9, 1.0, 1.0)

Adapted from Mohd Ridhuan & Nurul Rabihah [32]

This study employed eight systematic steps to validate the questionnaire items related to AR-integrated instructional strategies and teaching activities before finalising the instrument. To make the validation process transparent, the overall Fuzzy Delphi procedure used in this study is summarised in Table 3.

Table 3. Fuzzy Delphi procedures used in the study

The procedures in Table 3 show the full sequence from item development to final item ranking. The first two steps addressed instrument development and refinement, while the remaining steps addressed expert consensus analysis using the Fuzzy Delphi Method.

Step	Procedure	Description
1	Development of initial items	Items were generated from literature review, document analysis, and preliminary needs analysis.
2	Expert validation of instrument	Three validation experts reviewed the draft instrument for clarity, relevance, wording, and construct alignment.
3	Formation of FDM expert panel	Eleven experts from Food Preparation and Production, instructional module design, and educational technology were selected through purposive sampling.
4	Collection of expert responses	Experts rated each item using a seven-point linguistic scale ranging from strongly disagree to strongly agree.
5	Conversion into fuzzy values	Linguistic responses were converted into triangular fuzzy numbers (m_1 , m_2 , m_3).
6	Calculation of threshold value	The threshold value (d) was calculated to determine expert agreement. Items with ($d \leq 0.2$) were considered acceptable.
7	Calculation of expert consensus percentage	Consensus percentage was calculated based on the proportion of experts whose responses met the threshold criterion. A value of 75% or above was accepted.

8	Defuzzification ranking	and	Defuzzification values (A) were calculated. Items with ($A > 0.5$) were retained and ranked according to priority.
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FINDINGS

In interpreting the results, the expert consensus percentage should be understood as the proportion of experts whose responses met the accepted Fuzzy Delphi threshold criterion. Therefore, a consensus value of 100% indicates that all experts' responses for the item were within the acceptable threshold range. It does not imply that all experts provided identical ratings, but rather that their judgements converged sufficiently according to the Fuzzy Delphi criteria used in this study.

Construct 1: Instructional Strategies

Table 4 shows the Fuzzy Delphi results for Construct 1, namely Instructional strategies. The analysis shows that all seven items fulfilled the three FDM acceptance criteria: threshold value, $d \leq 0.2$; expert consensus $\geq 75\%$; and defuzzification value, $A > 0.5$. The threshold values ranged from 0.01718 to 0.02672, while the overall construct threshold value was 0.02263. This indicates a high level of agreement among the experts. All items achieved 100% expert consensus and were therefore accepted for inclusion in the AR-supported pedagogical framework.

Table 4: Results of Expert Consensus on Instructional Strategies

Item code	Item statement	Threshold value, d	Expert consensus	Defuzzification, A	Rank
C1.1	The module should apply project-based learning as a teaching strategy to support competency-based culinary instruction.	0.02672	100%	0.93636	3
C1.2	The module should apply problem-based learning to guide students in solving practical culinary tasks.	0.01718	100%	0.98182	1
C1.3	The module should support teacher-guided demonstration through AR-enhanced visualisation of procedures, techniques, and product standards.	0.01718	100%	0.98182	1
C1.4	The module should encourage student-centred and collaborative learning during practical food preparation activities.	0.02672	100%	0.96364	2
C1.5	The module should align AR-supported teaching strategies with competency standards, work procedures, and performance criteria.	0.02672	100%	0.96364	2
C1.6	The module should use AR as a pedagogical scaffold to clarify work sequence, procedural accuracy, and guided practice.	0.01718	100%	0.98182	1
C1.7	The module should integrate feedback and reflection as part of teaching strategy	0.02672	100%	0.96364	2

	to support continuous improvement in practical instruction.				
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The defuzzification values for this construct ranged from 0.93636 to 0.98182, which exceeded the minimum acceptance criterion of 0.5. Items C1.2, C1.3, and C1.6 recorded the highest defuzzification values and were ranked first. These items emphasise problem-based learning, teacher-guided demonstration, and AR-supported procedural scaffolding. Items C1.4, C1.5, and C1.7 were ranked second, while C1.1 was ranked third. Although C1.1 recorded the lowest defuzzification value within this construct, it remained well above the acceptance threshold and was retained. Overall, the findings indicate that experts strongly agreed that instructional strategies in the AR-supported culinary TVET module should be pedagogically structured, teacher-mediated, competency-aligned, and directly connected to practical task performance. All items were accepted because they fulfilled the three Fuzzy Delphi criteria: threshold value $d \leq 0.2$, expert consensus $\geq 75\%$, and defuzzification value $A > 0.5$.

Construct 2: Teaching Activities

The Fuzzy Delphi results for Construct 2, which pertains to teaching activities, are summarised in Table 5. Each of the seven items satisfied the FDM requirements and was accepted. The threshold values varied from 0.01718 to 0.04008, generating an overall construct threshold value of 0.02399. Even though Item C2.7 had the highest threshold value, it was still much below the $d \leq 0.2$ cut-off point. This indicates that expert consensus regarding the teaching activities construct was robust and uniform.

Table 5: Results of Expert Consensus on Teaching Activities

Item code	Item statement	Threshold value, d	Expert consensus	Defuzzification, A	Rank
C2.1	The module should include teacher demonstration supported by AR visualisation to clarify culinary procedures and techniques.	0.01718	100%	0.98182	1
C2.2	The module should include recipe-based practical activities that guide students through ingredients, tools, methods, and expected product standards.	0.01718	100%	0.98182	1
C2.3	The module should include step-by-step procedural videos or QR-linked AR materials to support students' understanding of task sequence.	0.02672	100%	0.96364	3
C2.4	The module should include guided hands-on practice in the workshop or kitchen setting with continuous teacher monitoring.	0.01718	100%	0.98182	1
C2.5	The module should include interactive AR-based visual materials, such as 3D models, to support understanding of difficult-to-observe culinary processes.	0.02291	100%	0.97273	2

C2.6	The module should include discussion, questioning, and corrective feedback during practical teaching activities.	0.02672	100%	0.96364	3
C2.7	The module should include post-activity reinforcement or reflection to help students consolidate procedural understanding and performance improvement.	0.04008	100%	0.93636	4

The defuzzification values ranged from 0.93636 to 0.98182, confirming that all items exceeded the acceptance value of 0.5. Items C2.1, C2.2, and C2.4 were ranked first, indicating that experts gave the highest priority to demonstration, recipe-based practical activity, and guided hands-on practice. Item C2.5 was ranked second, suggesting that AR-based visual materials were also strongly valued, particularly when used to clarify processes that are difficult to observe directly. Items C2.3 and C2.6 were ranked third, while C2.7 was ranked fourth. Although C2.7 obtained the lowest ranking, it still achieved full expert consensus and remained acceptable for inclusion. Overall, the results suggest that experts viewed teaching activities as most meaningful when AR is embedded within authentic culinary practice, teacher guidance, and competency-based task performance. All seven items fulfilled the Fuzzy Delphi acceptance criteria and were therefore retained. The ranking values indicate the relative priority of the items within the teaching activities construct rather than a rejection of lower-ranked items.

DISCUSSION

The findings indicate that both teaching strategies and teaching activities achieved strong expert consensus, suggesting that the proposed AR-supported framework was judged by experts to be pedagogically appropriate for competency-based culinary TVET. This consensus is important because it shows that experts did not interpret AR as a stand-alone technological feature. Rather, AR was accepted when it was embedded within a structured teaching process that supports demonstration, guided practice, procedural clarity, feedback, and competency development. This interpretation is consistent with the nature of vocational pedagogy, where learning is closely connected to authentic task performance, occupational competence, and guided practical experience[2, 13, 33] . For the instructional strategies construct, the strongest prioritisation was given to the module should apply problem-based learning to guide students in solving practical culinary tasks, the module should support teacher-guided demonstration through AR-enhanced visualisation of procedures, techniques, and product standards, and the module should use AR as a pedagogical scaffold to clarify work sequence, procedural accuracy, and guided practice(items 2, 3, and 6).These items shared the highest defuzzification value and were ranked first. This pattern suggests that experts gave greater importance to strategies that position AR as a pedagogical scaffold within teacher-guided instruction. In culinary TVET, this is particularly relevant because students are required to interpret work procedures, make practical decisions, manage task sequences, and produce food products according to expected standards. Prior studies on culinary education have shown that practical learning remains strongly shaped by demonstration, modelling, and guided participation, although contemporary culinary pedagogy also requires more structured and learner-centred approaches [5, 34].Therefore, the value of AR lies not in replacing teacher expertise but in strengthening the teacher's role as demonstrator, facilitator, and provider of corrective guidance.

For the teaching activities construct, the highest-ranked items were that the module should include teacher demonstration supported by AR visualisation to clarify culinary procedures and techniques, the module should include recipe-based practical activities that guide students through ingredients, tools, methods, and expected product standards, and the module should include guided hands-on practice in the workshop or kitchen setting with continuous teacher monitoring (items 1, 2 and 4). These items indicate that experts prioritised activities directly related to practical culinary instruction, particularly demonstrations, recipe-based tasks, and guided hands-on practice. This ranking pattern confirms that AR-supported activities are most defensible when they remain closely connected to authentic workshop or kitchen practice. In this context, AR can assist students in observing procedures, following task sequences, identifying product standards, and understanding processes that may be difficult to observe clearly during live demonstrations. This aligns with evidence that multimedia

and digital learning resources can support culinary learning when they are integrated into task design, practical activity, and teacher facilitation rather than used as detached instructional media [5, 14, 17].

The lower-ranked items should not be interpreted as unsuitable, because all items fulfilled the FDM acceptance criteria and achieved full expert consensus. Instead, the ranking pattern indicates a hierarchy of pedagogical priority. Items associated with immediate practical instruction, procedural visibility, and teacher-guided performance were prioritised more highly. In contrast, items related to reinforcement, reflection, or supplementary digital interaction appear to function as supporting components. This distinction is important for module design because AR should be placed first, where it can directly support practical performance, and later as a tool for consolidation and reflection. Such an interpretation is consistent with competency-based vocational learning, which requires instructional activities to be sequenced around observable performance, guided practice, feedback, and the progressive development of occupational competence[33, 35, 36]. Overall, the prioritisation pattern shows that experts valued AR integration when it supported teacher mediation, authentic task performance, procedural sequencing, guided practice, and competency alignment. The contribution of this finding is that it clarifies what pedagogical suitability means in a practice-intensive vocational context. For culinary TVET, AR is not pedagogically meaningful simply because it is interactive or visually attractive. Its value depends on whether it strengthens vocational teaching processes that are already central to competence development, particularly demonstration, guided practice, corrective feedback, and performance-based learning. This strengthens the central argument of the study that AR-supported teaching frameworks in TVET should be designed around vocational pedagogy rather than technological novelty, a position consistent with wider scholars on AR integration in vocational and skills-based learning [2, 13, 37].

CONCLUSION

This study validated two pedagogical constructs for an augmented reality-supported teaching framework in competency-based culinary TVET: teaching strategies and teaching activities. Using the Fuzzy Delphi Method, the findings showed strong expert consensus across both constructs, with all items meeting the required criteria for threshold value, expert agreement, and defuzzification. This indicates that the proposed AR-supported framework is pedagogically acceptable for guiding Food Preparation and Production instruction in Malaysian vocational education.

The prioritisation results further show that experts gave the strongest emphasis to items associated with teacher-guided instruction, procedural scaffolding, demonstration, recipe-based practical tasks, and guided hands-on practice. These findings suggest that AR is most valuable when it is embedded within the practical realities of culinary teaching rather than treated as an independent digital tool. In this context, AR should support the teacher's role in explaining procedures, improving task visibility, guiding student practice, and reinforcing competency-based performance standards. This study enhances worldwide VET research by illustrating how digital pedagogical innovations can be evaluated by expert consensus prior to their adoption in competency-based, practice-intensive vocational environments. This transition reframes the discourse about augmented reality in vocational education from a focus on technological novelty to an emphasis on pedagogical congruence, occupational competency, and authentic task execution.

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Ethics Statement

This study received official research permission from the Ministry of Education Malaysia [KPM.600-3/2/3-eras (27428);29/01/2026]. The study involved expert judgement through a questionnaire and did not involve experimental treatment or vulnerable participants. All expert participants participated voluntarily and provided informed consent before data collection. Participants were informed about the study's purpose, the

confidentiality of their responses, the anonymous reporting of aggregated data, and their right to withdraw from participation. The manuscript reports no personally identifiable information.

AI Declaration

During the preparation of this manuscript, ChatGPT was used only for language editing and phrasing support. No generative AI tool was used to generate data, analyse data, interpret findings, formulate conclusions, or develop the scholarly argument of the article. All analytical decisions, interpretations, and final manuscript content were produced and verified by the authors, who take full responsibility for the work

REFERENCES

1. Azuma, R. T. (1997). A Survey of Augmented Reality. In *Presence: Teleoperators and Virtual Environments* (Vol. 6). <http://www.cs.unc.edu/~azumaW>:
2. Bacca, J., Baldiris, S., & Fabregat, R. (2019). Framework for designing motivational augmented reality applications in vocational education and training. In *Australasian Journal of Educational Technology* (Number 3). <http://piranya.udg.edu/quimica/files/TableOfFrameworksComparison.pdf>
3. Eh Phon, D. N., Murli, N., Che Lah, N. H., & Hashim, S. (2025). The Impact of Augmented Reality on Spatial Visualization Ability and Science Achievement: Exploring their Correlation. *International Journal on Advanced Science, Engineering and Information Technology*, 15(4), 1221–1228. <https://doi.org/10.18517/ijaseit.15.4.13498>
4. Carl Jonas, A. (2002). *Re-Imagining Culinary Arts Education: Beyond the Apprenticeship Model*. In Industry Training Authority.
5. Woodhouse, A., & Rodgers, L. (2024). Culinary arts education: Unpacking and disrupting its master-apprentice pedagogy. *International Journal of Gastronomy and Food Science*, 35. <https://doi.org/10.1016/j.ijgfs.2024.100898>
6. Alhebaishi, S., & Stone, R. (2024). Augmented Reality in Education: Revolutionizing Teaching and Learning Practices – State-of-the-Art. In *IJACSA) International Journal of Advanced Computer Science and Applications* (Vol. 15, Number 11). www.ijacsa.thesai.org
7. Sauli, F., Wenger, M., & Berger, J.-L. (2021). Supporting Apprentices' Integration of School-and Workplace-Based Learning in Swiss Initial Vocational Education and Training. *Research in Post-Compulsory Education*. <https://orcid.org/0000-0003-2629-2622>
8. Schaap, H., Baartman, L., & de Bruijn, E. (2012). Students' Learning Processes during School-Based Learning and Workplace Learning in Vocational Education: A Review. In *Vocations and Learning* (Vol. 5, Number 2, pp. 99–117). <https://doi.org/10.1007/s12186-011-9069-2>
9. Al-Jamea, M. M., & Shatnawi, H. F. (2024). Managing Learning Outcomes Assessment Methods in Vocational Training: A Case Study of Jubail Technical Institute. *Studies on Energy Applications International Journal Journal Homepage*, 1, 1–09. <https://journalseaij.com/>
10. Mark, P. (2016). A perspective on learning outcomes in curriculum and assessment. National Council for Curriculum and Assessment. <http://www.educationscotland.gov.uk/thecurriculum/howisthecurriculumorganised/experiencesandoutcomes>
11. Billett, S. (2003). Vocational Curriculum and Pedagogy: an activity theory perspective. In *European Educational Research Journal* (Vol. 2, Number 1).
12. Hermansyah, Amsari, D., Manvi, K. I., Susanti, R., Kahar, A., Saladin, K., Heriani, Pratama, V. M., & Yusman, A. F. (2025). Enhancing Hospitality Competencies: The Role of Mobile Augmented Reality In Indonesian Vocational Schools. *Salud, Ciencia y Tecnologia*, 5. <https://doi.org/10.56294/saludcyt20252271>
13. Rafiq, A. A., Triyono, M. B., & Djatmiko, I. W. (2022). Enhancing student engagement in vocational education by using virtual reality. *Waikato Journal of Education*, 27(3), 175–188. <https://doi.org/10.15663/wje.v27i3.964>
14. Saem, H., & Kyun, N. T. (2025). Project-based Flipped Classroom Method in a Cooking Practice Class: A Case Study. *SAGE Open*, 15(1). <https://doi.org/10.1177/21582440251321574>
15. Yuwono, V. K., Radianto, W. E. D., Padmalia, M., Pebrunto, D. S. W., & Utami, C. W. (2025). Pelatihan Teknik Memasak untuk Meningkatkan Daya Saing Usaha Mikro Kuliner. *Jurnal Leverage*,

- Engagement, Empowerment of Community (LeECOM), 7(2).
<https://doi.org/10.37715/leecom.v7i2.5840>
16. Wahyuda, N., & Ratnawulan, T. (2025). Task Analysis for Making Sosis Sandwiches for Mildly Mentally Disabled Grade VII Students at SLB Madhani, Garut Regency. Print) Journal of English Language and Education, 10, 2025. <https://doi.org/10.31004/jele.v10i5.1363>
17. Chen, Y.-C., Tsui, P.-L., Lee, C.-S., Chiang, M.-C., & Lan, B.-K. (2022). Incorporating Multimedia Teaching Methods and Computational Thinking into the Baking Dessert Course. Electronics (Switzerland), 11(22). <https://doi.org/10.3390/electronics11223772>
18. Hsu, C.-C., & Sandford, B. A. (2007). The Delphi technique: Making sense of consensus. Practical Assessment, Research and Evaluation. <https://www.scopus.com/inward/record.uri?eid=2-s2.0-70349779297&partnerID=40&md5=3bc95d5360a0c49deb559fb05001cdbf>
19. Okolie, U. C., Elom, E. N., Igwe, P. A., Binuomote, M. O., Nwajiuba, C. A., & Igu, N. C. N. (2021). Improving graduate outcomes : Implementation of problem-based learning in TVET systems of Nigerian higher education. Higher Education, Skills and Work-Based Learning, 11(1), 92–110. <https://doi.org/10.1108/HESWBL-12-2018-0140>
20. Skulmoski, G. J., Hartman, F. T., & Krahn, J. (2007). The Delphi Method for Graduate Research. Journal Of Information Technology Education-Research, 6, 1–21.
21. Ishikawa, A., Amagasa, M., Shiga, T., Tomizawa, G., Tatsuta, R., & Mieno, H. (1993). The Max-Min Delphi method and fuzzy Delphi method via fuzzy integration*. In Fuzzy Sets and Systems (Vol. 55).
22. Hakimi, H., Abdullah, R. S., Kamalrudin, M., Octaviani, D., Misron, A., & Azmi, S. S. (2025). Employing Fuzzy Delphi Technique to Validate the Component and Contents of Software Security Readiness for Remote Working Employee in Public Organization. Journal of Advanced Research in Applied Sciences and Engineering Technology, 64(2), 114–129. <https://doi.org/10.37934/araset.64.2.114129>
23. Mustapha, R., Paris, T. N. S. T., Mahmud, M., Musa, M. S., Zaini, A. A., & Zakaria, J. (2023). Managing students' mental health: The use of NGT and FDM to generate a concrete solution. International Journal of Asian Social Science, 13(2), 89–100. <https://doi.org/10.55493/5007.v13i2.4736>
24. Jailani, M. A., & Loy, C. K. (2023). The Application Of Fuzzy Delphi Method In Content Validity Analysis. <https://www.researchgate.net/publication/378774648>
25. Mat Deli, M., Rauf, A., Purwati, A., & Mustapha, R. (2023). Expert Agreement towards the Orang Asli Community Learning Center Model Based On the Local Environment: Analysis of the Fuzzy Delphi Method. In Tuijin Jishu/Journal of Propulsion Technology (Vol. 44, Number 3).
26. Adler M, & Ziglio E. (1996). Gazing into the oracle:the delphi method and its application to social policy and public health. JessicaKingsley.
27. Jones, H., & Twiss, B. L. (1978). Forecasting Technology for Planning Decisions. Macmillan.
28. Jamil, M. R. M., Hashim, A. T. M., Othman, M. S., Ahmad, A. M., Noh, N. M., & Kamal, M. F. M. (2023). Digital Pedagogy Policy in Technical and Vocational Education and Training (TVET) in Malaysia: Fuzzy Delphi Approach. Journal of Technical Education and Training, 15(2), 1–10. <https://doi.org/10.30880/jtet.2023.15.02.001>
29. Mokhtar, S., & Yasin, R. M. (2018). Design of Teaching Influences the Training Transfer Amongst TVET's Instructors: Fuzzy Delphi Technique. International Journal of Academic Research in Business and Social Sciences, 8(6). <https://doi.org/10.6007/ijarbss/v8-i6/4303>
30. Berliner, D. C. (2004). Expert teachers: Their characteristics, development and accomplishments. Bulletin of Science, Technology and Society, 3(24), 200–212.
31. Gambatese, J. A., Behm, M., & Rajendran, S. (2008). Design's role in construction accident causality and prevention: Perspectives from an expert panel. Safety Science, 46(4), 675–691. <https://doi.org/10.1016/j.ssci.2007.06.010>
32. Mohd Ridhuan, J., & Nurul Rabihah, M. N. (2020). Kepelbagaian Metodologi Dalam Penyelidikan (N. Izra, Ed.; Vol. 3). QaisarPrestige.
33. Asnur, L., Jalinus, N., Faridah, A., & Utami, F. (2024). Enhancing Soft Skills in Culinary Education through Project Based Learning and Vlogs: A Quasi-Experimental Study. Powertech Journal, 48(1). <https://powertechjournal.com>

34. Koerich, G. H., & Müller, S. G. (2022). Gastronomy knowledge in the socio-cultural context of transformations. *International Journal of Gastronomy and Food Science*, 29. <https://doi.org/10.1016/j.ijgfs.2022.100581>
35. Okoth, E. (2023). Teaching Factory Concept in TVET. *Africa Journal of Technical and Vocational Education & Training*, 2023(1), 52–65.
36. Teferi, G. B., Gu, Q., & Wu, Z. (2025). The Role of the Technical and Vocational Education and Training (TVET) Curriculum in Enhancing Workforce Readiness. *Vocational: Journal of Educational Technology*, 2(2), 80–88. <https://doi.org/10.58740/vocational.v2i2.481>
37. Salleh, M., Khairani, M. Z., Mohd Rafee, Y., & Mohamad, S. A. (2025). Harnessing Fuzzy Delphi: Designing the innovative DiD-Art application. *Environment-Behaviour Proceedings Journal*, 10(SI24), 89–95. <https://doi.org/10.21834/e-bpj.v10isi24.6371>