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Development of Virtual Tours for Baba Nyonya Museum Using Mixed Reality Portal Technology

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Abstract

Baba Nyonya, also called as Peranakan Chinese or STRAITS born-Chinese, is one of the iconic culture in Malaysia. Today, to preserve their culture, their descendants have established the Baba Nyonya Museum. However, the present resources online and museum established related with Baba Nyonya is limited. Thus, the application that can let public visit to Baba Nyonya Musuem in an alternative way is proposed. XR Nyonya Walk is a mobile-based application developed on Android platform is developed with Multimedia Mobile Content Development (MMCD) methodology using Unity Software with the implementation of XR origin. The application is initiate to boost the tourism in Malaysia by digging the unique culture herritage in Malaysia. It was high hopes that the XR Nyonya Walk will be used by public for an alternative way to learn the culture of Baba Nyonya and to visit to Baba Nyonya Museum.

1. Introduction

Baba Nyonya is one of the unique heritage cultures in Malaysia. The cultural inheritance of Baba Nyonya is precious to be preserved, such the richness of Baba Nyonya material including kebaya or Nyonya dress, ornaments, crafts from porcelain and ceramic is important or educate our future generation of its precious material culture in Malaysia [1]. Yet, the popularity for Baba Nyonya culture is declining due to limited resources and museum in Malaysia. Besides, according to Berita Awani [2], most of the young descendants of Baba Nyonya today are more interested in K-pop trends due to the advent of media. Thus, it is necessary to implement the culture of Baba Nyonya with technology such as virtual tours using Mixed Reality to encourage public to know more about this culture heritage.

Among the viewpoints in tourism, the museum is one of the attractive spots for visitors. Meanwhile, the Baba Nyonya Museum is one of the unique museums that only can be found in Malaysia [3] and Singapore [4]. According to Cedric [5], the Baba Nyonya culture is important, especially to Malaysian, a multicultural country. Today, the ways to promote Baba Nyonya culture are still limited through social media. Besides, visitors as foreigners from all around the world, only be able to learn about Baba Nyonya culture by visiting the museum in Singapore or Malaysia. Not at all, although students in Malaysia can learn about Baba Nyonya from their historical textbook at standard six Chapter 4, "Kaum Di Malaysia", there is just limited knowledge they can get from the book [6].

The virtual tour can be presented in the way of 360-degree photos, Virtual Reality (VR), Augmented Reality (AR) and Mixed Reality (XR) where Mixed Reality is the combination of AR and VR. In the AR world, the virtual items to be shown can be triggered by whether to use the detection of a marker or marker-less meanwhile VR requires users to wear a VR headset to display a screen of experience directly in front of users. However, mixed reality bring convenience to users in terms of device-free to have to virtual experience. Hence, to further enhance tourism in an alternative way, the implementation of XR in virtual tours is becoming popular as this brings new growth opportunities to the tourism sector [7].

Thus, the goal of the study is to design an "XR Nyonya Walk" mobile application with the implementation of XR in the Baba Nyonya Museum, it can become an alternative way for people who is interested to access. The target audience for the application is public. Puan Hajah Mariam binti Abd Hamid, a Historial Subject teacher at SK Pintas Raya is the Subject Matter Expert (SME) involved in this project. This is expected that the proposed application can help in Malaysia tourism by promoting the beauty of multicultural in Malaysia via virtual approach.

2. Related Work

This section will explain the study domain, the technology applied and the comparative analysis results.

2.1 Baba Nyonya

There are many appellations for the Baba and Nyonya, which are "Straits Chinese", "Straits-born Chinese", "Baba Chinese", "Peranakan", and also called "Baba-Nyonya". These terms all describe the descendants of late 15th and 16th-century Chinese immigrants to Malay Indonesia during the Colonial era. In Malaysia, there is one famous Baba Nyonya Museum which is located in the old district of the UNESCO Heritage area of Malacca town, on Jalan Tun Tan Cheng Lock [8]. The existing method to preserve the culture of Baba Nyonya is through delivering the message to the new generation**.** Besides, through visiting the Baba Nyonya Museum, more people can get to know the beauty and specialty of the culture of Baba and Nyonya. There are also e-sources and school materials related to the Baba Nyonya [9].

However, there is a limitation in the existing method. The limited resources on Baba Nyonya cause it hard to expose to a larger community. For example, in Malaysia, there are only Melaka and Penang have the Baba Nyonya Museum or mansion. This has greatly stopped the pace of people visiting the Baba Nyonya Museum due to issues such as being far away from their homes or always being crowded. Besides, according to Straits Born Chinese Association [10], the number of members in the association are just around 1800 members during the year 2020. Generally, the existing method of introducing Baba Nyonya culture is not effective as it can only be introduced to a limited population. Therefore, there is a need to deliver the history of Baba Nyonya using an alternative method. For example, in this project, an application namely Nyonya Walk is been proposed.

2.2 Virtual Tour

According to the study of the visual Indonesian virtual tour of Surabaya [11], the virtual tour is an alternative way to virtual tourism. It can provide users travel experience to feel how it is to be in a certain place without having there physically. Virtual tours have been used in many fields as they can let users explore a particular place remotely. It can be used in the introduction of the school environment to let students know or feel more about the school environment before their enrolment. Not at all, there is also an ample example of which virtual tours have been used in tourism. As an example, research namely Gonggong Building uses virtual reality in designing information tourism [12].

In [13], the travel and leisure business are being impacted by technology such as augmented and virtual reality in various ways. It also stated these innovative technologies able to improve and influence visitor experience in the tourism field. Thus, the rise of virtual tours has contributed to tourism in term of providing an alternative and interesting ways for people to travel. The implementation of virtual tours can be in different forms, for example, through virtual reality, 360 virtual tours with panorama photos, and augmented reality. Overall, the virtual tour is still new to the community and has emerged to the public due to the pandemic back in 2018.

2.3 Mixed Reality Technology

In mixed reality, VR and AR aspects are combined. Augmented reality is a technology that superimposes digital information on objects or places in the real world with the aim of strengthening the user experience [14]. This digital information is embedded in a digital marker. The markers are distinct patterns that can be recognized easily by using mobile cameras, they can be either paper-based or physical objects that exist in the real world. Meanwhile, VR describes a visual, immersive, offer 3D experience that provides users the feeling of being placed in a digital world. VR requires users to wear a VR headset to display a screen of experience directly in front of users. However, mixed reality bring convenience to users in terms of device-free to have to virtual experience.

The XR now is implemented in various field, including in tourism and education. XR is now one of the trending methods to educate students in the plan of "Pendidikan Malaysia Untuk Masyarakat 5.0". Also, the uses of XR in tourism bring an alternative choice for human to travel to a certain place. It can free humans from being bandaged by several factors while considering a trip, such as financial issues, transportation, and time issues. Among the attractive spots, the heritage museum is one of the favorable visiting places using Mixed Reality. This also become a new platform of learning and understanding certain events and historical elements for the students and researchers [16]. Ariffin [17] claims that, the users experience when travelling in the museum can be enhanced by adding additional value to the artefacts, which are the pop-up virtual information that describing the artefacts.

In the same time, with VR technology users are allow to move around in the virtual room with more immersive experience. Thus, it shows that mixed reality does benefits in virtual tours.

2.4 Comparative Analysis

In this section, the comparisons between existing applications and the proposed application are presented. Discussion is made based on the features of the application. The first feature that can differentiate among the applications is Mixed Reality (XR) technology used. There is existing application that used AR technology and VR technology. The increase of implementation of multimedia elements in tourism has driven the idea of creating the XR Nyonya Walk application. The comparison between the existing applications which are Maldives Virtual Tour [19], Hisraya WalkTour [20], London Virtual Tour [21] and the proposed application, named XR Nyonya Walk is shown in the Table 1 below.

Table 1 *Comparison between existing application and proposed application*

Application	Maldives Virtual Tour	Hisarya WalkTour	London Virtual Tour	XR Nyonya Walk
Augmented Reality (AR)	Does not provide AR features bur realistic panorama	Provide marker-based AR features to the users	Does not provide AR features bur realistic panorama	Provide marker-less AR features to the users
Virtual Reality	Enable users to change into VR mode	Does not provide users with VR features		Allow users to explore the rooms in VR environment
Explore Module	Provide a explore module which having different perspective	Provide a 2D map for user	Provide a explore module which having different perspective	Provide a explore module which allow user to walk around physically
Voice-over description	Does not provide voice-over description to users	Provide voice-over description with users but having no reference text.	Does not provide voice-over description to users	
Unlock features	Does not need to unlock to explore	User need to unlock the AR object through scanning the marker for at least once	Does not need to unlock to explore	
Integrate knowledge with exploring	Does not provide knowledge to users during using the application	Knowledge is given to the users as using the application		

In comparison, XR Nyonya Walk is able to provide users with a more interactive and immersive exploring experience through the implementation of mixed reality. The brief introduction for every part of the Baba Nyonya museum able to provide new knowledge to users as they using the application. Unlike the Maldives Virtual Tour and London Virtual Tour, XR Nyonya Walk provides concise information of the building to increase understanding level of the users. In Hisraya WalkTour, audio descriptions present but having no reference text make non-native speakers face difficulties when listening to the audio.

The difference between the existing application and the proposed application also can be show through the explore module provided. In both Maldives and London Virtual Tour, there does provide a explore module for users to look around the site and having different perspective but due to neither AR nor VR technology is used, users can only navigate to the next point by tapping the phone screen. Meanwhile, only a 2D map for scanning marker is provided in Hisraya WalkTour. This is due to most of the tourism applications are aiming to show the

overall beauty of their view but XR Nyonya Walk does not just focus on tourism but also knowledge can be gained by users.

3. Methodology/Framework

The chosen methodology for this project is Multimedia Mobile Content Development (MMCD). According to Saidudin [22], this framework can help developers speed up the development activities and ensure that these activities will be performed as planned.

The MMCD methodology used for this project is shown in Figure 1. The methodology contains of five main components which are the application idea creation stage, analyze the structure stage, design the process stage, develop main functions stage and testing stage. This methodology is mostly focusing on content navigation and objects used as the main characteristics.

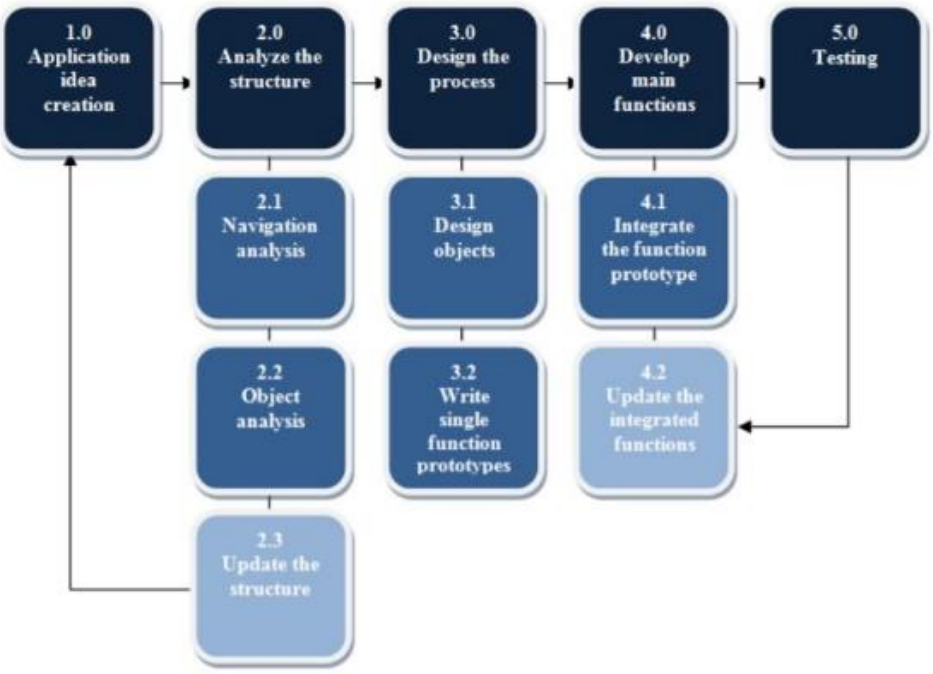


Fig. 1 *Process of MMCD Methodology*

3.1 Application Idea Creation

For the first stage of MMCD, data required to design and develop XR Nyonya Walk is needed. To identify the user requirements, an interview session with the Subject Matter Expert of this project, Puan Hajah Mariam Binti Abd Hamid, a Historical subject teacher in SK Pintas Raya was carried out. The transcripts have been tabulated in Appendix A while a complete user analysis result is tabulated in Table 2. Also, in Table 3, the application idea creation checklist tabulated to have a clearer view on the required elements of XR Nyonya Walk.

Table 2 *User Analysis of XR Nyonya Walk*

Stakeholder Category	Role in Application	Design Implication	Action Taken
Subject Matter Expert	Consultant expert in related field	User-friendly interface	• Interface design should have more graphics instead of text content • A user manual should be provided to improve user understanding • The navigation structure of the application should be simple
		Sufficient Content	• Knowledge related to Baba Nyonya should be accurate and details • Complicated words should be avoid
		Colorful Interface	• The color used for interface design should be attractive

Table 3 *Idea Creation Checklist*

Item	Note
Type of application	Mobile Application
Target device	Android OS Smart Phone and Tablet
Target users	General (Children, Teenagers, Adults, and Old Folks)
FPS and Application settings	C# script Unity version: 2021 FPS: 24 Resolution: 720x1280
GUI	Background (home page, main menu, setting, and info)
Images	- Button icon - Cultural Relics of Baba Nyonya
Video	- None
Audio	- Background music (home page, and every module) - Clicking audio
Application synopsis	- XR Nyonya Walk is an interactive mobile exploring application where the users able to choose a room in Baba Nyonya Museum. Then, the application will display a portal door using marker-less AR technology which allow users to explore the room by mixed reality technology. The proposed application will cover 5 rooms in the museum, which are reception hall, ancestor hall, kitchen, dining room and bedroom. The proposed application will also having lore corner module for users to learn more about Baba Nyonya.

3.2 Analyze the Structure

In this phase, two sub components navigation and objects are analyze based on the requirements from the previous stage. In Table 4, some of the autonomous activity functional requirement and user interaction will be show, while the rest will be in Appendix C. In Table 5, there will be show the non-functional requirements. While the flowchart is provided in Figure 2 with the navigational structure is shown in Figure 3. There is also storyboard for XR Nyonya Walk in Appendix B. The complete system requirements including hardware and software requirements will be show in Appendix C.

Table 4 *Functional Requirements of XR Nyonya Walk*

Functional Requirement	Module	Description
Autonomous Activity	Home page Explore module	• The application will display a main menu interface after logging in. • The system will ask the users for access to their camera permission. • The system will display the 3D AR portal door after the user clicks on a specific room button. • The system should recognize thedifferent rooms with different furniture and provide relevant information to the users.

Table 4 *Functional Requirements of XR Nyonya Walk*

Functional Requirement	Module	Description
Autonomous Activity	Explore module	• The system should deliver audio for the user to enhance the exploring experience.
User Interaction	Home page	• The application shall provide users with the ability to start the application.
	Main menu	• The application should provide users with the ability to choose which modulesto enter.

Table 5 *Non-Functional Requirements*

Non-functionalRequirements	Description
Performance	• The application should display all the 3D models with timenot more than 2 seconds. • Any interactions between the user and the system should notexceed two seconds.
Operational	• The application should be able to operate on any Androiddevice with Android version 7 and above.
Cultural	• The application should be developed in English.
Legal	• The application should not allow users to modify any information displayed in the application
Usability	• The application should be user-friendly and easy to use for any user.

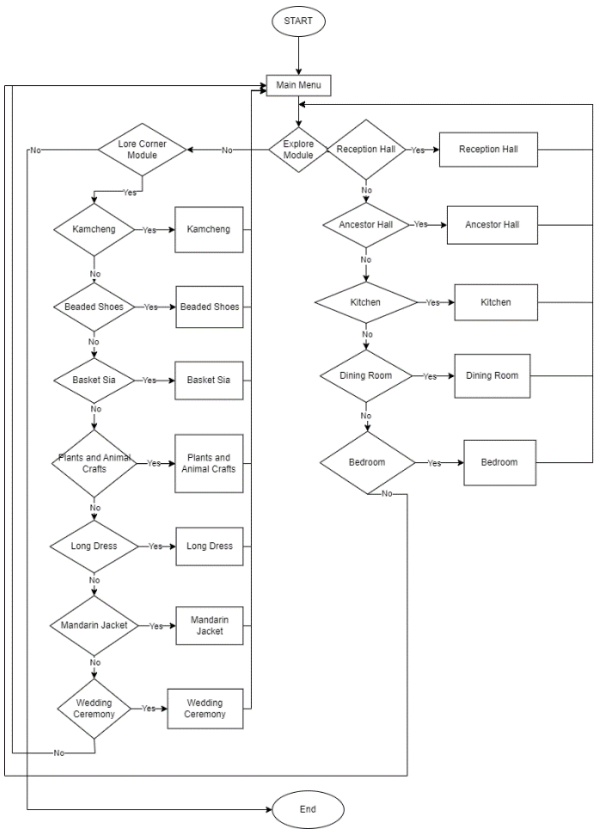


Fig. 2 *Flowchart of XR Nyonya Walk*

Fig. 3 *Navigational Structure of XR Nyonya Walk*

3.3 Design the Process

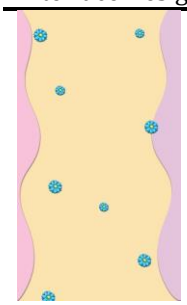
In this section, the main activities are to design the objects and components that been identified in previous stage. Designs such as button and interface designs will be shown below in both Table 6 and 7. The complete 3D models created will be tabulated in Appendix D.

Applied Information Technology and Computer Science Vol. 5 No. 2 (2024) p. 901-924

Table 6 *Button Design*

Button	Description	Button	Description
	This is the start button to navigate users to main menu.		This is the info button that shows extra info to users.
	This is the explore button to navigate users to explore module.		This is the music off button.
	This is the lore corner button to navigate users to lore corner module.		This is the music on button.
	This is the settings button.		This is the deny button.
	This is the exit button.		This is the confirmation button
	This is the home button.		This is the sound off button.
	This is the option list button.		This is the sound on and on audio description button.

Table 7 *Interface Design*

Interface Design	Description
	• This is the interface design that will be used on home page and main menu. • The background color of this interface will be used across the application.
	• This is the interface design for every pop-up panel. • Example of pop up panel will be exit confirmation panel and settings panel.

3.4 Develop the Main Function

The key features of the suggested application are put into place at this phase. It is required building applications assets, such as 3D objects needed to be placed in the XR room of explore module. After modelling the 3D objects, there are integrating into Unity, other assets such as button and interface design has also been imported. In Table 8, some of the examples of development have been shown.

Table 8 *Application assets development*

Assets	Development	Description
Graphics		• This is the interface for starting panel of XR Nyonya Walk • The buttons and graphics created from Photoshop is also implemented into Unity to complete the user interface.

Table 8 *Application assets development (cont)*

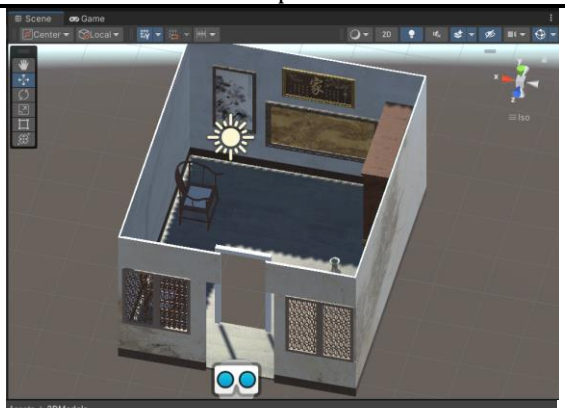
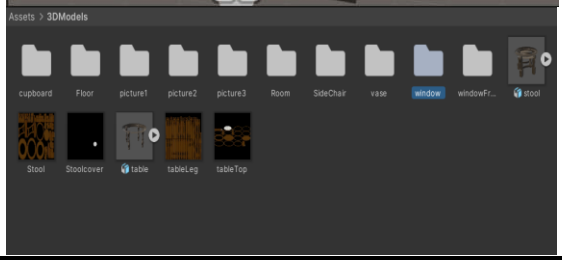
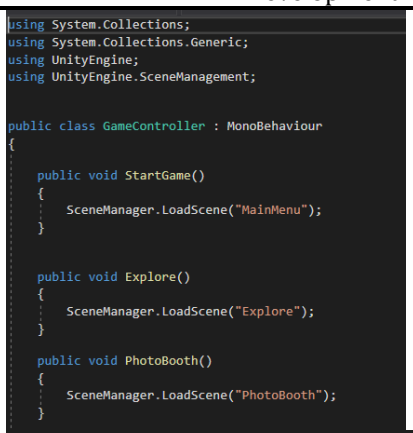
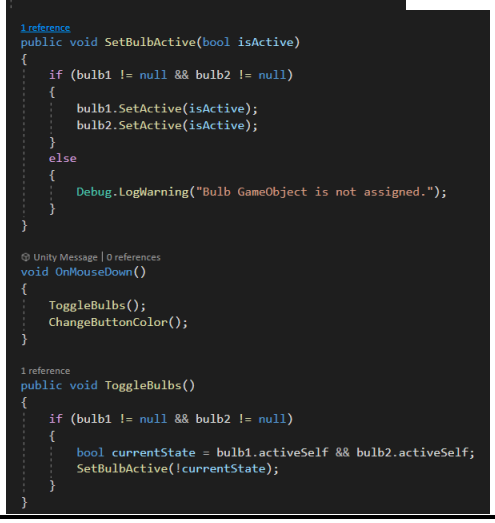
Assets	Development	Description
3D room		• The 3D objects needed in the development of XR Nyonya Walk is modelled in Blender software and exported in .fbx file. • The is the view of reception hall for XR Nyonya Walk which will be used in explore module.
Materials		• This is the material will be used to attach to the furniture which bake from Blender software.

Table 9 show some of the example of C# scripts created to enable the application's key features. These C# scripts are scene manager script, Trigger Manager script, audio management script and object interactivity script. The description of the scripts which explained their functionality is included.

Table 9 *Integration in Unity*

Assets	Development	Description
Scene Manager		In XR Nyonya Walk the scenes are managed by scene manager. This script is first attached on the game object then been added as the onClick function of a button. Hence, once the button is clicked, the script will run and navigate users to the relevant scene.
Object Interactivity (switch on bulbs)		This script is used to allow interactivity between users and the game objects in the virtual scene. This script will be used in the bedroom of explore module. As the user moving close to the switch, an arrow will appeal and pointing to the switch to prompt user click on the switch button. Once the switch is on, the light bulb in the bedroom will light up and the switch will show green color after clicked.

Applied Information Technology and Computer Science Vol. 5 No. 2 (2024) p. 901-924

Table 9 *Integration in Unity (cont.)*

Assets	Development	Description

Trigger Manager	`// Arrays to store objects to show/hide and objects to trigger collision`
	`public GameObject[] objectsToShowHide;`
	`public GameObject[] triggerObjects;`
	
	`private Dictionary<GameObject, GameObject> objectMapping = new Dictionary<GameObject, GameObject>();`
	
	`Unity Message | 0 references`
	`private void Start()`
	`{`
	`  // Populate the dictionary with trigger objects and their corresponding objects to show/hide`
	`  for (int i = 0; i < triggerObjects.Length; i++)`
	`  {`
	`  objectMapping.Add(triggerObjects[i], objectsToShowHide[i]);`
	`  }`
	`}`
	
	`Unity Message | 0 references`
	`private void OnTriggerEnter(Collider other)`
	`{`
	`  // Check if the collider is one of the trigger objects`
	`  foreach (var kvp in objectMapping)`
	`  {`
	`  if (other.gameObject == kvp.Key)`
	`  {`
	`  SetObjectActive(kvp.Value, true);`
	`  break;`
	`  }`
	`  }`
	`}`
		This script is used to appeal the hidden objects name by using trigger of box collider. All the triggers are added with box collider properties, thus, as the trigger objects hit the camera, the object name will be revealed. As contrary, the object name will be hidden after users moving out from the trigger area.

Audio Manager	`Unity Message | 0 references`
	`private void Start()`
	`{`
	`  if (BgScripts.BgInstance.Audio.isPlaying)`
	`  {`
	`  toggleMusicTxt.text = "On";`
	`  musicToggleBtn.image.sprite = musicOnIcon;`
	`  }`
	`  else`
	`  {`
	`  toggleMusicTxt.text = "Off";`
	`  musicToggleBtn.image.sprite = musicOffIcon;`
	`  }`
	
	`  //sfx`
	
	`  if (SfxManager.sfxInstance.musicToggle == true)`
	`  {`
	`  toggleSfxTxt.text = "On";`
	`  sfxToggleBtn.image.sprite = sfxOnIcon;`
	`  }`
	`  else`
	`  {`
	`  toggleSfxTxt.text = "Off";`
	`  sfxToggleBtn.image.sprite = sfxOffIcon;`
	`  }`
	
	`}`
		This script is used to managed to sound and music buttons of XR Nyonya Walk. It enabled the audio to be on and off as users click on the button attached with this script. Relevant status text such as “ON” and “OFF” also will be shown according to the status of the audio.

Table 10 *Interfaces of the developed application*

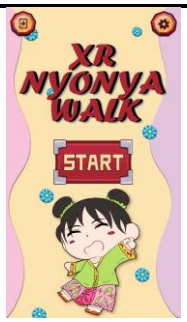
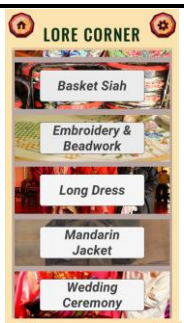
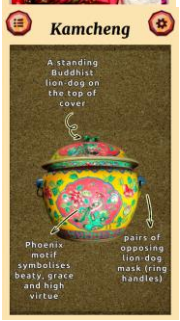
Module	Interfaces	Module	Interfaces
Startup Interface		Main Menu	

Table 10 *Interfaces of the developed application (cont.)*

Module	Interfaces	Module	Interfaces
Explore Menu		Lore Corner Menu	 
Explore Module	 	Lore Corner Module	 
Pop Up Interface	 		

3.5 Testing

Two types of testing will be done in the testing phase which are alpha testing by developer and beta testing by the target users. In Table 11, the result of functional testing for the main buttons and interfaces will be shown meanwhile the full functional testing will be attached in Appendix E.

Table 11 *Functional Testing*

Test	Expected Result	Actual Result	Corrective Action
Start button	Navigates to main menu interface.	Works well as planned.	Not Required.
Setting button	Shows setting panel when click.	Works well as planned.	Not Required.
Audio button (Music and Sound effect button)	Mute audio if the audio is on or vice versa.	Audio setting being reset when navigate to next interface.	Ensure audio manager is applied correctly in the developed application.
Exit button	Show exit confirmation panel when clicked	Works well as planned.	Not Required.
Home button	Navigate to back to main menu	Works well as planned.	Not Required.
Menu button	Navigate back to the option list interface	Works well as planned.	Not Required.

Applied Information Technology and Computer Science Vol. 5 No. 2 (2024) p. 901-924

Table 11 *Functional Testing (cont.)*

Test	Expected Result	Actual Result	Corrective Action
Pop Up interface	Navigate confirmation panel will show up when trigger is touched	Works well as planned.	Not Required.

Based on Table 11, there is no major problem in the developed application. The only part of the button having issue which is the malfunction of music and sound button. The music and sound button setting re not consistent as navigating to the next interface, causing the muted background music or sound effect will still on in the next scene. Therefore, the corrective actions which is ensure that the audio manager is correctly applied in every scene and the script within the audio manager work well.

4. Result and Discussion

This section presents an analysis obtained from System Usability Scale (SUS) testing. This testing is carried out with the target users which is the public living near the testing area, Parit Raja by using the template statement provided by the SUS [23]. The main purpose for carrying out this testing is to obtain feedback and satisfaction levels from the target users regarding the experience of using XR Nyonya Walk. After filling out the question sheet, the developer and the users also had a short discussion regarding their answers.

There is a total of 22 users involved in this testing and the user acceptance level can be obtained by calculating the SUS score with its formula. There are 3 levels of grade which are scoring 80.3 or above will be an A, 68 or thereabout will be a C and finally 51 or under will be a F. Meanwhile, in SUS there are 5 scales with 1 denoted as "Strongly disagree" and 5 denoted as "strongly agree".

Based on Figure 4, although 7 people are "neutral" to the statement, the response of "agree" with the statement, "I think I would like to use this application frequently." is more than the response of "disagree". Thus, we may conclude that most of the respondent feels that they are willing to use this application frequently. This might be due to the users being attracted by the application features as they can have room exploration. While for the next statement, which is the opposite of the first statement, "I found the application unnecessarily complex", there are more respondents who "disagree". There are almost 50% of respondents "strongly disagree" with this statement and 31.8% of respondents have the opinion of "disagree", which is also the second highest response for Figure 5. In short, the majority of the respondents think the functionality of XR Nyonya Walk is direct and complete, hence making them feel the application is unnecessarily complex.

Following Figure 6, it is clear to see that most of the respondents felt the application was easy to use. There are only 2 people each who stand on "strongly disagree" and "disagree", which do not exceed 50% of the respondents. Overall, most of the users think that the application was easy to use. This might be due to a simple user interface was designed, to make them felt XR Nyonya Walk is user-friendly. In contrast, the statement, "I think that I would need the support of a technical person to be able to use this application" is set to examine whether users think that XR Nyonya Walk is easy to use. Clearly, with the analysis of user responses, the majority of the respondents think that they do not need a technical person to be a guide. Yet, there are 3 users who "agree" and 4 users "strongly agree" with this statement. This might be due to there are some respondents who gave their feedback on their first time using of mixed reality application which is unfamiliar for them. Additionally, extra features such as user manuals and tutorials may be added to the application to make users feel more user-friendly.

In term of function integrated in XR Nyonya Walk, over 50% of respondent think the functions were well integrated, only 1 person "disagree" and 2 people "strongly disagree" with this statement. This is because the function integrated such as the interaction between 3D objects and users, and knowledge given in the application make them feel useful. In addition, 54.5% of users "disagree" and 2 people "strongly disagree" that there was too much inconsistency in this application. Yet, there are also people who "agree" with there are inconsistency in the application. This might be caused by the inconsistency of the XR technology integrated show unstable in the "explore" module.

From Figure 10, 14 out of 22 respondents feel that most people would learn to use this application very quickly. This denoted that majority of the respondents think that the application is not complicated and it is easy to use. The well-structured and design of the application make the users able to use XR Nyonya Walk effectively. Only minority of users "disagree" and "strongly disagree" with this statement. Hence, further improvement such as user manual able to be added. As a proof, there are only 4 respondents agree with the statement that the application is very cumbersome to use while there is a total of 17 respondents disagree with this.

Based on Figure 12, there are 9 respondents felt confident using the application, but there is also same amount of respondent felt neutral for this. This may be caused by the implementation of XR technology is still new in the market cause unfamiliar to a certain group of people. Thus, XR Nyonya Walk have brought a new experience to some of the users. Also, in the next statement there are users that think they need to learn a lot of things before they could get going with the application. On the other hand, most of the users still consider XR Nyonya Walk is

an application with clear and direct instructions. Hence, there are no extra knowledge needed to learn before accessing this application.

After analyzing the result obtained from all 10 statements, we are able to obtain the average System Usability Scale (SUS) score for XR Nyonya Walk. The SUS score for XR Nyonya Walk is 63.9, which is a grade C. The calculation will be shown in Appendix F. This denoted that this application is still acceptable for most of the users. Yet, adjustment and improvement still needed to implement to further improve the functionality and usability of the application.

There are some suggestions on the future work of XR Nyonya Walk. Firstly, more activity module could be added into this application to increase the using experience for the users. For example, an activity module that enable users to interact with the real-world object in Baba Nyonya Museum will be more interactive for users. This will also encourage users to visit to the real museum to boost the tourism of Malaysia. The number of interactable object in the exploration room also can be added, hence users can have a more immersive experience through exploring. Also, the deploy of XR room in explore module also could be more consistent by applying AR plane manager. Thus, users able to choose their desired space to deploy the XR room.

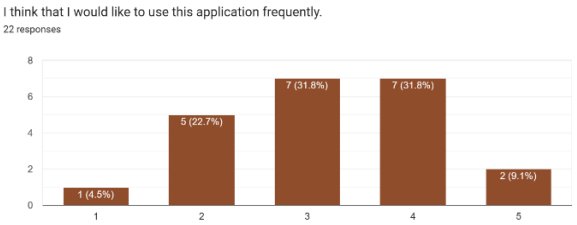


Fig. 4 *User Analysis of SUS (1)*

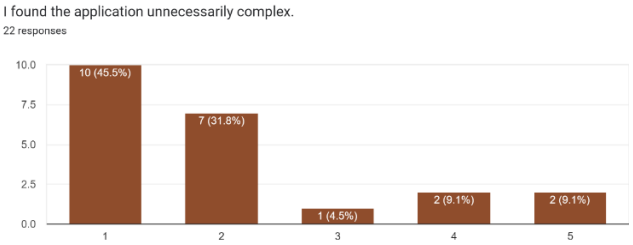


Fig. 5 *User Analysis of SUS (2)*

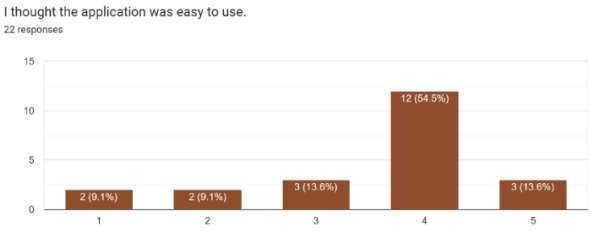


Fig. 6 *User Analysis of SUS (3)*

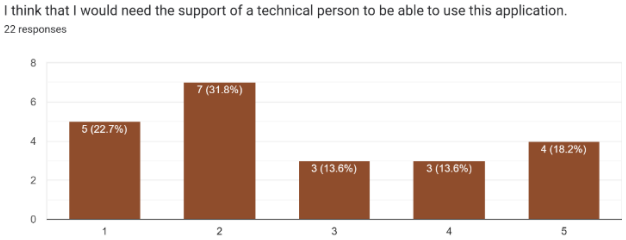


Fig. 7 *User Analysis of SUS (4)*

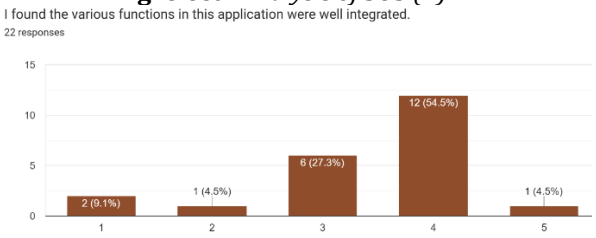


Fig. 8 *User Analysis of SUS (5)*

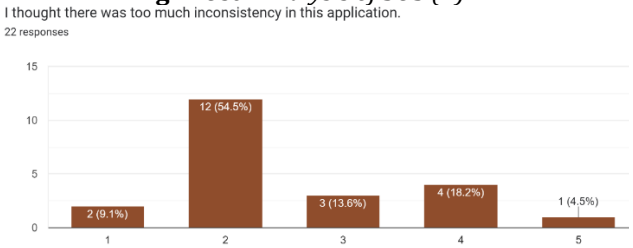


Fig. 9 *User Analysis of SUS (6)*

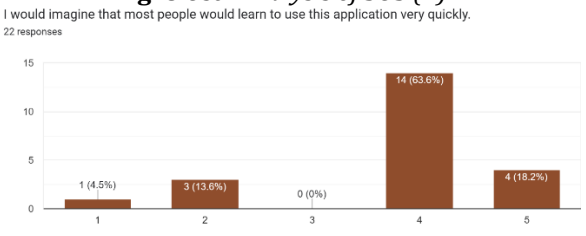


Fig. 10 *User Analysis of SUS (7)*

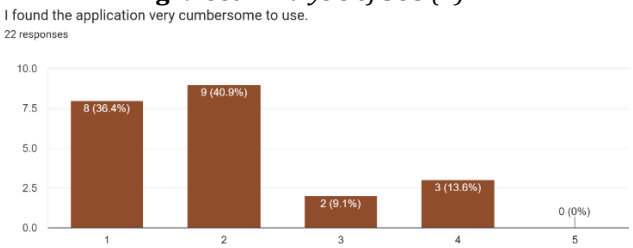


Fig. 11 *User Analysis of SUS (8)*

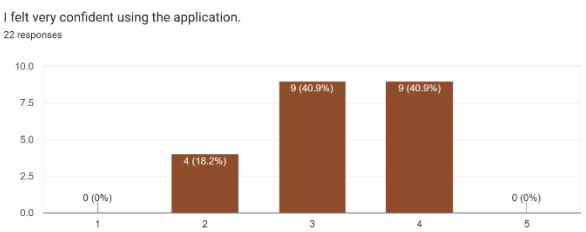


Fig. 12 *User Analysis of SUS (9)*

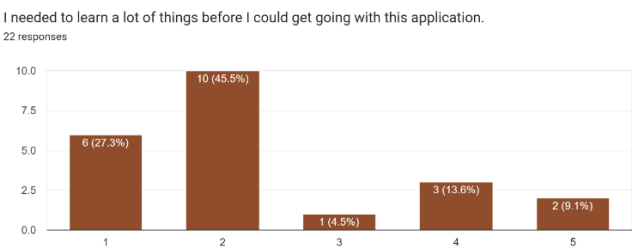


Fig. 13 *User Analysis of SUS (10)*

5. Conclusion

In a nutshell, according to the overall analysis of the testing phase results, we could conclude that XR Nyonya Walk is acceptable for most of the users. It is also suitable for public to learn and explore culture about Baba Nyonya. In addition, all three objectives of XR Nyonya Walk were successfully achieved. The first objective is obtained by implementing XR technology in the development of XR Nyonya Walk, while the second objective is obtained by building the application on Android platform. Lastly, the user acceptance level and functionality also been testing using System Usability Scale testing.

By using MMCD methodology to develop this application, the application managed to be complete developed within the time frame. The advantages and limitations of the XR Nyonya Walk also be concluded in Table 12. Meanwhile for the future work, it is recommended to provide a scanning module for users to enable interaction with the artifacts in Baba Nyonya Museum and implementing an AR Plane Manager within XR Nyonya Walk. Hence, users may be able to deploy the XR room with their preferences.

Table 12 *Advantages and limitations of XR Nyonya Walk*

Advantages	Limitations
- Provide interactive experience to all age users - Act as a media to promote culture of Baba Nyonya - Complete functionality	- Limited interaction with the virtual 3D objects in XR Nyonya Walk. - Inconsistency of the placement of XR room in explore module

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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:*** *Ng Yee Von, Norhalina Binti Senan;* ***data collection:*** *Ng Yee Von;* ***analysis and interpretation of results:*** *Ng Yee Von;* ***draft manuscript preparation:*** *Ng Yee Von, Norhalina Binti Senan. All authors reviewed the results and approved the final version of the manuscript.*

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Applied Information Technology and Computer Science Vol. 5 No. 2 (2024) p. 901-924

Appendix A: Transcript of user analysis

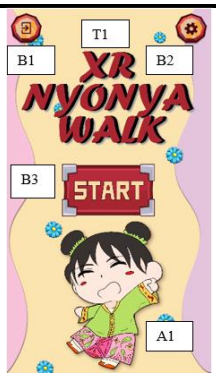
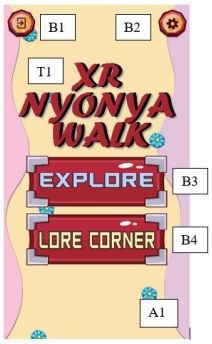
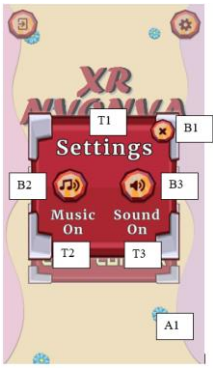
The interview session is carried out by using Bahasa Melayu.

Table 13 *Transcripts of user analysis*

Question	Answer
Selamat pagi Cikgu Mariam. Izinkan saya memperkenalkan diri sendiri sebelum kami bermula sesi temu duga ini. Nama saya Ng Yee Von, pelajar tahun 3 dari UTHM dan sedang menjalankan projek sarjana muda sekarang ini. Tujuan saya memohon sesi temu duga dengan Cikgu Mariam adalah untuk mendapat pendapat dari Cikigu sebelum pembangunan aplikasi saya.	Selamat pagi, saya Puan Hajah Mariam binti Abd Hamid, cikgu Sejarah di Sekolah Spira Parit Raja.
Terima kasih, cikgu. Bolehkan sayabertanya berapa lama sudah cikgu ajar sebagai seorang guru sejarah?	Saya telah mengajar Subjek Sejarah lebihkurang 10 tahun.
Adakah cikgu rasa kontent dalam buku teks Sejarah cukup untuk pelajar belajarsejarah?	Kalau cakap kontent buku teks, kebanyakkan kontentnya hanya basis untuk beri pelajar sekolah rendah untuk mendapatsatu imej untuk belajar Subjek Sejarah saja.Sebab kefahaman budak sekolah rendah juga terhad. Jadi, boleh dikatakan kontent dia basis saja.
Baik, cikgu. Faham. Izin tanya juga, pernahkah cikgu melaksanakan apa-apa aktiviti dalam kelas sejarah?	Kebanyakan pelakonan. Sebab melalui pelajar berlakon sebagai seseorang tokoh sejarah, keingatan mereka akan lebih kuat dan kukuh.
Faham, melalui pelakonan, pelajar juga akan lebih faham apa yang mereka sedang belajar. Boleh saya tanya, adakah cikgupernah dengar realiti maya atau reality tambahan?	Maksudnya apa-apa yang tidak sebenardari fizikal?
Dalam Bahasa Inggris, realiti tambahan bernama augmented reality. Secara mudah, maksudnya dapat mempaparkan sesuatu secara maya di pesekitaran sebenar. Dan Cikgu ini papan cerita saya yang menunjukkan idea kesuluruhan aplikasi saya. Izin tanya, adakah Dr rasa kontent yang digunakan ini sesuai untuk budak sekolah rendah?	Kontent ini cukup tapi adakah awak menyatakan tentang kedatangan Baba Nyonya? Kontent ini dapat ditambah pada sesi “lore corner” sebagai satu maklumat extra.
Faham, cikgu. Yang permukaan aplikasi, rasanya warna apa yang sesuai kepada aplikasi ini?	Awak dapat gunakan warna ceria sebabsasaran awak merangkumi budak kecil juga. Warna yang ceria dapat menambah tampilan.
Soalan yang terakhir, adakah cikgu rasaapplikasi ini dapat membantu orang ramai lebih memahami kebudayaan Baba Nyonya?	Boleh. Cuma awak dapat menambah butir- butiran dalam bahagian informasi bilik- bilik.

Appendix B: Storyboard of XR Nyonya Walk

Table 14 *Storyboard*

Scene No.	Scene Name	Interface	Elements	Behaviors
1	Home Page		B1 B2 B3 T1 A1	This button will confirm users to whether quit the application This button will display settings panel to the users This button will navigate users to the main menu page. This text represents the title of the application The background music of the application will be played.
2	Exit Confirmation Button		B1 B2 T1 T2 A1	This button will confirm users to quit the application. This button will deny users from quit the application. This text represents the title of the panel. This text represents the content of the panel. The background music of the application will be played.
3	Main Menu Page		B1 B2 B3 B4 T1 A1	This button will confirm users to whether quit the application This button will display settings panel to the users This button will navigate users to the explore module. This button will navigate users to the photobooth module. This text represents the title of the application. The background music of the application will be played.
4	Settings panel page		B1 B2 B3 T1 T2 T3 A1	This button will close the settings panel for the users This slider button will let users to adjust music volume. This slider button will let users to adjust sound effect volume. This text represents the title of the panel. This text represents the name for B2 This text represents the name for B3 The background music of the application will be played.

Applied Information Technology and Computer Science Vol. 5 No. 2 (2024) p. 901-924

Table 14 *Storyboard (cont.)*

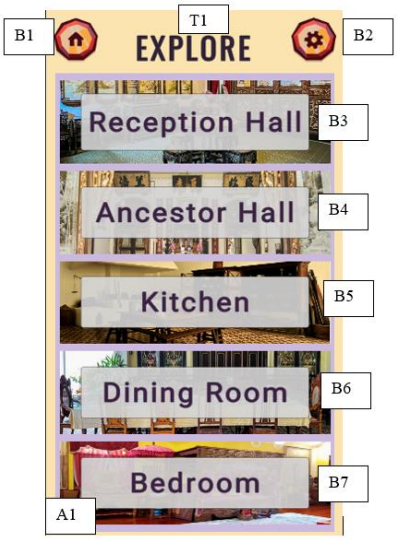
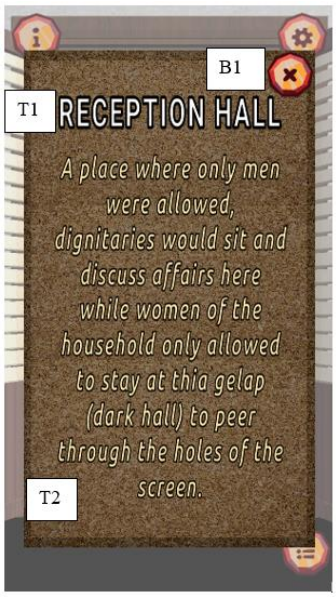
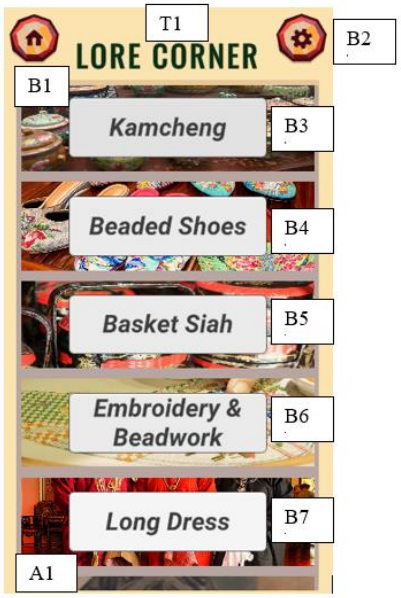
Scene No	Scene Name	Interface	Elements	Behaviors
5	Explore Module		B1 B2 B3 B4 B5 B6 B7 T1 A1	This button will navigate users to the main menu page. This button will display settings panel to the users This button will navigate users to the reception hall. This button will navigate users to the ancestor hall. This button will navigate users to the kitchen. This button will navigate users to the dining room. This button will navigate users to the bedroom. This text represents the title of the module. The background music of the explore module will be played.
6	Reception Hall		B1 B2 B3 A1	This button will display info panel of the room to users. This button will display settings panel to the users. This button will navigate users to the explore module. The background music of the explore module will be played.
7	Info Panel		B1 T1 T2 A1	This button will close the info panel to the users. The text refers to the title of the panel. The text represents the description of the particular room The background music of the application will be played.

Table 14 *Storyboard (continued)*

Scene No	Scene Name	Interface	Elements	Behaviors
8	Lore Corner Module		B1 B2 B3 B4 B5 B6 B7 T1 A1	This button will navigate users to main menu. This button will display settings panel to the users This button will navigate users to the Kamcheng. This button will navigate users to the Beaded Shoes. This button will navigate users to the Basket Sia. This button will navigate users to the Embroidery and Beadwork. This button will navigate users to the Long Dress This text represents the title of the module. The background music of the application will be played.
9	Content of Lore Corner		B1 B2 T1 T2 A1	This button will navigate user to Lore Corner Module. This button will display settings panel to the users The text represents the title of the knowledge The text represents the content of the knowledge The background music of the photobooth module will be played.

Appendix C: System Requirements

Table 15 *Functional Requirement*

Functional Requirement	Module	Description
Autonomous Activity	Home page	• The application will display a main menuinterface after logging in.
	Explore module	• The system will ask the users for access to their camera permission. • The system will display the 3D AR portaldoor after the user clicks on a specific room button. • The system should recognize thedifferent rooms with different furniture and provide relevant information to the users. • The system should deliver audio for the user to enhance the exploring experience.
User Interaction	Home page	• The application shall provide users with the ability to start the application.
	Main menu	• The application should provide users with the ability to choose which modulesto enter.
	Setting panel	• The application should provide userswith a slider to adjust the music volume and audio effect.
	Explore Module	• During users enter the explore module, users are provided with 5 options of room and able to choose the preferred room. • The application shall provide users withan info button in each room to enhancethe understanding of users • If the info is too long for the user, the application should provide users with a voice button to read the text. • The application should provide users with a menu and back button which allow users to navigate back to the list of choices and main menu.
	Lore corner module	• During users enter the lore corner module, users are provided with a list tochoose from among the knowledgepoints. • The application should provide users with the ability to navigate to the next knowledge point with a button. • The application should provide users with a menu and back button which allow users to navigate back to the list of choices and main menu.

Table 16 Non-*Functional Requirement*

Non-functionalRequirements	Description
Performance	• The application should display all the 3D models with time not more than 2 seconds. • Any interactions between the user and the system should notexceed two seconds.
Operational	• The application should be able to operate on any Android device with Android version 7 and above.
Cultural	• The application should be developed in English.
Legal	• The application should not allow users to modify anyinformation displayed in the application
Usability	• The application should be user-friendly and easy to use for any user.

Table 17 *Hardware and Software Requirement*

Requirement	Item	Description
Hardware	Laptop Acer Nitro - AN515-57	Allow developers to use Unity and Blender to develop the application. Specification as follow: • Operating System: Windows 10 • Processor: 11th Gen Intel(R) Core(TM) i5-11400H @ 2.70GHz 2.69 GHz • Installed Memory: 8GB 3200MHz DDR4 • Graphics: Nvidia GeForce RTX3050 4GB GDDR6
	XiaoMi Mi9Phone	Allow developers to test the application. Specification as follows: • Operating System: Android 9.0 (Pie) • Resolution: 1080 x 2340 pixels • RAM: 8GB • Internal Storage: 128GB • Processor: Octa Core - Qualcomm SM8150 Snapdragon 855
	Input-outputdevices	Allow the developers to communicate with the computer using: • Mouse • Keyboard
Software	Unity 2022.3.15f1	• Use to integrate the asset and develop the application.
	AR Foundation with XR core	• Use to support AR technology in Unity.
	Adobe Photoshop CC 2021	• Use to design project background and aesthetic elements.
	Blender 3.5	• Use to model 3D models of furniture.
	Visual Studio 2019	• Use to write C# scripts for the project
	Adobe Illustrator CC 2020	• Use to design UI buttons for the application

Applied Information Technology and Computer Science Vol. 5 No. 2 (2024) p. 901-924

Appendix D: 3D models

Table 18 *3D models created*

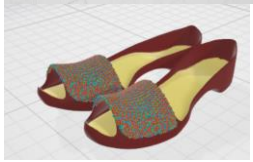
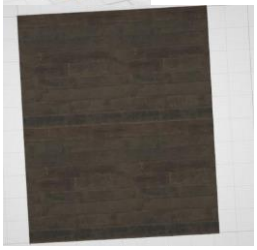
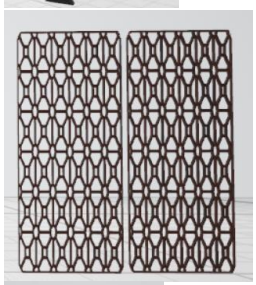
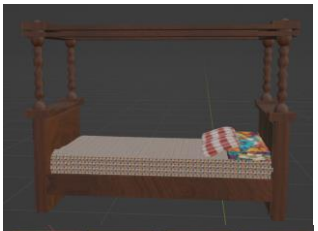
3D models	Explanation	3D models	Explanation
	This is the wooden cupboard that normally used to place some collections of the Baba Nyonya. Some of the Baba Nyonya will display their collection to show their social status to outsiders.		This is the side chair that will be putat the left or right side of the reception hall. This chair is used when the visitor has to wait the room owner or willbe normally sit by the femaledependents of the visitors.
	This is the table that will be located at the middle of the reception hall which normally used for Baba todiscuss affair with the visitors.		This is the wall for the reception hall.
	This is the stool chair which is a setwith the table.		This is a traditional beaded shoe of Nyonya which called “Kasut Manik” or Beaded Shoe.
	This is a vase that normally used for decoration.		This is a traditional porcelain vase.
	This is the floor of the reception hall.		This is the wooden window if the reception hall
	This is the wooden frame of the window.		This is one of the paintings that willbe hang on the wall of the reception hall. Sometimes Baba Nyonya will hangsome valuable artworks in their reception hall.
	This is one of the paintings that willbe hang on the wall of the receptionhall.		This is one of the paintings that willbe hang on the wall of the receptionhall.

Table 18 *3D models created (cont.)*

3D models	Explanation	3D models	Explanation
	This is the model of candle stick that will be used in Ancestor Hall.		This a censer that used for holding incense
	This is an ancestor plaque that will crave with the name of their ancestor		This is a couplet that will be normally hang on the wall
	This is a wooden table for putting candlestick, censer and ancestor plate		This is a set of vintage chair and table that place at ancestor hall
	This is a wider chair to be placed at ancestor hall		This is an old-fashioned vanity that normally placed at bedroom which used for Nyonya to make up of set their hair style.
	This is a surname plaque of the ancestor hall.		This is a zafa cushion placed in front of the ancestor plate. People kneel on it when they are praying
	This is a chamber bed. This bed will be decorated as a bridal chamber during wedding ceremony of Baba Nyonya.		This is a teapot set that will be used to serve for customers.
	This is the 4 season paintings that Baba Nyonya like to collect and hanging on their wall in dinning room or reception hall.		This is a dinning set that used in dining room.
	This is a charcoal stove that used to boil kettle water or soup.		This is a rattan basket which used to hold food ingredients like vegetables

Applied Information Technology and Computer Science Vol. 5 No. 2 (2024) p. 901-924

Appendix E: Functional Testing Analysis

Table 19 *Functional Testing*

Test	Expected Result	Actual Result	Corrective Action
Start button	Navigates to main menu interface.	Works well as planned.	Not Required.
Setting button	Shows setting panel when click.	Works well as planned.	Not Required.
Music On/Off button	Mute background music if background music is on or vice versa.	Background music setting being reset when navigate to next interface.	Ensure there is only one audio manager in the developed application.
Sound On/Off button	Mute sound effect if sound effect is on or vice versa.	Sound effect setting being reset when navigate to next interface.	Ensure there is only one audio manager in the developed application.
Cross button	Close setting panel when click	Works well as planned.	Not Required.
Exit button	Show exit confirmation panel when clicked	Works well as planned.	Not Required.
Tick button	Exit the application when clicked	Works well as planned.	Not Required.
Explore Module button	Navigate to content interface of explore module	Works well as planned.	Not Required.
Lore Corner Module button	Navigate to content interface of lore corner	Works well as planned.	Not Required.
Home button	Navigate to back to main menu	Works well as planned.	Not Required.
Reception Hall button	Navigate to room 1, reception hall	Works well as planned.	Not Required.
Ancestor Hall button	Navigate to room 2, ancestor hall	Works well as planned.	Not Required.
Kitchen button	Navigate to room 3, kitchen	Works well as planned.	Not Required.
Dining Room button	Navigate to room 4, dining room	Works well as planned.	Not Required.
Bedroom button	Navigate to room 5, bedroom	Works well as planned.	Not Required.
Info button	Show room info interface when clicked	Works well as planned.	Not Required.
Pop Up interface	Navigate confirmation panel will show up when trigger is touched	Works well as planned.	Not Required.
Menu button	Navigate back to the option list interface	Works well as planned.	Not Required.
Kamcheng button	Navigate into knowledge 1, Kamcheng.	Works well as planned.	Not Required.
Beaded Shoes button	Navigate into knowledge 2, Beaded Shoes.	Works well as planned.	Not Required.
Basket Siah button	Navigate into knowledge 3, Basket Siah.	Works well as planned.	Not Required.
Embroidery and Beadwork button	Navigate into knowledge 4, Embroidery and Beadwork.	Works well as planned.	Not Required.
Long Dress button	Navigate into knowledge 5, Long Dress.	Works well as planned.	Not Required.
Mandarin Jacket button	Navigate into knowledge 6, Mandarin Jacket.	Works well as planned.	Not Required.
Wedding Ceremony button	Navigate into knowledge 7, Wedding Ceremony.	Works well as planned.	Not Required.

Appendix F: Functional Testing Analysis

Respondent	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Total Score
R1	4	1	3	4	4	3	4	2	3	1	67.5
R2	5	2	4	5	4	2	5	1	4	1	77.5
R3	3	1	4	1	4	4	5	4	4	1	72.5
R4	4	1	4	2	4	1	4	1	4	2	82.5
R5	3	1	3	3	4	2	5	2	4	3	70
R6	2	2	4	5	5	2	4	2	4	5	57.5
R7	4	2	4	3	4	2	4	1	3	2	72.5
R8	2	2	4	1	4	2	5	2	3	2	72.5
R9	3	2	4	2	3	2	4	1	3	1	72.5
R10	3	1	5	2	4	1	4	2	4	1	82.5
R11	3	5	4	2	3	2	4	2	4	2	62.5
R12	4	1	4	2	3	2	4	2	3	2	72.5
R13	1	3	2	4	2	4	2	2	2	5	27.5
R14	2	5	2	5	3	5	1	4	2	4	17.5
R15	2	4	1	5	1	4	2	4	2	4	17.5
R16	4	2	4	2	4	3	4	1	4	2	75
R17	3	1	5	1	4	2	4	2	3	1	80
R18	4	2	3	2	3	3	4	3	3	2	62.5
R19	4	1	5	1	4	2	4	1	4	2	85
R20	2	4	1	4	1	4	2	1	2	4	27.5
R21	3	1	4	3	3	2	4	3	3	2	65
R22	5	1	4	1	4	2	4	1	3	2	82.5
											63.75

Fig.14 *SUS score analysis*