

Development of a Virtual Reality Baking Lab Application for Bakery Students at UTHM : KitchenLab

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DOI: <https://doi.org/10.30880/aitcs.2025.06.02.100>

Article Info

Received: 13 June 2025

Accepted: 19 Nov 2025

Available online: 30 Nov 2025

Keywords

Virtual Reality, Baking, TRES-D,
Culinary Students,

Abstract

The Bakery and Pastry Arts course at UTHM is designed to equip students with essential baking knowledge and hands-on skills through practical modules and kitchen-based training. However, traditional methods face challenges such as high resource consumption, time constraints, and limited practice opportunities. To overcome these issues, KitchenLab was developed as an innovative Virtual Reality (VR) application tailored for UTHM bakery students. Guided by SME Dr. Siti Hajar Binti Zakariah, the app follows the TRES-D methodology, which emphasizes iterative evaluation, design, development, and testing. KitchenLab simulates critical baking stages, including preparation, proofing, and baking, offering an immersive and efficient learning alternative. To assess usability, the System Usability Scale (SUS) was administered to 20 UTHM bakery students. The application achieved an average SUS score of 73.75, indicating above-average usability and positive user acceptance among its target users.

1. Introduction

The Universiti Tun Hussein Onn Malaysia (UTHM) provides an extensive baking course designed to prepare students with vital skills in the culinary field. This program focuses on hands-on training to ready students for careers in professional baking settings. Nonetheless, conventional teaching methods encounter various obstacles, such as expensive materials, inefficient resource use, and restricted opportunities for practical experience because of time and facility limitations. These obstacles impede the success of baking education, necessitating the investigation of inventive strategies that can connect theory and practice while fostering sustainability [1][2].

In recent years, Virtual Reality (VR) has developed into a significant resource for improving education and training in multiple areas. Through engaging users in virtual settings, VR provides an unmatched degree of interactivity and involvement, making it especially beneficial for skill-oriented education. Research has shown that VR can enhance learning results, lower training expenses, and offer a secure and regulated setting for practice [3][4].

Using these abilities, KitchenLab was established as a VR-technology approach to address the issues encountered in UTHM's baking curriculum. At present, the baking program depends on conventional teaching approaches, requiring students to invest significant time to acquire the skills. Nonetheless, these techniques have considerable disadvantages. A major issue is the substantial food waste produced during training, as novice students frequently make mistakes while trying out new recipes and methods. This not only raises the expense of running the kitchen but also adds to worldwide environmental issues related to food waste. Furthermore, the conventional arrangement fails to mimic the high-pressure environments of professional kitchens, which are

essential for fostering time management and multitasking abilities. VR technology was chosen to solve the challenges in UTHM's baking education due to its ability to create realistic, interactive learning environments. KitchenLab uses motion tracking and simulations to let students safely practice baking skills, reduce food waste, and handle tasks under time pressure—skills that are hard to teach in traditional labs. As supported by Mulders et al. [5] and Xie et al. [6], VR training improves accessibility and helps students learn more flexibly, making KitchenLab a modern, effective solution for baking education.

The anticipated results of this research involve developing a comprehensive VR application that aligns with educational goals, lowers training expenses, and reduces material waste. KitchenLab aims to act as a prototype for incorporating VR into vocational education, showcasing its capacity to transform learning in resource-heavy sectors. The remainder of this paper is structured as follows: Section 2 examines relevant studies and technologies in VR-oriented education. Section 3 outlines the approach taken to create KitchenLab, which incorporates the TRES-D framework. Section 4 provides the findings and assessment of the application, whereas Section 5 explores the implications, constraints, and possible future advancements. Ultimately, Section 6 wraps up the research by summarizing the main findings and offering recommendations.

2. Related Work

This section discusses the background of the study, the technology used, and the result of the comparative analysis

2.1 Baking Subject for UTHM's Culinary students

Baking has become an important part of education, offering hands-on skills that go beyond the classroom. Often taught in home economics or culinary courses, baking helps students learn both the art and science behind it. Like chemistry, it involves heat, chemical reactions, and precise measurements. Success in baking depends on understanding these concepts to achieve the desired results.

At UTHM, students in the bakery program generally participate in one 2-hour lecture each week, where they study the theoretical elements of baking, including fermentation, chemical reactions, and the scientific principles of baking methods. Furthermore, they engage in a weekly 8-hour laboratory practical session, where they refine their baking abilities through practical exercises. In these hands-on sessions, students don chef coats and hats, fully engaging in a professional kitchen setting.

Like any skill, teaching baking should adapt to different student needs. Using modern technologies like virtual reality (VR) can greatly enhance learning. VR allows students to practice in realistic, safe environments, making it easier to understand complex baking techniques. This approach is similar to other subjects like chemistry, where digital tools help improve learning and engagement.

2.2 Virtual Reality

Virtual reality (VR) is a 3D simulation technology that allows users to experience and interact with digital environments in real time, creating a strong sense of presence [7]. VR comes in three main types: non-immersive, semi-immersive, and fully immersive. Fully immersive VR offers the highest level of interaction using tools like headsets, sensors, and haptic devices to deeply engage users [8]. VR is now widely used across fields like gaming, healthcare, and especially education [9]. In learning environments, fully immersive VR enhances student engagement by simulating realistic tasks and environments. This is particularly useful in baking education, where students can practice skills—such as kneading, temperature control, and decorating—without needing physical ingredients or tools. Despite its potential, VR baking apps tailored to UTHM's curriculum are limited. KitchenLab addresses this gap by offering a sustainable, hands-on VR solution that supports skill mastery while minimizing food waste [10].

2.3 VR-enhanced Learning

The KitchenLab project adopts a learning strategy that emphasizes the incorporation of virtual reality (VR) to improve baking education by offering students an engaging and interactive setting. This method enables students to hone and improve their abilities in a virtual kitchen, mimicking real-life situations without the limitations of a physical classroom. Using VR, learners can participate in practical tasks like ingredient preparation, mixing, and baking, providing a more profound insight into baking methods and procedures [11]. Studies suggest that VR-enhanced education has been proven to boost student involvement and memory retention by providing a more interactive and hands-on learning environment [12]. Moreover, utilizing VR enables customized learning, as learners can progress at their own speed, review challenging tasks, and obtain immediate feedback [13]. The integration of VR in baking education overcomes the drawbacks of conventional techniques

and offers UTHM students a chance to develop essential skills in a safe, regulated setting, thereby enhancing their comprehension and expertise in baking [14].

2.4 Comparative Analysis

A comparative study was performed on three VR applications related to the suggested KitchenLab system: IKEA VR Pancake Kitchen, The Cooking Game VR, and Lost Recipes. These applications were assessed according to six main features: VR technology, virtual setting, intended user, hardware, app content, and pricing. Although all these applications provide an engaging experience for cooking and baking, they vary in their VR technology, content emphasis, and target audience. The analysis intends to showcase the advantages and drawbacks of these current solutions and illustrate how KitchenLab can meet educational requirements for UTHM bakery students, especially in baking sourdough and blueberry muffins.

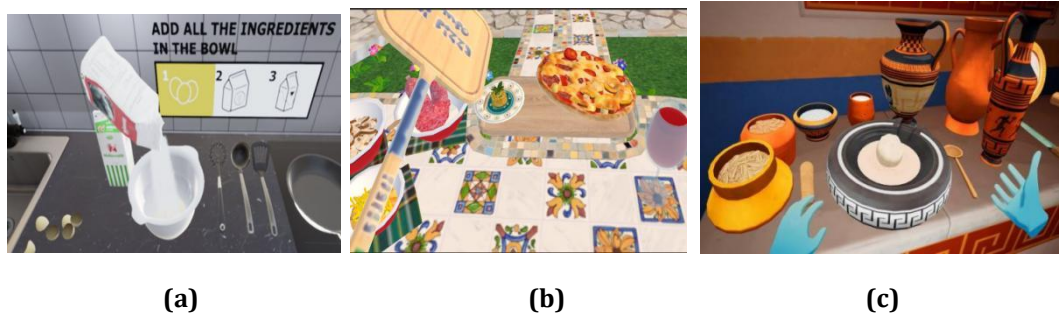


Fig. 1 Similar VR application (a) IKEA VR Pancake kitchen; (b) The cooking game VR; (c) Lost recipes

Table 1 Application Comparison

Feature/Apps	Lost recipes	IKEA VR pancake kitchen	The cooking game VR	KitchenLab
VR technology	room scale VR with hand tracking	Non-immersive VR with basic hand interactions	Room-scale VR with immersive touch controllers	Fully immersive
Virtual location	Historical kitchens	IKEA styled kitchen	Virtual restaurant	UTHM bakery kitchen
Target user	Casual VR gamers	IKEA customer	Casual VR gamers	UTHM bakery students
Hardware	Oculus Rift, Meta quest devices	PC VR setup	Oculus Rift, Meta quest devices, PC VR-compatible setups	Meta quest device
App content	Historical recipes	Basic pancake task	Comprehensive restaurant gameplay	Training of basic baking recipes
Cost	\$10 USD	Free	\$20 USD	Free

3. Methodology

The KitchenLab has been developed using the TRES-D methodology, as depicted in Fig. 2. This is so because VR application development is the focus of the TRES-D methodology [15] and for its comprehensive coverage of the development process. The six phases of this methodology are the initial requirement phase, understand requirement phase, concept design phase, iterative design phase, development phase, and testing phase. The iterative design process contains two more sub-phases, abstract design and presentation design. In this project, deployment and maintenance phase will not be conducted. Some slight modifications have been made to the TRES-D methodology to fit this project Table 7 to provides a summary of the output of the six phases of the TRES-D methodology.

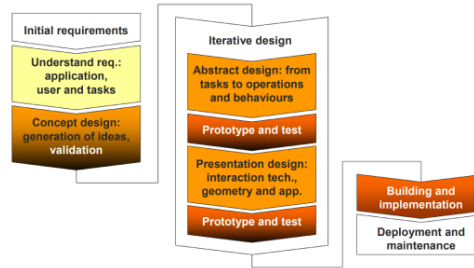


Fig.2 TRES-D Methodology

3.1 Initial Requirement Phase

In this first phase, the initial requirements needed for the development of the KitchenLab are determined. This phase involved reviewing existing applications, interview with Subject Matter Expert (SME), and a questionnaire from the target user, culinary students, which was conducted through Google Forms. An interview session has been conducted with SME, Dr Siti Hajar Binti Zakariah, who is teaching Bakery And Pastry Skills at Fakulti Pendidikan Teknikal Dan Vokasional, UTHM. A total of 41 respondents is participating in this questionnaire. As a result, an initial requirement checklist has been created, as shown in Table 2. Meanwhile, Table 3 shows the user analysis extracted from an interview with SME and a questionnaire.

Table 2 Initial requirement Checklist

Item	Description
Type of application	<ul style="list-style-type: none"> Simulation application
Objectives	<ul style="list-style-type: none"> Design KitchenLab application using virtual reality approach. Develop KitchenLab application using Unity technology. Test the functionality and usability of the developed application on the UTHM Bakery Student.
Target Platform	<ul style="list-style-type: none"> Android-Based
Target Device	<ul style="list-style-type: none"> Oculus Meta Quest
Targets Users	<ul style="list-style-type: none"> UTHM's culinary students
Content	<ul style="list-style-type: none"> Bakery subject focuses on practical lab
Technology used	<ul style="list-style-type: none"> Virtual Reality (VR)

Table 3 User Analysis

Stakeholder Category	Role in product	Design Implication	Action needed
Subject Matter Expert (SME) Dr Siti Hajar Binti Zakariah	Content consultant expert in Bakery subject	Less use of words, simple sentences	Use more icon based, use simple sentences
		Multimedia Content	Put audio such as music and sound fx. Put images
		User friendly	Use the start, play, next, previous, and home buttons to navigate the user to relative pages.
		Content, based on the UTHM baking syllabus	Follow the main the recipe based on UTHM baking syllabus. Example soft rolls and blueberry muffin
UTHM's Bakery Student	End-user of proposed application	User preferences	The application should be developed on Meta Quest devices. Audio and music should be implemented.

3.2 Understand Requirement Phase

In this second phase, it is necessary to understand the requirements needed to develop this project. The structure of the application to be developed is analyzed in this phase. Table 4 and Table 5 show the Functional and non-functional requirements of the proposed application. The system flowchart, navigation structure, diagram, and content structure of each module flowchart application module are shown in Appendix B to Appendix G.

Table 4 *Functional requirements*

Functional requirement	Module/ scene	Description
Autonomous system activities	Practical Module	The sound and music should play when the users enter the Practical Module.
Learning/practice Content	Practical Module	The application should allow users to practice 2 different types of recipes.
User interaction	Onboard Interface	The application should allow users to click on the Start button to go to the main menu page.
	Main Menu	The application should allow users to select the Practical Module and Setting buttons.
	Practical Module	The application should allow users to select two different recipes they want.

Table 5 *Non-functional requirements*

Non- functional requirements	description
Performance	The applications should be able to perform and load all the modules and pages. The average respond of the application is 2 seconds.
Legal	Users should only be able to view the content of the application and are not able to edit or modify the content
Usability	Users should be able to access the application everywhere, and anywhere they want if they have the hardware required for the application to run.
Operational	The application should be able to operate on Meta Quest devices with an Android-based platform.

3.3 Concept Design Phase

The third phase of the TRES-D methodology involves defining the concept design for KitchenLab. Based on insights from SME interviews, user questionnaires, and application reviews, this stage outlines the key tasks users will perform in the VR environment such as preparing, proofing, and baking. These user actions guide the design of interactive elements, ensuring the application meets practical learning needs. Table 6 illustrates the button design integrated during this phase.

Table 6 *Button Design*














Button	Description
	<ul style="list-style-type: none"> ● Start button ● It navigates the user to the main menu
	<ul style="list-style-type: none"> ● Labelled button for encyclopedia ● It will bring the user to the encyclopedia
	<ul style="list-style-type: none"> ● Setting button ● It will bring user to setting page
	<ul style="list-style-type: none"> ● Back Button ● It will bring user to page before
	<ul style="list-style-type: none"> ● Recipe 1 button ● It will bring user to recipe 1 activities
	<ul style="list-style-type: none"> ● Recipe 2 button ● It will bring user to recipe 2 activities

Table 6: *(continued)*

	<ul style="list-style-type: none"> ● Music button ● It will bring user to music setting
	<ul style="list-style-type: none"> ● Sound fx button ● It will bring user to sound effect setting
	<ul style="list-style-type: none"> ● Volume up and down button ● It will adjust the volume according to user's need
	<ul style="list-style-type: none"> ● Pause button ● It will pause the simulation according when user's need
	<ul style="list-style-type: none"> ● Home button ● It will bring user to the main homepage ● Appear when user press pause button during simulation
	<ul style="list-style-type: none"> ● Settings button ● It will bring user to setting page ● Appear when user press pause button during simulation
	<ul style="list-style-type: none"> ● Restart button ● It will restart the whole scene

3.4 Iterative Design Phase

The fourth phase of the TRES-D methodology is iterative design, an essential step that guarantees ongoing enhancement and perfection of the project. This stage features a repetitive process of creating, evaluating, collecting input, and enhancing to reach the best design outcome. Iterative design is made up of two primary sub-phases: abstract design and presentation design. During the abstract design phase, the emphasis is on developing a conceptual framework that defines the essential functionality and architecture of the system. This includes outlining the user interface arrangement, interaction progression, and essential design features without getting into specific aesthetics. The presentation design stage expands on the abstract design by incorporating visual elements, colors, and styles, enhancing the design's engagement and aesthetic appeal. A vital part of the iterative design process is user feedback, collected after each sub-phase to assess the design's efficacy and pinpoint areas needing enhancement. Users participate at various phases to guarantee the design meets their requirements and expectations. Input language feedback gathered in this stage is methodically examined to identify inadequacies or flaws in the design. After feedback is examined, adjustments are made to resolve the noted problems. This could entail adjusting interface designs, refining navigation, or upgrading visual components to more effectively satisfy user needs. The cyclical aspect of this method facilitates ongoing improvements, guaranteeing that the end product is user-focused, practical, and visually appealing. Sections 3.4.1 and 3.4.2 offer a thorough explanation of the abstract design and presentation design phases.

3.4.1 Abstract Design Phase

The portion of the design that is platform-independent is the focus of this sub phase. Plans of the virtual environment is created, showing where things are located and how to get around. The objects' behaviors and their responses to user input are identified. The decomposition of the tasks leads to the identification of individual operations, which are functions that can be applied to specific objects. These operations are specified with respect to their preconditions, parameters, and outcomes, and they provide a high-level dialogue between the user and the objects. These are the items' abstract perspectives. A detailed storyboard is attached in Appendix I.

3.4.2 Presentation Design

In this phase, the visual and interactive aspects of the application are analyzed. The low-level conversation is now covered in depth, beginning with the choice of interaction styles for every operational group. Each operation's necessary information is then converted into one or more fundamental interaction tasks. These tasks are linked to specific interaction techniques, and the behavior of the techniques is then defined in terms of actions performed by the input device. Figure 3 presents the interface design of the KitchenLab application.

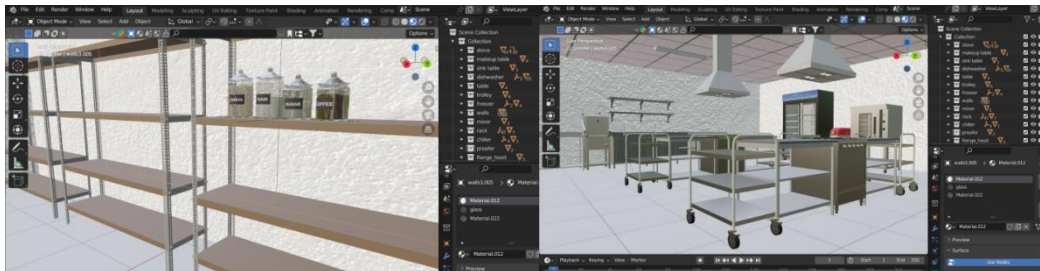


Fig. 3 the presentation design

3.5 Development Phase

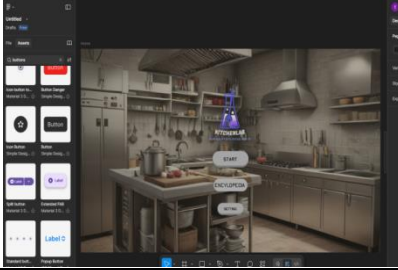

In this phase, the first thing to do is select the suitable development tools for the development of the VR application. After the development software is decided, the 3D model designed through Blender software will be integrated into the Unity software to ensure proper scaling and alignment. In this phase, the main functions of the application are also developed. The application has one module, the practical modules. User interactions are implemented using VR controllers and other input methods. In this part, the navigation of how users select objects and interact with the VR environment is determined through programming and scripting. The C# script is used to do the programming for the user interaction implementation. Thorough testing and debugging are carried out to find and fix any problems, and testing input is used to inform incremental improvements to the user interface and overall experience.



Fig 4. the application development process

Table 7 Application assets development

Assets	Development	Description
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Graphics		<p>Figma was utilized to design and integrate the storyboards and background elements for the KitchenLab application. Additionally, user interface components such as buttons and icons were crafted within Figma, ensuring a consistent visual identity across the application.</p>
Audio		<p>Audio elements for the KitchenLab application were sourced from Freesound.org, a collaborative database of Creative Commons licensed sounds. Once selected, the audio clips were edited and refined using MP3Cut.net, allowing precise trimming and adjustment to fit the application's requirements.</p>

Subsequently, C# scripting was implemented to ensure the core functionalities of the VR KitchenLab application operate smoothly. These functionalities include the recipe book interaction, scene transitions, background music and sound effect controls, gameplay management, and pause menu activation, as outlined in Table 8.

Table 8 *Integration in Unity*

Functions	C# Scripts	Description
Audio Manager	<pre>public void PlayMusic(AudioClip clip) {if (clip == null musicSource == null) return; musicSource.clip = clip; musicSource.Play(); }</pre>	<p>The AudioManager script manages background music and sound effects in the VR KitchenLab application using a singleton pattern to ensure only one instance persists across scenes. It uses two audio sources—one for music and one for SFX—and loads audio clips into a dictionary for quick access by name. On start, it plays assigned background music and applies saved volume settings. The script allows playback of audio clips by reference or name and supports real-time volume adjustments, storing changes with PlayerPrefs.</p>
Main Menu selection	<pre>public void QuitGame() {Application.Quit(); } public void SelectSourdough() {SceneManager.LoadScene("Sourdough scene");}</pre>	<p>This script handles basic scene transitions and quitting the application in VR KitchenLab. The QuitGame() function exits the application, while SelectSourdough() and Selectblueberrymuffin() load the respective VR scenes for the Sourdough and Blueberry Muffin recipes using Unity's SceneManager.</p>

Table 8: (Continued)

Encyclopedia	void UpdateUI()	This script manages the encyclopedia feature in VR KitchenLab, allowing users to view information about various items like ingredients, tools, or machines. It stores each item's title, description,
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	<pre>{nameitems.text = items[currentIndex].ti tle; descriptiontext.text = items[currentIndex].d escription;} void NextItem() {if (currentIndex < items.Length - 1) {currentIndex++;Upda teUI();}}</pre>	<p>and image in an array and displays the current item’s details using Unity UI elements. The NextItem() and PreviousItem() functions let users navigate through the items with corresponding buttons, while UpdateUI() updates the display content based on the current index.</p>
UI follow the camera	<pre>public class UIFollowCamera : MonoBehaviour {void Update() { Vector3 lookDirection = cameraTransform.posi tiontransform.position ; lookDirection.y = 0; // Lock Y axis transform.forward =lookDirection.normal ized;}}</pre>	<p>This script makes a UI element (like a menu or label) always face the player's camera in VR KitchenLab. It updates every frame to adjust the UI's forward direction toward the camera's position, keeping the Y-axis locked to prevent tilting up or down, ensuring the UI stays upright and readable.</p>
Book Recipe	<pre>public void StartRecipe() {closedBook.SetActive (false);openBook.SetA ctive(true); }</pre>	<p>This script manages the interactive recipe book in the VR KitchenLab app. It handles switching between a closed and open book model and displays step-by-step cooking instructions using UI elements like title, description, and images. Users start the recipe by pressing the Start button, which reveals the open book and the first step. Navigation is handled with Next and Previous buttons, which only become active when conditions are met (e.g., a step is marked completed). The ShowStep() function updates the UI for the current step, and MarkStepDone() allows external scripts to validate completed steps.</p>
Trigger collision	<pre>public class ObjectCollisionTrigger : private void OnCollisionEnter(Colli sion collision) { // For trigger- based detectionif (other.gameObject == targetObject) {onCollisionEvent.In voke(); }}</pre>	<p>This script allows you to trigger custom events when a specific object collides or enters a trigger zone in the VR KitchenLab environment. You assign a targetObject, and when it either collides (OnCollisionEnter) or enters a trigger area (OnTriggerEnter) with this script's GameObject, the assigned onCollisionEvent is invoked—enabling actions like playing a sound, showing a UI, or changing scenes.</p>
Mixer Controller	<pre>public void StartMixing() { Debug.Log("Button Pressed!"); // TEMP: override for testing ingredientsPoured = true;}</pre>	<p>This script manages the dough mixing process within the VR KitchenLab application. Upon activation of the mixing function, the system verifies whether the necessary ingredients have been poured; for testing purposes, this condition may be overridden. The mixing arm then rotates continuously for a predefined duration to simulate the mixing action. Following the completion of the mixing phase, a dough object is instantiated at a designated spawn point, and all ingredient models involved in the process are hidden from the scene to reflect their usage.</p>

Table 8: (Continued)

Proofing machine controller	<pre>public void StartProofing() {if (isProofing) { Debug.Log("Proofing already in progress..."); return;}}</pre>	This script controls the proofing process of dough within the VR KitchenLab environment. It manages indicators such as red and green lights to reflect the proofing status and ensures that proofing only begins when the dough bowl is inside the proofing chamber and the door is securely closed. The proofing process lasts for a predefined duration, after which the dough's size is adjusted to simulate the rising effect. Proper checks are included to handle the door's state and the presence of required objects, providing realistic feedback and interaction during the proofing stage of the baking simulation.
Oven Controller	<pre>public void StartBaking() {bakingStarted = true; greenLight.SetActive(false); redLight.SetActive(true);}</pre>	This OvenController script manages the baking process within the VR KitchenLab environment. It controls oven status indicators such as green and red lights to reflect readiness and active baking states. The script tracks baking parameters including selected time and temperature, and whether the dough tray is correctly placed inside the oven. Upon satisfying these conditions, the baking process can be initiated through a UI button. The baking routine waits for the specified duration, then replaces raw dough models with either well-cooked or overcooked variants depending on the baking settings. The script also ensures proper parenting and positioning of cooked dough objects at designated spawn points. It maintains the oven's interactive state, disables the start button during baking, and resets parameters once the baking cycle completes, thereby simulating realistic baking behavior and feedback in the virtual environment.
Door trigger	<pre>public void ToggleDoor() {spring.spring = 500f; spring.damper = 10f;spring.targetPosition = isOpen ? closedTarget : openTarget;}</pre>	The DoorToggleButton script enables toggling the state of a hinged door within the virtual environment. It controls a HingeJoint component to smoothly open or close the door by adjusting the spring's target position. The door angle targets for open and closed states are configurable, with default values set to 0 degrees for closed and -90 degrees for open (assuming the door opens along the negative Z-axis). Upon toggling, the script updates the hinge's spring parameters including stiffness and damping to ensure realistic motion. This implementation allows interactive door control in VR, enhancing user immersion by simulating physical door mechanics.
Oven setting	<pre>public class OvenSettingSelector : MonoBehaviour {public OvenController ovenController; public static int selectedTime = 0; public static int selectedTemp = 0;}</pre>	The OvenSettingSelector script serves as an interface component for selecting and applying baking time and temperature settings to an OvenController. It provides public methods, SetTime and SetTemperature, which update the corresponding properties in the linked OvenController instance. These methods also output debug logs to assist with tracking user selections during development. The static fields selectedTime and selectedTemp maintain the currently selected baking parameters, ensuring consistent state management across the system. This script facilitates user interaction with the oven's baking configuration, enabling dynamic adjustments to baking conditions within the application.

4. Testing stage

The testing process is the last and most important step in creating multimedia mobile content to make sure the application works as planned. The general operation of the program, the precision and integrity of its content, and the potency of its multimedia components are all thoroughly assessed during this phase. Functional testing is carried out to ensure that every feature functions accurately and consistently, as shown in Table 9. Additionally, as explained in Section 4, the System Usability Scale (SUS) is used to evaluate the entire user experience and usability of the program. Multiple cycles of the testing procedure enable the detection and fixing of any flaws, guaranteeing that the application is fully improved and optimized before release.

Table 9 Functional testing

Test	Expected Result	Actual Result	Corrective action
Play button	Navigate to recipe selection	Work well as expected	Not needed
Encyclopedia button	Navigate to items info	Work well as expected	Not needed
Setting button	Navigate to settings panel	Work well as expected	Not needed
Quit button	Close the app	Work well as expected	Not needed
Back button	Navigate to previous panel	Work well as expected	Not needed
Soft rolls Button	Navigate to soft rolls scene	Work well as expected	Not needed
Blueberry muffin button	Navigate to blueberry muffin scene	Work well as expected	Not needed
Next items button	Change to next items	Work well as expected	Not needed
Previous items button	Change to previous items	Work well as expected	Not needed
Music slider	Change the music background volume	Work well as expected	Not needed
Sound fx slider	Change the sound fx volume	Work well as expected	Not needed
Pause button	Navigate to pause panel	Work well as expected	Not needed
Restart button	Restart the whole scene	Work well as expected	Not needed
Main menu button	Change to main menu scene	Work well as expected	Not needed
Start recipe button	Open the recipe book	Work well as expected	Not needed
Next step button	Show the next recipe step	Work well as expected	Not needed
Previous step button	Show the previous recipe step	Work well as expected	Not needed
Flour scoop	Scoop the flour into the scoop and pour into the mixer bowl	Work well as expected	Not needed
Egg	Crack the egg into the mixer bowl	Work well as expected	Not needed
Yeast	Pour the yeast grain into the mixer bowl	Work well as expected	Not needed

Table 9: (Continued)

Milk	Pour the milk into the mixer bowl	Work well as expected	Not needed
Butter knife	Cut a small pieces of butter and put into the mixer bowl	Work well as expected	Not needed
Mixer	Mix the ingredients inside the mixer bowl and spawn the dough	Work well as expected	Not needed
Proofing machine	Enlarge the dough	Work well as expected	Not needed
Oven machine	Bake the dough based on timer and temperature	Work well as expected	Not needed

4.1 System Usability Scale

The System Usability Scale (SUS) is a quick and simple usability evaluation tool consisting of 10 items rated on a Likert scale. It is designed to measure how easy and user-friendly a system or digital product is. The resulting score provides insight into the overall usability from the user's perspective. SUS is widely used because it is applicable to various types of systems and offers a clear overview of user experience with the technology being tested. Figure 5 shows the overall responds to the SUS questions while Figures 6 lists all the questions asked.

Responden	Skor Item										Skor Ganjil	Skor Genap	Jumlah Skor	Grading SUS Key	
	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10					
R01	4	3	3	4	1	4	2	5	3	2	8	7	37.5	92	Best imaginable
R02	4	2	4	2	2	5	1	4	2	1	8	11	47.5	85	Excellent
R03	5	2	5	4	2	4	2	4	3	2	12	9	52.5	72	Good
R04	4	2	4	4	2	3	1	4	4	2	10	10	50	52	OK/Fair
R05	5	3	3	3	3	3	3	3	3	3	12	10	55	38	Poor
R06	4	2	4	2	4	2	4	2	4	2	15	15	75	25	Worst imaginable
R07	5	3	4	2	4	2	4	4	4	3	16	11	67.5		
R08	4	1	4	1	4	1	4	2	5	3	16	17	82.5	>81	A
R09	5	2	5	1	4	2	5	1	4	2	18	17	87.5	68-81	B
R10	4	4	4	2	4	1	4	1	4	1	15	16	77.5	68	C
R11	5	5	5	3	5	3	3	2	2	2	15	10	62.5	51-67	D
R12	4	2	5	1	4	1	5	2	4	1	17	18	87.5	<51	F
R13	5	2	5	1	5	2	4	2	5	1	19	17	90		
R14	5	2	4	1	5	2	4	2	5	2	18	16	85		
R15	4	1	5	2	5	1	4	2	5	1	18	18	90		
R16	4	2	3	1	4	2	5	1	5	2	16	17	82.5		
R17	5	2	4	1	5	2	4	1	5	1	18	18	90		
R18	5	1	4	3	3	2	5	2	4	1	16	16	80		
R19	4	2	4	1	4	2	5	1	5	2	17	17	85		
R20	5	2	4	2	5	1	4	1	5	1	18	18	90		
											Skor Purata	73.75		1475	
														73.75	

Fig 5. SUS Average score

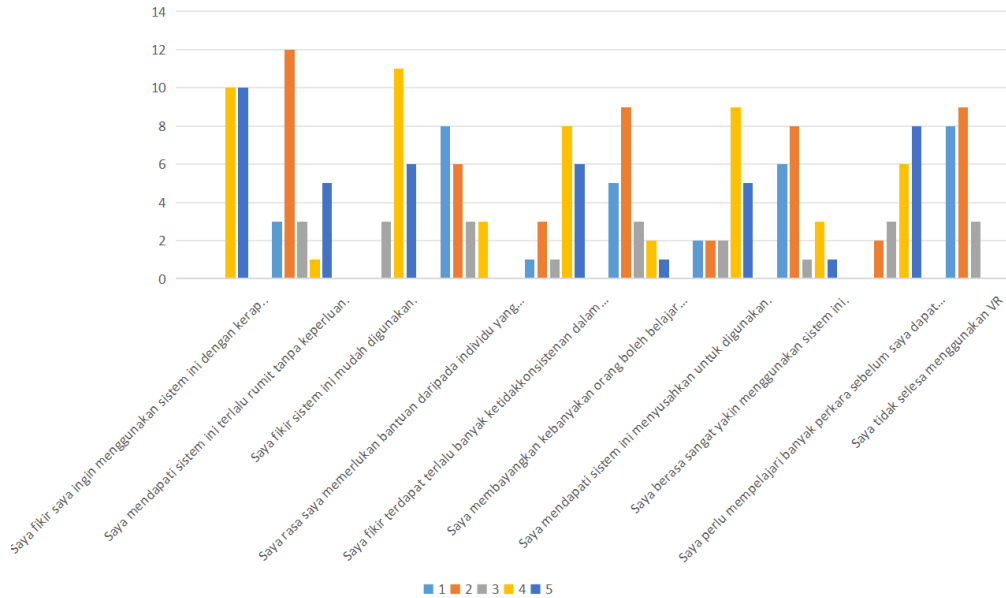


Fig 6. SUS Questions

The following formula was applied to get usability results based on the SUS:

$$Total\ score = (odd\ items + even\ items) \times 2.5$$

$$Average\ score = Total\ score / Total\ respondents$$

$$Odd\ items\ (Q1, Q3, Q5, Q7, Q9) = contribution - 1$$

$$Even\ items\ (Q2, Q4, Q6, Q8, Q10) = 5 - contribution$$

Therefore, Average score is = $(37.5 + 47.5 + 52.5 + 50 + 55 + 75 + 67.5 + 82.5 + 87.5 + 77.5 + 62.5 + 87.5 + 90 + 85 + 90 + 82.5 + 90 + 80 + 85 + 90) / 20 = 70.38$

20 respondents completed the System Usability Scale (SUS), and the results are displayed in the table. The average score was 73.75, and the total score was 1475.

5. Conclusion

The KitchenLab application was developed as an immersive virtual reality training tool designed specifically for bakery students at Universiti Tun Hussein Onn Malaysia (UTHM). The application allows users to simulate essential bakery procedures in a safe, repeatable, and waste-free environment. The main objective is to enhance students' practical skills by offering an interactive learning experience without depending on physical ingredients or equipment.

Several key components were successfully implemented, including baking mechanics such as preparing, mixing, proofing, and baking. Supporting features such as background music, sound effects, environmental lighting, a structured recipe book system, and an intuitive main menu interface contribute to a more engaging user experience. An encyclopedia module was also added to provide educational information about bakery tools, ingredients, and machines, reinforcing both theoretical and practical knowledge.

Two complete recipes, blueberry muffin and sourdough bread were included in the simulator, allowing students to follow step-by-step processes in a virtual environment. These modules were designed with attention to realism, usability, and educational value, enabling students to repeat activities for better understanding and skill retention.

A usability evaluation was conducted using the System Usability Scale (SUS), and the results indicated an average score which is 73.75 ranging from 68 to 81. According to the SUS grading scale, this corresponds to a Grade B, which is considered good. It demonstrates that the application is easy to use, effective in its functionality, and well-received by its target users. During the development phase, some challenges were encountered, particularly involving Unity configurations and code errors. These issues were identified and addressed to ensure smoother functionality and user experience.

Overall, the application meets its intended goals and has received positive feedback from users. It offers an efficient alternative for practical learning in baking, promoting hands-on skill development in a modern and sustainable way.

Acknowledgement

The authors would like to thank the Faculty of Computer Science and Information Technology, Universiti Tun Hussein Onn Malaysia for its support.

Conflict of Interest

Authors declare that there is no conflict of interests regarding the publication of the paper.

Author Contribution

This journal requires that all authors take public responsibility for the content of the work submitted for review. The contributions of all authors must be described in the following manner:

*The authors confirm contribution to the paper as follows: **study conception and design:** Ahmad Fahmi Mohd Faez, Che Samihah Che Dalim; **data collection:** Ahmad Fahmi Mohd Faez;; **analysis and interpretation of results:** Ahmad Fahmi Mohd Faez, Che Samihah Che Dalim; **draft manuscript preparation:** Ahmad Fahmi Mohd Faez, Che Samihah Che Dalim. All authors reviewed the results and approved the final version of the manuscript.*

An author name can appear multiple times, and each author name must appear at least once. For single authors, use the following wording:

The author confirms sole responsibility for the following: study conception and design, data collection, analysis and interpretation of results, and manuscript preparation.

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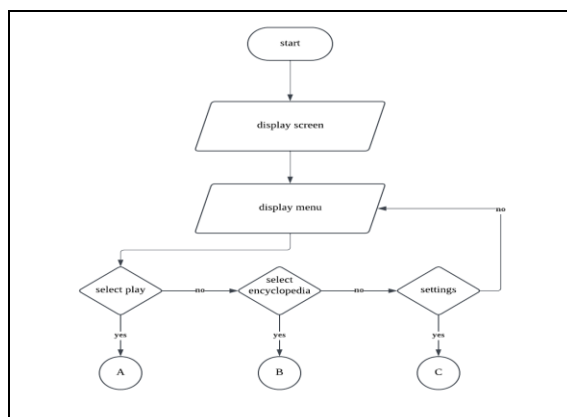
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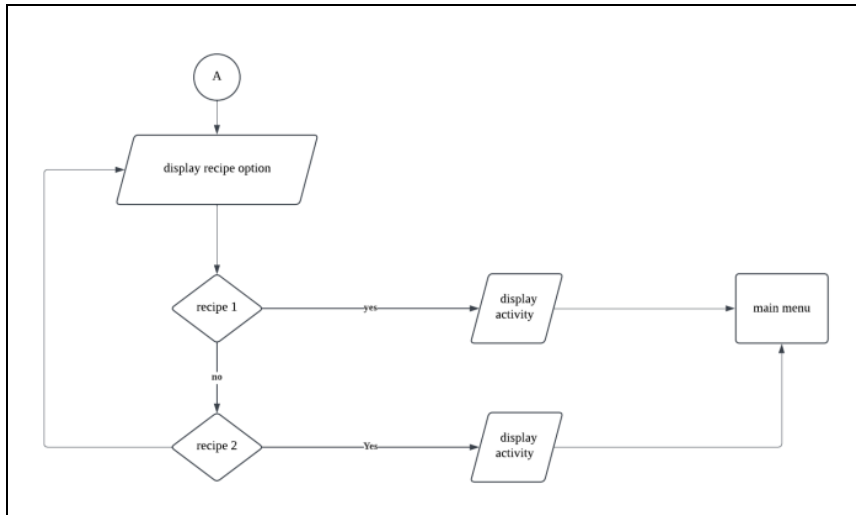
Appendix A : Questionnaire questions

1. Saya fikir saya ingin menggunakan sistem ini dengan kerap.
2. Saya mendapati sistem ini terlalu rumit tanpa keperluan.
3. Saya fikir sistem ini mudah digunakan
4. Saya rasa saya memerlukan bantuan daripada individu yang mahir dari segi teknikal untuk menggunakan sistem ini.
5. Saya fikir terdapat terlalu banyak ketidakkonsistenan dalam sistem ini.
6. Saya membayangkan kebanyakan orang boleh belajar menggunakan sistem ini dengan cepat
7. Saya mendapati sistem ini menyusahkan untuk digunakan.
8. Saya berasa sangat yakin menggunakan sistem ini.
9. Saya perlu mempelajari banyak perkara sebelum saya dapat menggunakan sistem ini.
10. Saya tidak selesa menggunakan VR

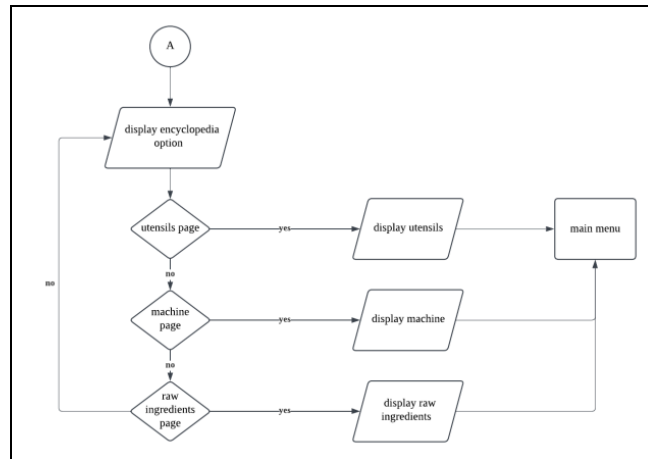
Appendix B : System Flowchart



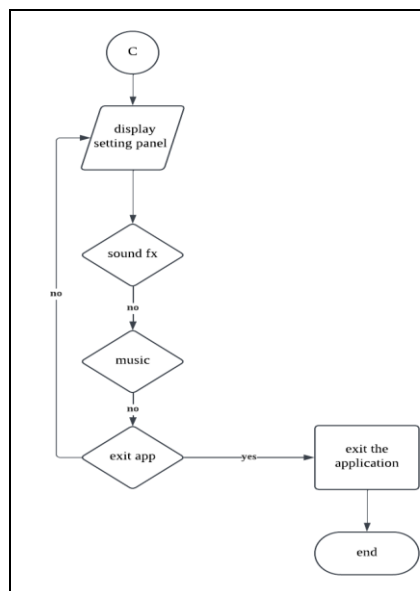
Appendix C : practical module Flowchart



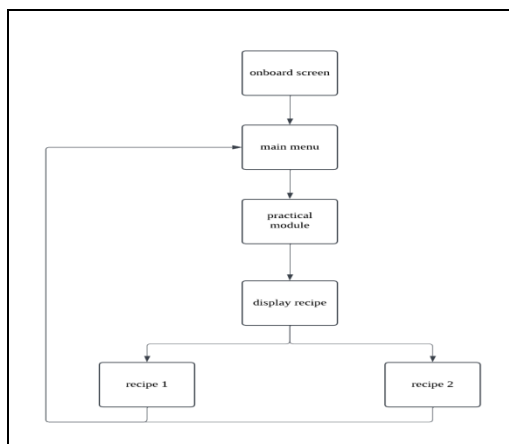
Appendix D : encyclopedia Flowchart



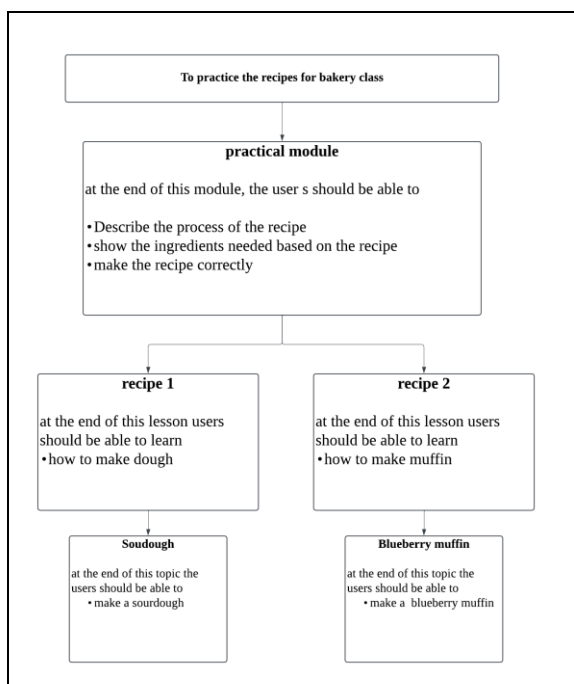
Appendix E : setting Flowchart



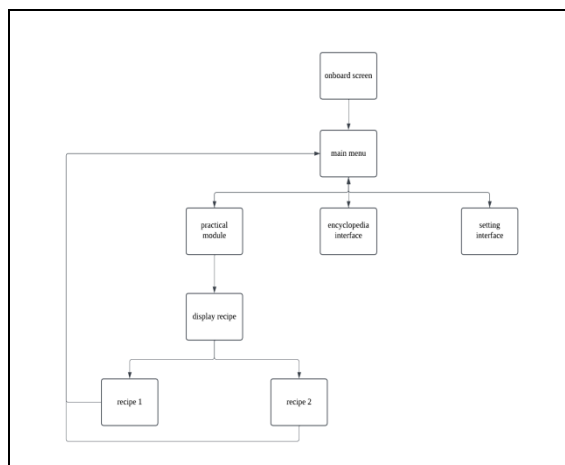
Appendix F : Application module diagram





Appendix G : Content Structure





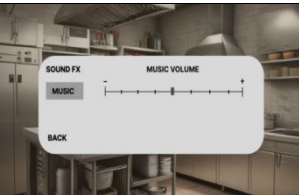

Appendix H : Navigation Structure



Appendix I : Storyboard

Items	Description
	<ul style="list-style-type: none"> Onboard screen There is a Start button here Start button will navigate user to the Main Menu page
	<ul style="list-style-type: none"> Homepage Start button will bring student to recipe page where they will choose which recipe will they do Encyclopedia contains information about the utensils, machine and ingredients Setting will navigate user to the setting scene

Appendix I continue

	<ul style="list-style-type: none"> Recipe page User need to choose on which recipe they would like to do.
	<ul style="list-style-type: none"> Practical module User will do the baking activity based on the recipe that they chose User have to do all the baking skills such as proofing and baking
	<ul style="list-style-type: none"> Setting page Allow user to change the sound fx and music according to their needs
	<ul style="list-style-type: none"> Encyclopedia page Allow user to see the information about utensils, machine and ingredient.

Appendix J : User Testing

