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DIGITAL TRANSFORMATION IN OCCUPATIONAL SAFETY EDUCATION: FORMULATING COMPONENTS OF VIRTUAL REALITY IN TVET HOSPITALITY PROGRAMS BY USING TPACK THEORY

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Abstract

Technical and Vocational and Educational Training (TVET) hospitality programs are related to practical training in culinary programs. Graduates are expected to implement safer and healthier practices in commercial kitchens, making them pioneers in adopting correct work attitudes during their education. This study recommends a tool for safer and healthier workplaces using Virtual Reality (VR) as a transformative tool in Malaysia's TVET hospitality programs, aligning with IR 5.0 principles to enhance human capital for the foodservice industry. Malaysia's TVET sector faces challenges in integrating industries and fostering workplace culture. The two-fold objectives of this study are: 1) to formulate a VR-based kitchen safety framework for kitchen safety in TVET's hospitality programs and 2) to validate a VR-based kitchen safety framework for kitchen safety in TVET's hospitality programs. This study employs a Design and Development Research (DRR) approach, using qualitative methods with industry experts—kitchen educators/trainers, Safety and Health officers (SHO), Instructional Designers (ID), and IT experts in VR—to develop and validate a VR-based kitchen safety framework. The results of Fuzzy Delphi from industry experts yielded six components: virtual automation with technological knowledge, content knowledge, content determination, coaching content and virtual assessment, and pedagogical expertise. Twenty industry and academic professionals consensually agreed that the ranks position of six constructs and validated the framework. The study emphasizes the importance of VR development by suggesting ideas for identifying and incorporating the necessary parts for VR development into the framework.

Keywords: Fuzzy Delphi; Kitchen Safety; Technical and Vocational Education and Training (TVET); Technology, Pedagogy, and Content Knowledge (TPACK); Virtual Reality (VR)

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INTRODUCTION

Virtual Reality (VR) has been widely used across diverse fields, including education, revealing the potential for expansion in training institutes to support workplace safety (Saad et al., 2023; Smutny, 2022). Safe kitchen environments are crucial due to hazards from heavy equipment like mixers and slicers in busy settings, especially in the food and beverage industry (Kabir, 2019). The study aims to develop and validate a VR-based kitchen safety framework for Technical and Vocational Education and Training (TVET) hospitality programs. This study proposes a robust framework for safety-focused VR as a transformative educational tool in TVET hospitality programs, aligning with Industry Revolution (IR) 5.0 to enhance human capital upskilling as per the National Tourism Policy (Ahmad, 2023).

LITERATURE REVIEW

Technical and Vocational Education and Training in Malaysia

TVET hospitality programs were selected for this study for several reasons. Graduates are expected to implement safer and healthier practices in commercial kitchens, making them pioneers in adopting correct work attitudes during their education. Over 500 public TVET institutions now offer diverse programs at all education levels, including Vocational College (KV), Giatmara, Mara High Skill College, Polytechnics, Community Colleges, and Malaysian Technical University Network (MTUN). Despite a nascent partnership strategy with industries, the Malaysian TVET landscape needs help fostering students' work culture understanding (Subri et al., 2022). Ensuring relevant curricula and educational programs is crucial to align skills with the evolving job market, particularly in food preparation sectors such as hotels, restaurants, catering businesses, and cruise ships (Zikri, 2023).

Using Technology in Kitchen Safety, Related Training Using Virtual Reality

Technology support in commercial kitchens focuses on using VR to develop sophisticated culinary skills and safety management among users (Smith, 2020). VR serves as a primary tool for kitchen safety, preparing individuals for future workplaces by reducing occupational accidents and illnesses. Despite efforts in Malaysian higher education, enhancing worker awareness of Occupational Safety and Health (OSH) has shown limited results (Jaafar et al., 2022). Studies indicate that learners using immersive head-mounted displays demonstrate higher engagement, increased time investment in learning tasks, and improved cognitive, psychomotor, and affective skills (Lähtevänoja et al., 2022; Yoo et al., 2023). VR technology's immersive nature and demand for concentration make it a contemporary instructional tool that enhances problem-solving abilities

(Paszkiewicz et al., 2022; Saad et al., 2024). VR environments enriched with computer game mechanics effectively familiarize students with digital circuits.

Technology, Pedagogy, and Content Knowledge Theory (TPACK)

Technology, Pedagogy, and Content Knowledge (TPACK) theory has been recognized for overcoming teaching challenges through effective instructional strategies (Gómez et al., 2019). However, there remains a gap in research on its application in TVET programs (Pecina & Andrisiunas, 2023). Abas et al. (2023) employed the Fuzzy Delphi method to identify seven strategies for promoting VR as a learning tool, supported by consensus among experts. Jamil et al. (2023) used a similar approach to affirm digital policy in TVET, involving curriculum developers and lecturers. Chen and Chan (2024) found that five digital teaching methods—blended learning, standards-based learning (SBL), game-based learning (GBL), flipped classrooms, and precision teaching—are effective with reliable connectivity. However, research focused explicitly on safety-based VR pedagogy remains unexplored.

RESEARCH METHODOLOGY

This study used a design and development research (DRR) approach with purposive sampling to meet its objectives (Richey & Klein, 2019). Twelve industry experts were involved as Sim et al. (2018) mentioned, at least five participants are needed for interviews. This study includes four (4) each from kitchen usage educators/trainers in TVET institutions, and two (2) safety and health officers (SHO), two (2) Instructional Designers (ID), and (4) Information Technology (IT) experts in VR. Semi-structured interviews guided by Mohammad (2020) were conducted, and their opinions were thematically analyzed. The resulting themes and components were evaluated using 7-point Likert scales and pre-tested before distribution to other industry experts for the Fuzzy Delphi method. The 7-point Likert scale is suitable for measuring experts' agreement levels, ensuring accurate data collection (Ismail et al., 2019). In this second stage FDM surveys typically need 10–50 experts (Yusof et al., 2022). There are two types of questionnaires of fuzzy Delphi, which require ten (10) experts, from four (4) IDs in Technology and Six (6) ID from TVET trainers, to validate the items that focus on the framework's content, along with ten (10) IT experts responsible for validating the VR components.

ANALYSIS RESULTS

Table 1 shows the participants' profiles. The demographic findings suggest that participants were experienced professionals. These professionals are characterized as individuals with industry information and technology and possess adequate skills in developing VR. Despite some having less than five years of experience, the IT experts were meticulously selected for their VR application development expertise.

Table1: Demographic Profile

	Gender	Age	Occupation	Education	Experience	Formulation	Validation
	SHO						
1	Female	47	Lecturer and SHO	PhD	14 years	/	
2	Male	44	SHO	Bachelor’s Degree	15 years and above	/	
	ID						
3	Male	40	Lecturer Technology Instructional	PhD	15 years and above	/	/
4	Male	42	Lecturer Technology Instructional	PhD	15 years and above	/	/
5	Female	48	Lecturer Technology Instructional	PhD	10-14 years		/
6	Male	46	Lecturer Technology Instructional	PhD	15 years and above		/
7	Male	44	TVET Trainer	Diploma	15 years and above	/	/
8	Female	34	TVET Trainer	Diploma	5-9 years	/	/
9	Female	50	TVET Trainer	Diploma	15 years and above	/	/
10	Male	43	TVET Trainer	PhD	10-14 years	/	/
11	Female	47	TVET Trainer	Diploma	15 years and above		/
13	Female	49	TVET senior trainer	Diploma	15 years and above		/
	IT						
14	Male	29	programmer	Master's degree	4 years	/	/
15	Male	30	PhD student and programmer	Master's degree	3 and ½ years	/	/
16	Female	29	Lecturer and Programmer	Master's degree	2 years	/	/
17	Male	27	Programmer	Bachelor's degree	2 years	/	/
18	Male	28	Software engineer, developing data platform	Master's degree	7 years		/
19	Female	51	Lecturer	PhD	15 years and above		/
20	Female	53	Lecturer	Master's degree	15 years and above		/
11	Male	55	Lecturer	Bachelor's degree	15 years and above		/
22	Male	46	Lecturer	PhD	15 years and above		/
23	Female	43	Lecturer	PhD	15 years and above		/

To validate a framework, this study organized the data based on the TPACK theory to establish supportive strategies for kitchen safety education. The data from the thematic analysis are converted into statement format and organized into a questionnaire employing a 7-point Likert scale to assess experts' consensus. The items shown are combined and reformed to develop the essential components of the framework.

A: Technological Knowledge

Technology knowledge demonstrates a deep understanding of integrating technology into kitchen safety lessons using VR technology. Based on the information, Table 1 shows the criteria needed to develop VR and combine it with the education suggested by the IT informants.

Table 2: Technological Knowledge Elements

	Construct 1: Virtual Automation
	Item / Element
A1	Providing users with suitable VR gadgets
A2	Equipping virtual environment with motion controllers to enable trainees to interact effectively in the environment
A3	Using essential sensory equipment
A4	Equipping motion controllers to enable trainees to interact with the virtual environment effectively
A5	Having high-quality audio is crucial to creating an immersive VR experience.
A6	Creating an immersive VR experience by having high-quality audio
A7	Programming immersive and interactive virtual environments for training (e.g., Unity, Unreal) by utilizing the free development software for VR development application
A8	Creating content for interactive virtual environments for training by utilizing paid content-management services for VR development application
A9	Monitoring the movement of VR gadgets and controllers by utilizing tracking systems like external sensors or inside-out tracking cameras
A10	Enhancing trainees' training experience through tactile sensations by equipping VR training with haptic feedback
A11	Enhancing the reality of training experience by equipping gloves, vests, or hand controllers with haptic feedback capabilities

B: Content Knowledge

The content knowledge assessment component's elements are derived from informants' information. ID experts have recommended this instructional design, which is suitable for inclusion in VR content. The goal is to enhance students' comprehension of safety education using VR. Table 3 outlines the elements within the content knowledge, which consists of four constructs: introduction, content delivery, learning activities, and tools.

Table 3: Content Knowledge Elements

	Constructs 2: Content Determination
	Item / Element
1	Stakeholder Description [Identify the problem statement by analyzing the existing issue]
2	Stakeholder Description [Determine learning objectives by stakeholder interest.]
3	Stakeholder Description [Determine the target audience (Food handler)]
4	Stakeholder Description [Determine the primary job description, which entails identifying the principal duties and obligations.]
5	Stakeholder Description [Determine language selection]
6	Principle [Using Addie Model principle for effective learning approach]
7	Principle [Using Addie Model principle DESCUM (reference for TVET curriculum development)]
8	Item B: Principle [Using Addie Model principle Using MERRILL (principle of instructions)]
	Constructs 3: Coaching content
	Item / Element
9	Kitchen activity specifications [Kitchen activity specification involves identifying job description]
10	Kitchen activity specifications [Kitchen activity specification involves identifying equipment]
11	Kitchen activity specifications [Kitchen activity specification involves identifying Hygiene]
12	Kitchen activity specifications [Kitchen activity specification involves identifying type of hazards (Physical Hazards, Ergonomics, Chemical Hazards, Biological Hazards)]
	Kitchen activity specifications [Kitchen activity specification involves identifying the type of accidents]
14	Kitchen activity specifications [Kitchen activity specification involves identifying Kitchen Rules]
15	Kitchen activity specifications [Kitchen activity specification involves identifying Behaviour or Etiquette in the kitchen]
	Constructs 4: Virtual Assessment
	Item / Element
16	Identifying Rules of equipment
17	Identifying working processes
18	Example working process, Worker falling from a slippery wet or oily floor
19	Example working process, Injuries from exposure to exposed sharp tools
20	Example working process, Injuries from exposure to hot stuff
21	Recognize risk ingredients [Example chemical ingredients]
22	Recognize risk activity in kitchen [ex: Tools dropped when workers collide with each while working in the small space of a commercial kitchen area]
23	Recognize risk activity in kitchen [lift heavy things]
24	Recognize risk activity in kitchen [Obstruction on the ground (bins and boxes)]
25	Recognize risk activity in kitchen [Gas accumulation and vapor cloud formation]
26	Recognize risk activity in kitchen [Injuries caused by falling tools and utensils]

C: Pedagogical Knowledge

The final development phase is pedagogical knowledge, where IT informants identify essential components of VR as an educational tool. VR enhances teaching methods within this framework. Table 4 in the VR framework lists criteria for effective student use, categorized into K-UX and machine learning constructs. Overall, experts strongly agree on elements related to VR-based safety training, with most items meeting the instructional design framework's acceptance criteria.

Table 4: Pedagogical Knowledge Elements

	Constructs 5: K-UX (Kitchen user experience)
C1	Incorporating a trainee's ability to spot hazards when exploring the virtual kitchen actively
C2	Encouraging trainees to utilize virtual controllers or gestures to identify possible risks
C3	Allowing trainees to experience the sensation of holding kitchen equipment and utensils
C4	Allowing trainees to perceive the sensation of cutting cooking ingredients in the kitchen
C5	Incorporating interactive elements like the sound system
C6	Incorporating interactive elements like videos
C7	Incorporating interactive elements like 3D animations
C8	Integrating communication tools that allow trainees to interact and communicate more effectively with facilitators and fellow trainees
C9	Incorporating text instructions alongside audio communication tools
C10	Designing an intuitive and user-friendly interface to facilitate navigation within the VR environment
C11	Developing an intuitive menu system enabling trainees to access various training program modules or sections
C12	Implementing user-friendly navigation controls so that trainees can move quickly in the virtual kitchen
C13	Setting up a section that gives trainees access to safety guidelines, procedures, and relevant information
C14	Integrating a voice command function to allow trainees to interact through spoken instructions within the VR environment
C15	Incorporating user-friendly features that permit trainees to pause or exit the VR training environment
C16	Prioritizing the trainee's comfort and safety throughout the experience
	Constructs 6: Machine Learning
D1	Using visual cues such as highlighting potential hazards with colors, arrows, or other attention-grabbing elements
D2	Implementing interactive prompts to guide trainees on what action to take when facing a hazard
D3	Using prompts to appear as text, voice instruction, or interactive objects within the VR environment
D4	Offering real-time feedback, such as positive reinforcements in the form of congratulatory messages or sounds
D5	Implementing a scoring system that tracks a trainees' hazard identification and response
D6	Including guided walkthroughs or tutorials for specific hazards or safety procedures

D7	Allowing repeated practice in VR
D8	Implementing an assessment section to accurately evaluate an employee's competence in identifying workplace hazards
D9	Incorporating a timed hazard identification test in VR safety training
D10	Simulating activities like following recipes and preparing ingredients to add substantial value to VR safety training
D11	Simulating real-world kitchen challenges, especially in emergencies, to add substantial value to VR safety training]
D12	Collecting trainees' feedback on the usability of the virtual kitchen for continuous improvement of VR safety training
D13	Simulating real-world kitchen challenges, especially in emergencies, to add substantial value to VR safety training

Table 5 displays each construct's position for the second objective, as Fuzzy Delphi suggested. This holds the rank list, suggesting which construct needs to be prioritized or considered most and least important among other items listed.

Table 5: Ranking of construct

Construct	*Average experts' consensus percentage of all items*	*Rank*
Virtual Automation	*91%*	*2*
K-UX (kitchen user experience)	*95%*	*1*
Machine Learning	*88.5%*	*6*
Content Determination	*90.9%*	*3*
Coaching Content	*90.91%*	*4*
Virtual Assessment	*90.91%*	*5*

Accordingly, Fig. 1 illustrates VR-based kitchen safety framework for kitchen safety in TVET's hospitality programs for this study.

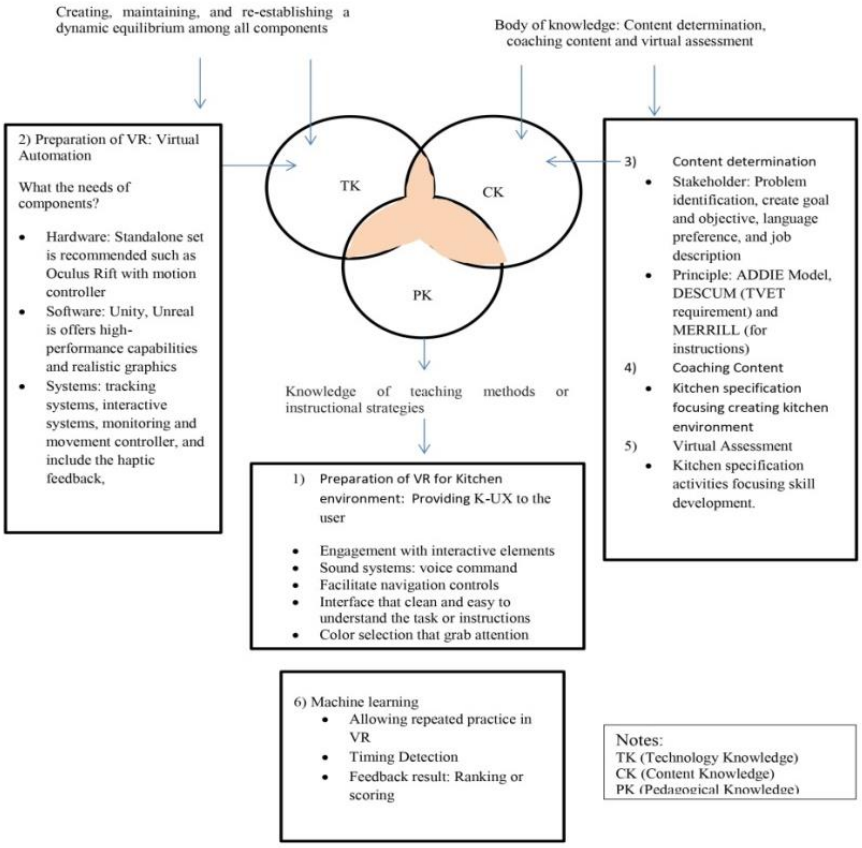

Figure 1: VR kitchen safety framework

DISCUSSIONS

The study finds that integrating TPACK in VR enhances the teaching and learning experience in TVET programs by organizing quality content. It highlights the effective delivery of safety knowledge through VR, agreed upon by industry and academic professionals. This approach focuses on skill development, which is crucial for TVET, and prepares students to accomplish real-life tasks using VR. Virtual automation is a key component for developing VR that supports technological knowledge, which involves preparing hardware and software like sensory equipment, motion controllers, high-quality audio, and development software such as Unity or Unreal. These tools help create immersive and interactive VR-based kitchen programs that promote active learning and safety awareness among trainees, aligning with the findings of Saad et al. (2023), Lee et al. (2023), and Jeinie and Nor (2022).

The VR-based safety knowledge component can help the Malaysian government enhance its TVET system by focusing on kitchen activities that identify risks and hazards and address training gaps noted by (Saad, 2023). The second component, content knowledge, involves content determination, coaching, and virtual assessment to ensure VR content meets industry requirements. This aligns with Kathirveloo and Puteh (2014), aiding students in organizing and adjusting topics to attract interest. Suitable content knowledge for a VR-based kitchen framework structures educational content, emphasizes skill development, and incorporates safety assessments.

Finally, pedagogical knowledge supports content knowledge in VR systems. K-UX defines interactive instruction systems, while machine learning provides feedback and guidance with various assessment tools. These findings align with Shulman's (1986) concept of creating effective educational environments through comprehension, alteration, instruction, assessment, and reflection. VR offers trainees an interactive, immersive safety education experience tailored to their learning needs and skill levels. The VR mechanisms developed in this study have created a TVET framework that addresses organizational issues hindering students' understanding of work culture, as Subri et al. (2022) noted.

CONCLUSIONS

In a nutshell, Malaysia's TVET curriculum must incorporate industry practices to ensure a seamless transition to employment. This study significantly contributes to the Department of Occupational Safety and Health, TVET institutions, and all stakeholders. Integrating TPACK in VR enhances the teaching and learning experience in TVET programs by organizing quality content and delivering effective safety knowledge, ensuring students are well-prepared for real-life tasks. Additionally, the VR mechanisms developed create a comprehensive TVET framework that addresses organizational issues and promotes active learning and safety awareness, aligning with industry and academic standards.

A limitation of the study is the scarcity of VR expertise in Malaysia, particularly in the hospitality industry. Future research should focus on developing a prototype of safety-based VR educational tools to evaluate the readiness and effectiveness of TVET hospitality program students and staff.

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