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Assessing the Usability of a Virtual Reality Training Tool for Coffee Handling and Hygiene: The SafeBrew VR Ex-perience

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ABSTRACT

Effective coffee handling and hygiene practices are paramount for quality as-surance and food safety in the coffee industry, yet traditional training meth-ods often fall short in providing hands-on, consistent learning experiences. This paper presents a usability assessment of a novel Virtual Reality (VR) training tool designed to teach coffee handling and hygiene skills. We con-ducted a mixed-methods usability study with [Number] participants, utiliz-ing a combination of quantitative metrics, including the System Usability Scale (SUS) and User Experience Questionnaire (UEQ), and qualitative data derived from post-test interviews and think-aloud protocols. Participants en-gaged in realistic VR scenarios covering tasks such as coffee brewing, milk steaming, and counter cleaning. Our findings reveal [summarize key positive aspects, e.g., high levels of immersion and perceived effectiveness] but also highlight specific usability challenges, including [summarize key challenges, e.g., difficulties with virtual object manipulation and navigation]. Based on these insights, the paper provides concrete recommendations for iterative de-sign improvements to enhance the tool's learnability, efficiency, and overall user satisfaction. This study contributes to the growing body of literature on VR in vocational training by offering empirical evidence on the usability of immersive tools in a specialized industry, guiding future development to-wards more effective and user-friendly VR learning solutions for critical practical skills.

Keywords: Virtual Reality Training, Usability Assessment, User Experience, Coffee Handling and Immersive Learning.

INTRODUCTION

Food handling and hygiene are critical components of food safety, significantly impacting both public health and customer experiences in food establishments. The importance of these practices lies not only in preventing foodborne illnesses but also in fostering consumer trust and satisfaction. Firstly, improper food handling practices are among the leading causes of foodborne outbreaks. Research indicates that pathogens such as Escherichia coli and Salmonella are frequently associated with poor hygiene among food handlers (Ifeadike et al., 2012; Kalid et al., 2024). Education and training in food safety are pivotal; a systematic review and meta-analysis showed that food handlers who received formal training were 5.38 times more likely to adhere to hygienic practices compared to their untrained counterparts (Negassa et al., 2022). Furthermore, the attitudes of food handlers significantly

influence their hygiene practices; those with positive attitudes are more likely to implement better food safety measures (Tesso et al., 2025; Saleem et al., 2022).

Coffee drinking in Malaysia is a deeply ingrained habit, reflecting a blend of traditional and modern influences. Malaysians typically enjoy coffee throughout the day, from breakfast to late-night mamak sessions. While traditional local brews like *kopi O* (black coffee with sugar) and *kopi susu* (coffee with condensed milk) served at *kopitiams* (traditional coffee shops) remain immensely popular, there's also a significant and growing trend towards specialty coffee, with cafes offering a wide range of artisanal preparations. Coffee consumption in Malaysia demonstrates a robust and accelerating growth trajectory, underscoring a significant shift in national beverage preferences. Recent data indicates a substantial increase in consumption, with figures rising from 635,000 60-kg coffee bags in 2020 to 800,000 60-kg bags in both 2021 and 2022, representing a notable spike in a short period. This surge positions Malaysia as a prominent player in the global coffee landscape, ranking among the top 50 coffee-consuming nations worldwide and securing the third position in Asia Pacific for its consumption growth rate in 2021. On a per capita basis, the average Malaysian consumed approximately 107 cups of coffee in 2021, illustrating the pervasive nature of the habit. In 2024, Malaysia consumed approximately 300,000 bags of coffee (each bag weighing 60 kilograms), which marks a decline from around 400,000 bags in 2023

Like any other consumable product, coffee necessitates stringent adherence to hygienic practices throughout its entire value chain to safeguard both food safety and security**.** From cultivation and harvesting to processing, storage, preparation, and final consumption, each stage presents potential avenues for contamination, including microbial proliferation, chemical residues, or foreign material ingress. Maintaining rigorous hygiene standards is therefore paramount to mitigate these risks, ensuring that the coffee product remains free from deleterious agents. This comprehensive approach not only protects public health by preventing foodborne illnesses but also upholds consumer trust and product integrity, contributing to the broader framework of food security by guaranteeing consistent quality and wholesomeness. Advancements in virtual reality (VR) technology have transformed how people engage with digital experiences. Consequently, there has been a significant rise in technologies that provide more immersive and enriched presentations of objects in a food security environment. Thus, this study aims to explore the use of VR to visualize coffee preparation and handling with a focus on the design and development of a VR application and its usability.

LITERATURE REVIEW

Immersive Technology in Food Security

The integration of immersive technology within the domain of food security—particularly focusing on food hygiene and cleanliness—offers innovative solutions to traditional challenges faced by the food industry. This emerging field encompasses various technologies, including augmented reality (AR), virtual reality (VR), and advanced digital training platforms that enhance knowledge, skills, and practices related to food safety.

One of the pivotal roles of immersive technology in food hygiene is its capacity to improve the training and education of food handlers. Traditional training methods may not adequately engage participants or effectively instill the necessary knowledge and practices required to maintain high hygiene standards in food establishments. Immersive training simulations can provide real-world scenarios that test and enhance the practical skills of food handlers while allowing them to experience and react to various food safety situations without real-world consequences (Lee & Seo, 2020). Research indicates that the use of VR for training significantly improves food safety knowledge and can lead to lasting behavioral changes compared to more conventional training methods (Xi et al., 2021).

Furthermore, AR applications can be utilized during food preparation and handling processes to ensure adherence to hygiene standards. For example, AR can display real-time prompts and reminders about best practices for food handling, such as proper washing techniques or safe storage temperatures (Đjekić et al., 2014). This type of immediate feedback has been highlighted as a crucial factor in enhancing compliance with food safety protocols, especially in high-pressure environments where food handlers might overlook essential safety procedures (Girmay et al., 2020; Naji et al., 2025). Such technologies create immersive experiences that not only educate but also encourage a culture of hygiene and safety (Naji et al., 2024).

In addition to improving training practices, immersive technology can facilitate inspections and monitoring of food hygiene standards. Digital platforms can be integrated with IoT devices to provide continuous monitoring of conditions in food preparation areas, ensuring that hygiene standards are met consistently (Xi et al., 2021). This proactive approach allows for real-time data collection and reporting, leading to quicker corrective actions when hygiene breaches are detected, thereby enhancing food safety and consumer confidence (Howton et al., 2016; Ghaleb et al., 2023).

Moreover, understanding consumer preferences and perceptions is vital in the realm of food security. Immersive technologies can simulate customer experiences in food settings, allowing businesses to test their hygiene protocols from a consumer standpoint. This approach not only highlights how hygiene impacts customer satisfaction but also offers businesses insights into areas that might require improvement (Ranasinghe et al., 2014). By leveraging such technology, establishments can better align their practices with customer expectations, fostering loyalty and enhancing the overall customer experience (Xi et al., 2021).

VR Application in Coffee Handling and Preparation

The application of virtual reality (VR) technology in coffee preparation and handling is an innovative approach that combines immersive learning with practical skill development. Such advancements aim to enhance the efficiency and effectiveness of training in the coffee industry while promoting adherence to hygiene standards and proper techniques. One significant use of VR in coffee preparation is highlighted in studies exploring the sensory experience associated with coffee. For instance, Escobar et al. examined how environmental cues in a virtual setting could influence the premium coffee experience, demonstrating that VR can create immersive scenarios that simulate different aspects of coffee origin and preparation (Escobar et al., 2021). This study illustrates how virtual environments can transport individuals into dynamic settings where they learn about the nuances of coffee, including the intricate processes of brewing and handling that are essential for maintaining quality and hygiene.

Moreover, VR has been utilized as an educational tool for individuals with cognitive impairments. Allain et al. developed a non-immersive VR task that involved preparing a virtual cup of coffee, aimed at assessing everyday action capabilities in patients with Alzheimer's disease (Allain et al., 2014). The study found that using a virtual coffee machine helped identify deficits in cooking skills, thus highlighting the practical benefits of VR in teaching specific food handling tasks. The ability to replicate coffee preparation processes in a controlled VR environment not only benefits individuals requiring skill assessment but can also serve as a training tool for staff in coffee-related businesses.

In addition, Allain et al. (2014). proposed a dual-modal VR kitchen approach focused on relearning essential cooking tasks, which included preparing coffee. Their incorporation of written and verbal instructions helped participants reduce errors, demonstrating how VR can significantly improve task execution in food-related activities, particularly when subjects may have cognitive impairments (Panerai et al., 2021). Such training emphasizes the importance of correct techniques in coffee handling while reinforcing safe and hygienic practices in an engaging manner.

The utilization of VR training is also evident in contexts beyond health assessments. For example, Rozevink et al. designed a VR environment where users play the role of a barista, tasked with preparing coffee orders while practicing the necessary manual skills involved in this process (Rozevink et al., 2023; Rozevink et al., 2025; Al-Ashmori et al., 2022). This application exemplifies how VR can create engaging and realistic scenarios for hands-on training, ensuring that workers enhance their proficiency in coffee preparation while concurrently practicing proper hygiene and cleanliness protocols.

METHODOLOGY

Requirement Gathering

The initial phase of the VR application development centered on comprehensive requirements gathering to clearly define its scope, objectives, and pedagogical content. This stage emphasized identifying the specific hygienic practices essential for ensuring coffee safety throughout the entire "farm to cup" process. A key focus was the identification of critical control points—those stages in coffee handling and preparation where the risk of contamination is highest, such as bean storage, grinding, brewing, and equipment cleaning. The team also worked on translating established food safety guidelines and best practices into actionable instructional content suitable for a VR environment. This involved organizing clear "do's and don'ts" related to personal hygiene, equipment sanitation, cross-contamination prevention, and proper storage conditions. Additionally, user experience (UX) needs were carefully considered, including the desired level of immersion, interactivity, and feedback mechanisms required to effectively engage users and support meaningful learning within the virtual reality context.

Storyboard Development

Following the detailed requirements phase, a comprehensive storyboard was created to visually and narratively map out the user's journey within the VR application. This phase was essential for structuring the learning experience and ensuring a coherent flow of information, especially given the application's straightforward narrative. The storyboard illustrated the progression of scenes, outlining each virtual environment—such as a coffee storage

facility and a simulated kitchen which includes a sink and an espresso machine—and the transitions between them. It also detailed the instructional interactions, showing how users would engage with virtual objects and characters to learn hygienic practices through visual cues, audio narrations, and interactive prompts. Specific hazard identification scenarios were designed to present users with potential contamination risks, encouraging them to apply their knowledge to recognize and resolve these issues. Additionally, the storyboard incorporated feedback mechanisms to provide immediate responses to user actions, reinforcing correct behaviors and guiding users in correcting mistakes.

VR Application Development

The third phase of the project focused on the technical development of the VR application using the Unity game engine. This stage involved transforming the storyboard into a fully interactive and immersive virtual environment, ensuring the smooth integration of visual assets, audio components, and interactive features. A major part of this phase was environmental modeling, which entailed creating realistic 3D representations of coffee handling settings, equipment, and consumables, with an emphasis on visual clarity to support hazard identification. Interaction programming was also a key task, involving the implementation of scripts that allowed users to pick up and manipulate virtual objects such as milk boxes, espresso machine parts and respond to instructional prompts. Additionally, hygienic procedural logic was programmed to simulate the outcomes of both proper and improper hygiene practices, offering immediate visual and auditory feedback to guide user behavior. To ensure a smooth and immersive experience, performance optimization was carried out to maintain consistent frame rates and prevent motion sickness on the target VR hardware.

Usability Testing

The final phase of the project centered on usability testing to assess the VR application's effectiveness, ease of use, and educational impact. This iterative process began with recruiting a diverse group of participants, including individuals with varying levels of experience in both coffee handling and VR technology. Participants were asked to perform specific tasks within the virtual environment that related to coffee hygiene and safety. Throughout the testing, both quantitative data—such as task completion rates, time spent, and error frequency—and qualitative data—such as user feedback and behavioral observations—were collected to evaluate the application's performance. The insights gained from this data were then used to identify areas needing improvement, including content clarity, user interface design, interaction mechanics, and overall learning outcomes. These findings informed subsequent refinements to enhance the application's usability and pedagogical effectiveness.

SafeBrew VR Design and Development

The foundational learning content for SafeBrew VR was gathered from two primary, authoritative sources to ensure comprehensive and accurate pedagogical material. Firstly, critical food safety principles and best practices were derived from the official food handling training curriculum mandated by the Malaysian Ministry of Health. This nationwide training program, a compulsory requirement for all individuals involved in food handling, provides a robust framework for general food hygiene, and its associated learning materials are readily accessible through public domain internet resources, allowing for thorough review and integration of fundamental safety protocols (Savelli et al., 2019; Naji et al., 2022). Secondly, to enrich the content with specialized, industry-specific knowledge pertaining directly to coffee preparation, proprietary learning materials were acquired from a reputable barista training company. This access was facilitated through a collaborative meeting, wherein the company generously granted permission to examine and utilize their comprehensive instructional modules, which detail advanced techniques and refined hygienic practices relevant to professional coffee environments. Collectively, these diverse yet complementary sources furnished a holistic and authoritative knowledge base, underpinning the educational efficacy of the VR training module. Table 1 shows the main scenes of SafeBrew VR.

Table 1. SafeBrew VR Main Scenes.

Scene	Description
Scene 1: Main Entrance	This scene shows the main entrance to the coffee shop
Scene 2: Hygiene	This scene contains narration regarding hygiene in coffee preparation such as hand washing, proper attire and cleaned utensils.
Scene 3: Raw Materials	The scene is set in a coffee shop's storage area, containing milk (kept in a cooler) and coffee beans as raw materials.
Scene 4: Espresso Machine	This scene takes place at the coffee shop counter, where the user, acting as a barista, uses the espresso machine to prepare a cup of coffee.

Figure x shows the system flow diagram for the SafeBrew. The flow outlines a structured user journey beginning at the "Scene 1 Main Page," which presents three initial options: "About," "Exit," and "Start." Selecting "Start" leads the user into the core interactive experience, branching into three main scenes. "Scene 2 Hygiene" that focuses on hygiene practices in coffee making. "Scene 3 Raw Materials" explores the foundational elements of coffee making, offering hygiene practices for handling "Milk," and "Coffee Bean". Meanwhile, "Scene 3 Coffee Preparation" delves into the actual process of making coffee which involves the use of the "Espresso Machine" parts and "Sink" which is used for cleaning the espresso machine parts. This flow ensures a comprehensive and immersive learning experience within the VR environment.

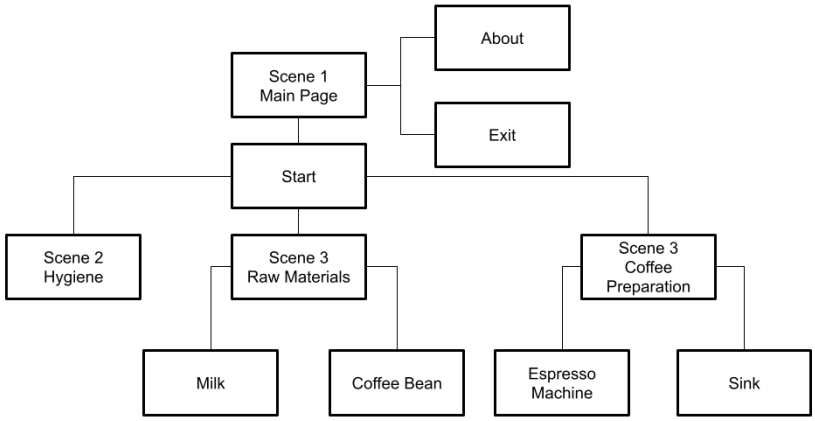

Figure 1. SafeBrew VR Scene Structure.

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Fig. 2 shows the scene for Scene 3: Raw Materials. This scene has gamification elements in which it prompts the user to check each item's expiry date and dispose of any that are expired given the current date displayed on the wall. The user must complete this task within a specified time frame. The activity requires the user to pick up boxes of milk from the cooler and check its expiration date. If it has expired, the user must dispose of the milk into a garbage bin. A similar action is required for coffee beans which shown on the right screen in Fig. 2. The coffee beans are placed on shelving units as shown in Figure x. The user has to dispose of the coffee beans into a nearby garbage bin.

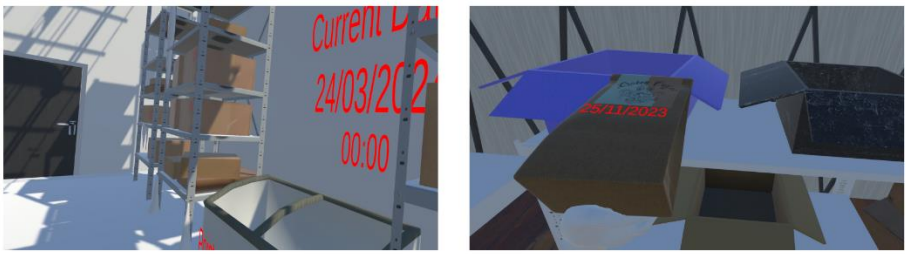

Figure 2. The Scenes from Scene 3: Raw Material

Fig. 3 shows the scene for Scene 4: Espresso Machine. In this scene, user will play the role as barista in preparing a coffee. Figure x shows a standard espresso machine. User begins the coffee making activity by pouring the fresh coffee bean into the grinder and grind it to a fine, consistent texture, crucial for proper extraction. Then, the user will dose and tamp the coffee into your portafilter basket, aiming for an even, firm puck. Once the portafilter is locked into the group head, you can extract the espresso shot. The used coffee grounds in the portafilter, often referred to as a "puck" after extraction, are thrown away into the sink. The activity is complete after the user place the portafilter back into the espresso machine's group head.

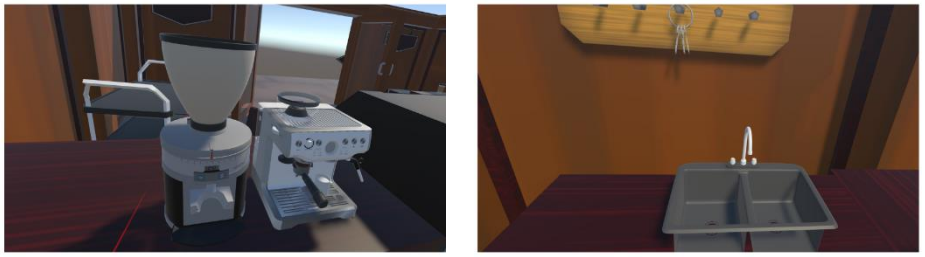

Figure 3. The Scenes from Scene 4: Espresso Machine

Usability Testing

Six participants tested the SafeBrew VR application in terms of its usability. These participants are primarily affiliated with a coffee shop located at a university. Their roles range from part-time baristas to more experienced staff, including a captain (supervisor-level role). From the interviews, it is learned that most participants have hands-on experience with coffee preparation and have undergone food handling training under Malaysia's Ministry of Health (KKM). Some received this training online, while others attended in-person sessions. Their familiarity with coffee-making tools and procedures, such as using espresso machines, checking expiry dates, and maintaining hygiene, provides a practical basis for evaluating the VR app.

The primary goal of the usability test is to identify usability strengths and areas for improvement to ensure the application meets the needs of its intended users and supports the learning objectives effectively. This protocol provides a structured approach for conducting the test sessions, collecting both quantitative and qualitative data, and analyzing results to inform future design iterations. The outcomes of this usability testing will contribute to refining the VR application to enhance its usability, accessibility, and educational impact for a diverse range of users.

Table 2. SafeBrew VR Usability Testing Results.

Usability Components	Mean	Standard Deviation
Consistency and Design Clarification	4.44	0.62
User Comfortability	4.07	1.00
Engagement and Satisfaction	4.57	0.68
Learning Factors	4.08	0.94
Language and Terminology	4.39	0.70
Control and Accessibility	4.5	0.84

Table 2 shows the results of the usability testing. From the usability testing, most participants appreciated the visual clarity, realistic graphics, and immersive experience of the VR environment. They found the app generally aligned with real-world coffee-making processes, especially in terms of hygiene practices and espresso machine operations. However, several participants noted that some steps were missing, such as disposing of used coffee grounds or steaming milk for lattes. They also pointed out that text instructions were lacking in certain parts, particularly during the espresso machine segment, which made navigation and task execution more difficult.

Participants also shared technical and ergonomic challenges, such as eye-level misalignment, controller responsiveness issues, and initial dizziness when using the VR headset. Despite these issues, many agreed that SafeBrew could serve as a valuable training tool, especially for reducing training costs and providing foundational knowledge before hands-on practice. Suggestions for improvement included adding vibration feedback, more detailed instructions, pre-training videos, and additional interactive elements like customer service scenarios or staff coordination tasks. Overall, the feedback was positive, with most participants rating the app between 4 and 4.5 out of 5 stars and supporting its use in barista training programs.

Overall, the user experience appears to be generally good. This conclusion is primarily supported by the high average ratings across most questions. The majority of mean scores are well above 4.0 (on a scale that likely goes up to 5, given the max values), indicating that participants generally agreed with positive statements or found the aspects being tested to be satisfactory.

CONCLUSION

This usability assessment of SafeBrew VR, a novel training tool for coffee handling and hygiene, reveals a generally positive user experience. Participants largely appreciated the visual clarity, realistic graphics, and immersive qualities of the VR environment. The application was found to align well with real-world coffee

preparation processes, particularly concerning hygiene practices and espresso machine operations. Quantitative metrics for user satisfaction and engagement also reflected positive feedback, with most participants rating the app between 4 and 4.5 out of 5 stars and supporting its use in barista training programs. Specific areas such as "Consistency and Design Clarification," "Engagement and Satisfaction," and "Control and Accessibility" demonstrated high average mean scores, indicating strong user reception.

However, the study also identified several areas for improvement. Common feedback included the absence of certain steps, such as proper disposal of used coffee grounds or the steaming of milk for lattes. Participants noted a lack of clear text instructions in some segments, particularly within the espresso machine scene, which sometimes hindered navigation and task execution. Technical and ergonomic challenges were also reported, including issues with eye-level alignment, controller responsiveness, and initial dizziness experienced by some users. Despite these challenges, there was broad consensus that SafeBrew could serve as a valuable training tool, particularly for its potential to reduce training costs and provide foundational knowledge prior to hands-on practice.

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