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# MicroWorld: Development of Microorganisms Learning Application for Year 6 Using Augmented Reality Technology

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**Abstract**: Microorganisms are tiny living things to be seen with the naked eye and a microscope is required. They are indispensable and bring benefits to our daily life. However, only a small piece of knowledge about microorganisms is offered in the science year 6 Dual Language Programme (DLP) textbook which causes the students might misunderstanding towards microorganisms are all harmful to us. Besides, the images provided in the textbook are static which leads to difficulty in learning. Therefore, an application called MicroWorld is designed and is expected to act as a learning aid for the target users who are twelve-year-old primary school Year 6 students. Multimedia Mobile Content Development (MMCD) methodology is utilized to develop this learning application on the Android platform. Positive feedback is obtained in the beta testing with an average score of 94.58% which falls in the acceptable range of the scale of the SUS score.

**Keywords**: Microorganisms, Learning Application, Augmented Reality

## 1. Introduction

Microorganisms are single-celled living things of microscopic size. Since microorganisms also known as microbes are too small to be seen with the naked eye, a microscope is required [1]. Without the use of the microscope, people might not be aware of the invisible world [2]. They are everywhere, even on the surface of water, dirt, and fingernails. In the Year 6 Dual Language Programme (DLP) Science subject textbook, the topic of microorganisms is limited and led to the misconceptions that all of them are harmful to us [3]. Other than that, the traditional method like a textbook to convey information to students is a challenge for students to visualize nowadays through the static images and text provided [4]. Therefore, to aid students in studying the topic of microorganisms, Augmented Reality (AR) technology is implemented.

A representation of the real world that has been augmented with digital graphics, music, or other sensory information is referred to as augmented reality (AR) [5]. For example, Pokémon Go is a game which applied AR technology and was well-known in 2016. In today's globalized world, learning

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applications also use this technology, in addition to games. It can pique children's interest in studying to use AR technology rather than just text and static images. Other than that, there are risks when the students carry out experiments related to microorganisms. When the students are using Bunsen Burner, they might get injured without following the instructions given by the teacher. With the proposed application called MicroWorld, this situation can be avoided but still can carry experiments safely by using the AR lab module offered.

The objective of this project is to design and develop a Microorganisms Learning Application for Year 6 using Augmented Reality on the Android platform. The Visual, Auditory, Read/Write, Kinesthetic (VARK) design approach is implemented during the design and development of the application. The alpha and beta testing for the developed application to the target users will involve twelve-year-old primary school Year 6 students. Miss Chiung Huei Yee, a subject matter expert (SME), has experience teaching Science subjects in SJK(C) Sungai Chua Kajang. Moreover, English is the primary language used in this application and the visual and auditory are mainly focused on the VARK learning style.

The application consists of three modules which are the Learning module, Quiz module and AR module. In the Learning module, there is a list of microorganisms provided for users. When the user selects the desired microorganism, a 3D microorganism will display on the screen. Next, the images and a description of text with audio are intended for primary school Year 6 students in each microorganism. The following module is the Quiz module, there will randomly display the 10 questions and answer feedback is shown for every question. Lastly, the marker is expected to perform well in the AR module and prompt out the 3D models used in the experiments. Overall, all navigation buttons should be able to work properly without any errors.

The rest of the paper is structured as follows: The literature overview of the relevant studies and current applications is covered in Section 2. Next, Section 3 outlines the methodology employed to construct the application, including the analysis and design. Then, Section 4 covers the result and discussion whereas Section 5 summarizes the conclusion of the application.

## 2. Related Work

The domain of the study, the technology utilized and the comparison between existing applications and MicroWorld are covered in this section.

### 2.1 Microorganisms Topic in Year 6 Primary School

A unicellular living thing of microscopic size is defined as a microorganism. Microorganisms are divided into a few types including fungi, bacteria, algae and protozoa. It is well-known in science that some microbe species might endanger or even harm people, and throughout the history of microbiology, research on humans has concentrated on the disease-causing organisms that could be discovered on or in humans [6]. While there has been far less study on the benefits of microbes. As a sequence, some people could think inaccurately that all germs are bad [7]. Moreover, Unit 3 of the Year 6 Dual Language Programme (DLP) Science subject textbook had just one small topic [3]. As they only have a basic understanding of microbes, they would not fully understand the topic. Moreover, children find it challenging to visualize information, it will be tough for them to learn with the materials presented in text and static graphics.

### 2.2 Technology Utilized

The technologies implemented in this application are Augmented Reality technology and visual, aural/auditory, reading/writing, and kinesthetic (VARK) learning style. Firstly, augmented reality (AR) was termed by Azuma [8] as 3D virtual components that are smoothly integrated into a real-time and 3D environment. Users can observe the real world with virtual objects layered or blended in using

augmented reality (AR). The two basic categories into which augmented reality technology belongs are marker-based AR and markerless AR. Marker-based AR is implemented in this application. A set marker between the AR device and the real-world object must be supplied by either an optical marker reader (OMR) or a quick response (QR) scanner for this technology to operate. The marker-based AR application shows digital 3D content based on the markers through a camera viewport or the user's visual field [9].

Besides, VARK learning style is visual, aural/auditory, reading/writing, and kinesthetic scale [10]. Charts, maps, as well as graphics that present information visually are interesting to visual learners. The preferred learning techniques for aural learners involve speeches, group discussions and self-talk. The auditory learners are also referred to as aural learners who prefer reading and writing when students focus on text-based materials including reports, notes, and blogs whereas kinesthetic learning prefers role-playing, case studies, and practical work [11]. This technology is used since the mobile application can provide multimedia elements in learning content and thus it will be a great learning tool for students.

## 2.3 Comparison Between Existing Applications and Proposed Application

There are many existing apps available on Google Play Store, but three of them such as Bacteriology & Microbiology [12], Virus & Bacteria in 3D AR [13] and Kids Learn Science Experiments [14] are shown in Table 1. They are used in this section as samples to compare to the proposed application, called MicroWorld as in Table 2.

**Table 1: Existing applications**

| | | |
|---|---|---|
|  |  |  |
| Bacteriology & Microbiology [12] | Virus & Bacteria in 3D AR [13] | Kids Learn Science Experiments [14] |

**Table 2: Comparison of existing applications with the proposed application**

| Features | Bacteriology & Microbiology | Virus & Bacteria in 3D AR | Kids Learn Science Experiments | MicroWorld |
|---|---|---|---|---|
| Types of Augmented Reality | Non-AR (2D). | AR Marker-based with 3D models. | Non-AR (2D). | AR Marker-based with 3D models. |
| Operating system required | Android 5.0 and above | Android 4.1 and above | Android 4.4 and above | Android 8.0 and above |
| Weaknesses | • No animation<br>• No background music | • Consists of exit button but no exit confirmation window | • No background music<br>• No sound effect | • No entertainment module such as mini-game module |

| Features | Bacteriology & Microbiology | Virus & Bacteria in 3D AR | Kids Learn Science Experiments | MicroWorld |
|---|---|---|---|---|
| | • No sound effect<br>• No exit button and exit confirmation window<br>• Consists of text and static images only<br>• Portrait mode<br>• No quiz module | • Inconsistent button<br>• A lot of text | • No exit button and exit confirmation window<br>• No learning module and quiz module | |
| Strengths | • Free to use<br>• Consistent button | • Free to use<br>• Consists of animation<br>• Consists of background music and sound effect<br>• Landscape mode<br>• Consists of quiz module | • Free to use<br>• Consists of animation<br>• Consistent button<br>• Consists of sound effect<br>• Landscape mode | • Free to use<br>• 3 modules provided (Learning module, Quiz module, AR module)<br>• Consists of animation<br>• Consistent button<br>• Consists of background<br>• Consists of sound effect<br>• Landscape mode<br>• Short and precise information |

Based on Table 2, it outlines the features of the four applications such as types of augmented reality (AR), the operating system required, weaknesses and strengths. One of the obvious differences between the existing applications and MicroWorld is that the latter uses augmented reality marker-based technology with 3D models, but the other existing applications do not, as is the case with MicroWorld and Virus & Bacteria in 3D AR. Although both MicroWorld and Virus & Bacteria in 3D AR utilize augmented reality marker-based technology with 3D models, MicroWorld has the advantage when it comes to its usage of short and precise information as opposed to Virus & Bacteria in 3D AR's dense text-based content.

## 3. Methodology

The chosen methodology applied in this application is Multimedia Mobile Content Development (MMCD) because it can help to speed up the development activities and accomplish the project as planned. Figure 1 illustrates the simple process of MMCD methodology [15].

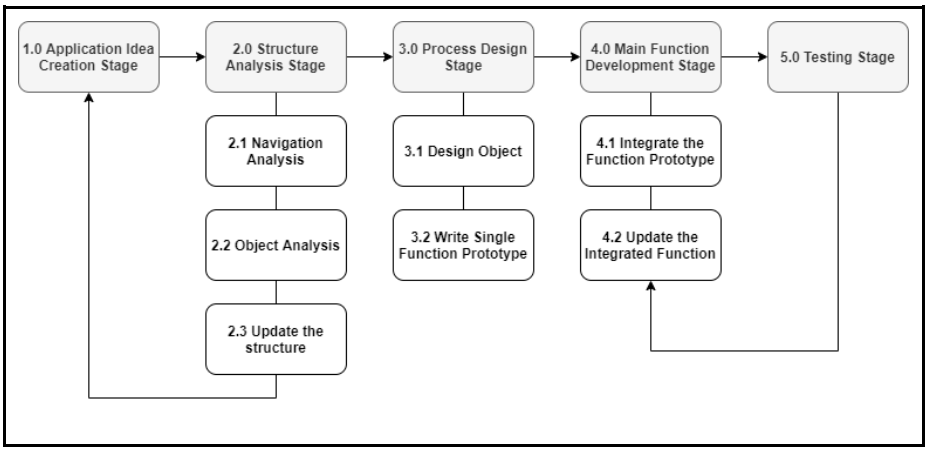



**Figure 1: MMCD methodology [15]**

### 3.1 Application Idea Creation Stage

The MMCD methodology's application idea creation stage is where all the relevant data is accumulated before going on to the application's design and development stage [15]. Table 3 demonstrates the application idea creation checklist and Table 4 shows the user requirement analysis. The Subject Matter Expert (SME) is Miss Chiung Huei Yee, is experience teaching subject Science in SJK(C) Sungai Chua Kajang.

**Table 3: Application idea creation check list**

| Item | Note |
|---|---|
| Kinds of application | m-learning |
| Target device | Android OS Smart Phone |
| Intended audience | Year 6 primary school students |
| Graphical user interface (GUI) | Learning module, Quiz module, AR module |
| Images | Background images of the homepage (2D static images) |
| Text | Description of microorganisms in the learning module and the questions and choices in the quiz module. |
| Video | None |
| Audio | • Background music<br>• Narration of description microorganisms<br>• Answer sound effects in the quiz module |

| Item | Note |
|---|---|
| Application synopsis | MicroWorld is an AR-based mobile learning application for Year 6 primary school students in Malaysia. It can avoid students' misunderstanding of all microorganisms that are harmful to us, and it allows students to study the topic of microorganisms and carry out the experiments anywhere and anytime for their better understanding. |

**Table 4: User requirement analysis**

| Stakeholder | Role | Design Implications | Action Needed |
|---|---|---|---|
| Subject Matter Expert (SME) | Consultant for the content design | Based on the interview,<br>Easy to use and learn | Simple and clear instruction given |
| | | Simple user interface design | • Suitable type of font and font size used.<br>• Use icons compared to text.<br>• Use consistent colour and button shape. |
| | | Reliable content | The proposed application should offer correct information about microorganisms. |
| | | Easy to navigate | • Consists of the home button and back button.<br>• Home button can help the user navigate to the home page.<br>• Back button will let the user navigate to the previous page. |

## 3.2 Structure Analysis Stage

The second stage of the MMCD methodology is the structure analysis stage. The two sub-components being assessed are the application's navigation and its components. All objects and navigation are critical elements of a well-planned MMCD, thus it is important to monitor these two sub-components to avoid negative effects on the design and development stages. Figure 2 shows the content structure and Figure 3 shows the navigation structure of MicroWorld.

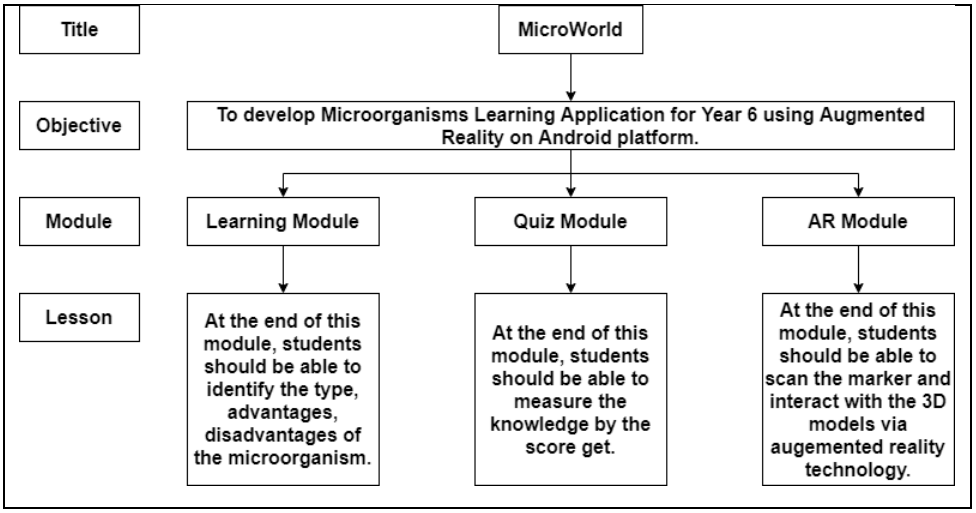



**Figure 2: Content structure of MicroWorld**

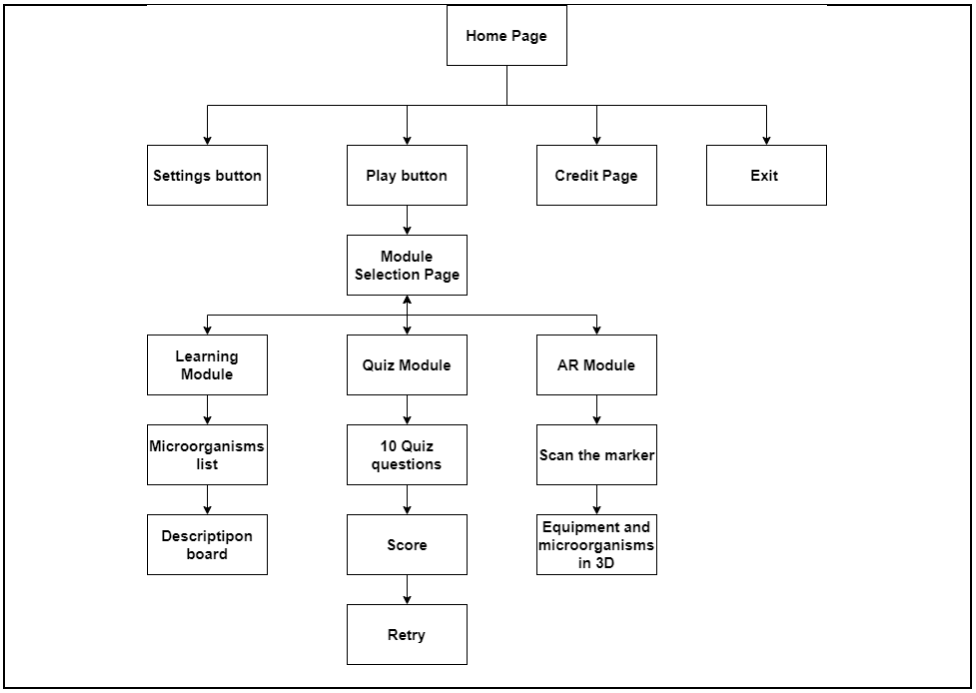



**Figure 3: Navigation structure of MicroWorld**

## 3.3 Process Design Stage

This stage is the third stage of the MMCD methodology. The two primary sub-components of this stage are producing objects and writing scripts for single-function prototypes. The main flowchart is illustrated in Figure 4 whereas the three sub-process flows can be referred to in Appendix A. Next, the prototype included entire artwork, element designs such as button design as in Table 5, component positioning on stage as in Table 6 can be referred to in Appendix B which records the interface design, and single programming that was used in each frame. Specifically designed designing tools like Adobe Photoshop, Adobe Illustrator, and Blender are used to produce the artwork and element designs.

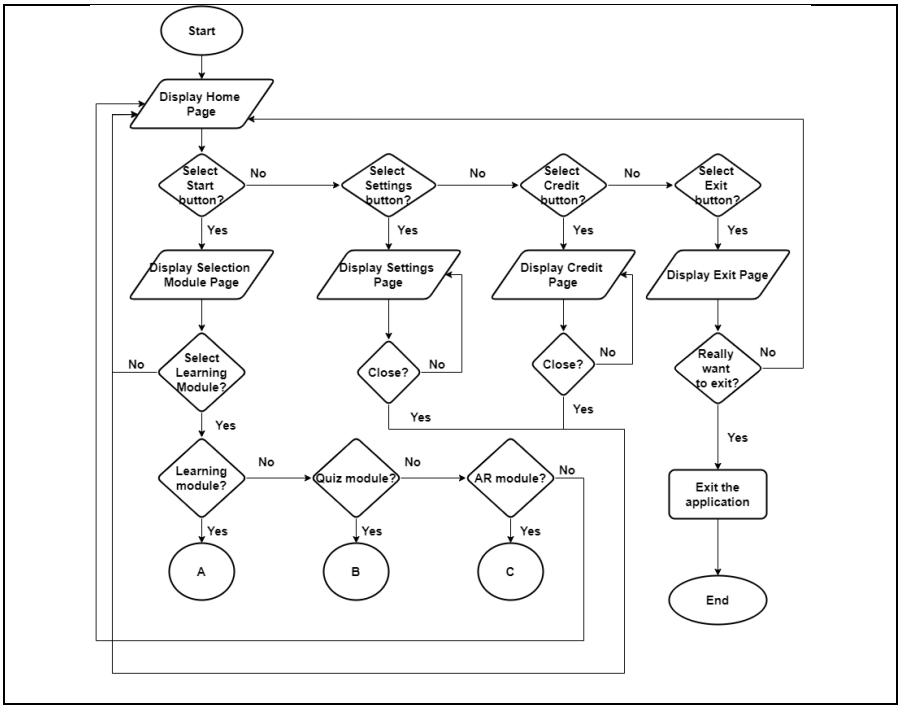



**Figure 4: Main Flowchart of MicroWorld**

**Table 5: Button design**

| Button | Description | Button | Description |
|---|---|---|---|
|  | This is the play button. |  | This is the exit button. |
|  | This is the credit button. |  | This is the home button. |
|  | This is the settings button. |  | This is the back button. |
|  | This is the retry button. |  | This is the close button. |
|  | This is the previous button. |  | This is the next button. |
|  | This is the unmute button. |  | This is the mute button. |

## 3.4 Main Function Development Stage

Main function development stage is the fourth stage of MMCD methodology. The major goal of the MicroWorld application is to ensure it is possible for users to navigate between the specific interfaces. The successful operation of such navigational buttons depends on the C# scripting. Furthermore, the calibration of the AR camera within the AR module while scanning the marker to activate the marker-based AR technology is also a part of the next feature. The 3D models will appear once the marker has been correctly calibrated by the AR camera. Table 6 records asset development whereas Table 7 lists the snippet code of the main functions in the MicroWorld application.

**Table 6: Asset development**

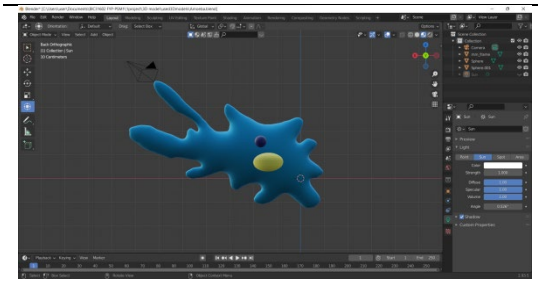
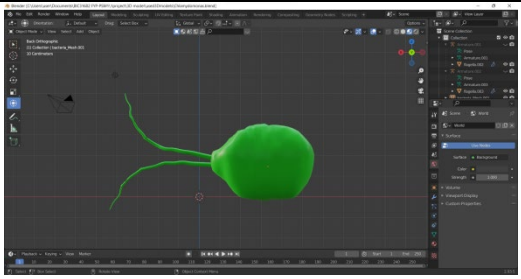
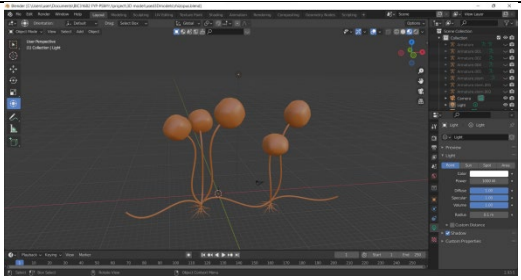
| Asset | Description |
|---|---|
|  | This is a 3D amoeba which is created in Monster Mash and then imports the body shape of it into the Blender. Next, add the sphere mesh as its nucleus and vacuole and then scale it. |
|  | It is a 3D Chlamydomonas which is developed in Blender. A sphere mesh is added as the body scales and sculpts it. Moreover, add a cylinder mesh, set its location and scale one end of the cylinder in the edit mode. Then, duplicate it and their roles are the flagellum of Chlamydomonas. |
|  | It is a 3D Rhizopus stolonifer, also known as bread mould. It is created in the Blender. A cylinder mesh is added and scaled as sporangium. Then, a cylinder mesh is added, location set and scale one end of the cylinder to act as the sporangiophore, stolon and rhizoids. |
|   | The title of the application is designed in Adobe Illustrator CC 2020. Offset path and shadow effects are applied to the text and make it feel more solid and 3D. |

**Table 7: Main function**

| Function | Snippet code | Description |
|---|---|---|
| Single function prototype | public void ChangeToScene(string scene_name)<br>{<br>SceneManager.LoadScene(scene_name);<br>} | `UnityEngine.SceneManagement` package serves as the tool for navigating the scene inside the application. LoadScene behaves when the argument `scene_name` is used, and it executes the operation by putting the scene's name into the play button. |

| Function | Snippet code | Description |
|---|---|---|
| Quit application | public void QuitApps()<br>{<br>Application.Quit();<br>Debug.Log("Quit");<br>} | This function allows the user to quit the application by clicking the check button on the exit confirmation window. |
| Link marker to Google Drive | public void buttonGoogleDrive()<br>{<br>Application.OpenURL("https://drive.google.com/drive/folders/11fauvCgxeFGtsNEW0IUsIyEgr88LsDZe?usp=share_link");<br>} | When the user clicks the Google Drive icon on the credit page, this function will lead the user to Google Drive where the image had been uploaded. The user can download the marker and access the AR module. |
| Background music | private void Awake()<br>{<br>if (backgroundMusic != null && backgroundMusic != this)<br>{<br>Destroy(this.gameObject);<br>return;<br>}<br>backgroundMusic = this;<br>DontDestroyOnLoad(this);<br>}<br>private void Start()<br>{<br>Audio = GetComponent<AudioSource>();<br>} | This snippet code can let the background music to be played automatically when entering the home page and avoid the background music to be destroyed or need to be replay again when entering another scene. |
| Mute and unmute | public void UnMute()<br>{<br>BGM.mute = true;<br>}<br>public void Mute()<br>{<br>BGM.mute = false;<br>} | These two functions are attached to the icon sound off and icon sound on respectively which enable the user to mute and unmute the background music. |
| Check the answer | public void correct()<br>{<br>score += 1;<br>questionNumber += 1;<br>questionLeft.text = questionNumber + "/10";<br>source.clip = correctSfx;<br>source.Play();<br>QnA.RemoveAt(currentQuestion);<br>generateQuestion();<br>}<br><br>public void wrong()<br>{<br>source.clip = incorrectSfx;<br>source.Play();<br>questionNumber += 1;<br>questionLeft.text = questionNumber + "/10";<br>QnA.RemoveAt(currentQuestion);<br>generateQuestion();<br>} | These two functions will check the answer. If the user answers correctly, a correct sound effect is played and increases one mark to the score whereas if the user answers incorrectly, a wrong sound effect is played. After that, it will compute the current question number and then generate a new random question. |

| Function | Snippet code | Description |
|---|---|---|
| Computation of the score | `public void GameOver()`<br>`{`<br>`  StartCoroutine(LoadNextPanel());`<br>`  if (score >= 5)`<br>`  {`<br>`  missionComplete.SetActive(true);`<br>`  ScoreTxt.text = score + "/" + totalQuestions;`<br>`  }`<br>`  else`<br>`  {`<br>`  missionFail.SetActive(true);`<br>`  ScoreTxt2.text = score + "/" + totalQuestions;`<br>`  }`<br>`}`<br>`IEnumerator LoadNextPanel()`<br>`{`<br>`  yield return new WaitForSeconds(2.0f);`<br>`}` | This snippet of code will identify whether the score is fulfilling the condition to display a mission complete panel. |
| Retry the quiz | public void retry()<br>{<br>SceneManager.LoadScene(SceneManager.GetActiveScene().buildIndex);<br>} | This snippet code allows the navigation to the Quiz module and answers the quiz questions again. |
| Assign the answer to the answer button | `void SetAnswer()`<br>`{`<br>`  for (int i = 0; i < options.Length; i++)`<br>`  {`<br>`  options[i].GetComponent<AnswerScript>().isCorrect = false;`<br>`  options[i].transform.GetChild(0).GetComponent<Text>().text = QnA[currentQuestion].Answers[i];`<br>`  if (QnA[currentQuestion].CorrectAnswer == i + 1)`<br>`  {`<br>`  options[i].GetComponent<AnswerScript>().isCorrect = true;`<br>`  }`<br>`  }`<br>`}` | With the assistance of AnswerScript.cs, the variable can be used in the SetAnswer() of the QuizManager.cs. The multiple choice of answer options can be set via an array. |
| Generate the quiz questions | `void generateQuestion()`<br>`{`<br>`  if (QnA.Count > 0)`<br>`  {`<br>`  currentQuestion = Random.Range(0, QnA.Count);`<br>`  QuestionImage.transform.GetChild(0).GetComponent<Image>().sprite = QnA[currentQuestion].Question;`<br>`  SetAnswer();`<br>`  }`<br>`  else`<br>`  {`<br>`  Debug.Log("Finished.");`<br>`  GameOver();`<br>`  }`<br>`}` | The total number of the question can be set via an array. The type of question can be set only in the image form. After all the questions had been set and hit the play mode, the quiz question will display randomly since the `currentQuestion = Random.Range(0, QnA.Count)` is used. |

## 3.5 Testing Stage

The fifth stage will be the testing stage. In the creation of this application, it is a crucial phrase. This is because it helps the detection of bugs and guarantees the smooth operation of the application by alpha

and beta testing. The functionality and performance of the entire application will be evaluated during alpha testing, as outlined in Table 8. Moreover, primary school year 6 students participated in beta testing via a Google Form.

**Table 8: Alpha Testing**

| Test | Expected Result | Actual Result | Improvement Needed |
|---|---|---|---|
| Play Button | Navigates to the Module Selection scene. | Works well as expected. | Not needed. |
| Settings Button | Display the Settings Page. | Works well as expected. | Not needed. |
| Credit Button | Display the Credit Page. | Works well as expected. | Not needed. |
| Back Button | Navigates to the previous scene. | Works well as expected. | Not needed. |
| Exit Button | Display the Exit Panel. | Works well as expected. | Not needed. |
| Learning Module Button | Navigates to the Learning Module scene. | Works well as expected. | Not needed. |
| Quiz Module Button | Navigates to the Quiz Selection scene. | Works well as expected. | Not needed. |
| AR Module Button | Navigates to the AR Module scene. | Works well as expected. | Not needed. |
| Home Button | Navigates to the home page. | Works well as expected. | Not needed. |
| Retry Button | Reset the quiz questions. | Works well as expected. | Not needed. |
| Mute Button | Mute the background music. | Works well as expected. | Not needed. |
| Unmute Button | Unmute the background music. | Works well as expected. | Not needed. |
| Slider | Change the volume. | The handle knot needs to be pulled a lot to make a noticeable volume change. | Set a larger value to increase or decrease in the script. |
| Close Button | Close the panel. | Works well as expected. | Not needed. |
| Previous Button | Return to the previous microorganism and experiment. | Works well as expected. | Not needed. |
| Next Button | Display the next microorganism and experiment. | Works well as expected. | Not needed. |
| Description Button | Display the description panel. | Works well as expected. | Not needed. |
| Reaction Button | Make a reaction or animation in the AR module. | Works well as expected. | Not needed. |
| Answer Button | Answer the quiz questions. | Works well as expected. | Not needed. |

## 4. Results and discussion

The results of beta testing and discussion are covered in this section. System Usability Scale (SUS) [16] is implemented to measure the user acceptance towards the application from the aspect of usability. The reason that the SUS is applied is to easily distinguish between usable and non-usable systems and provide a theoretical justification for the effective implementation of technology [16, 17]. Thirty students from SJK(C) Sungai Chua Kajang's primary school year 6 participated in this beta testing as shown in Appendix C. After trying out the MicroWorld application, they must fill out the Google Form.

### 4.1 Usability

There are ten questions to measure the usability of the application. According to Figure 5, most respondents (50%) strongly agree, 13 respondents (43.3%) agree that they would like to use the application regularly, and 2 respondents (6.7%) had no opinion. The 30 respondents all vehemently disagree that the application is extremely complicated and requires a technical user's assistance to utilize it. A full 100% of respondents also strongly agree that the application is simple to use. Most respondents (53.3%) consist of 16 respondents and 14 out of 30 respondents (46.7%) strongly agree with Question 5's statement that the application's many functionalities are properly integrated.

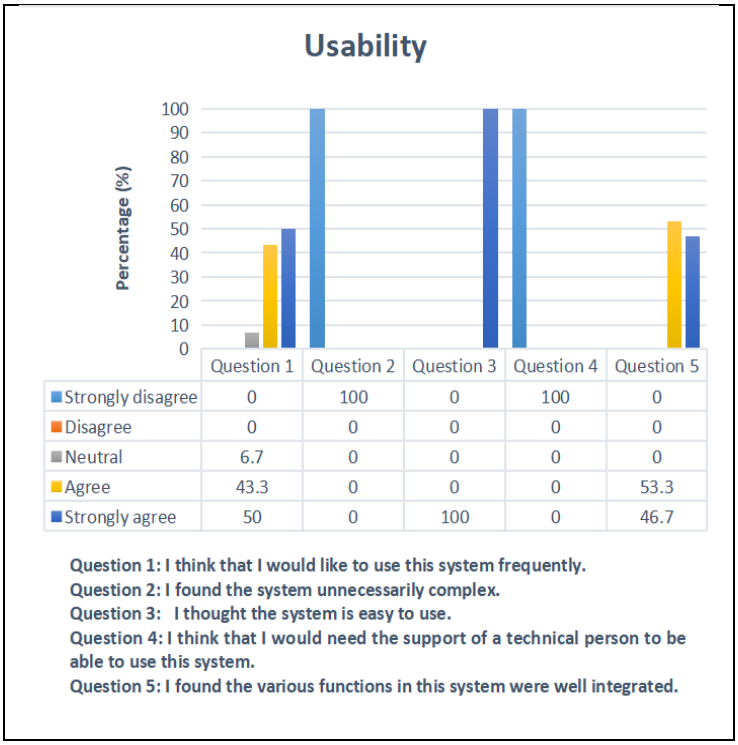



**Figure 5: Analysis of Usability (Question 1 - 5)**

As shown in Figure 6, questions 6 through 10 will be covered. There are 27 respondents (60%) who strongly disagree, and 3 respondents (10%) disagree that the application contains too much inconsistency. The reason for this is that only a little portion of the font style varies from the others. Next, all the respondents responded that strongly agree they feel that most people would learn to use the application very quickly and feel confident to use the application. In addition, most replies (50%) indicate that using the system is very difficult, whereas 26.7% and 23.33% of respondents indicate that they strongly disagree and are indifferent, respectively. The major reason they did not choose strongly disagree is that they had to download the marker from one device and scan it with another device to be able to continue with the AR module. Otherwise, they must print off the marker. Furthermore, 100% of respondents strongly disagree that using the application requires extensive prior knowledge because of its user-friendly design. In short, it can be said that the respondents offered a positive reaction.

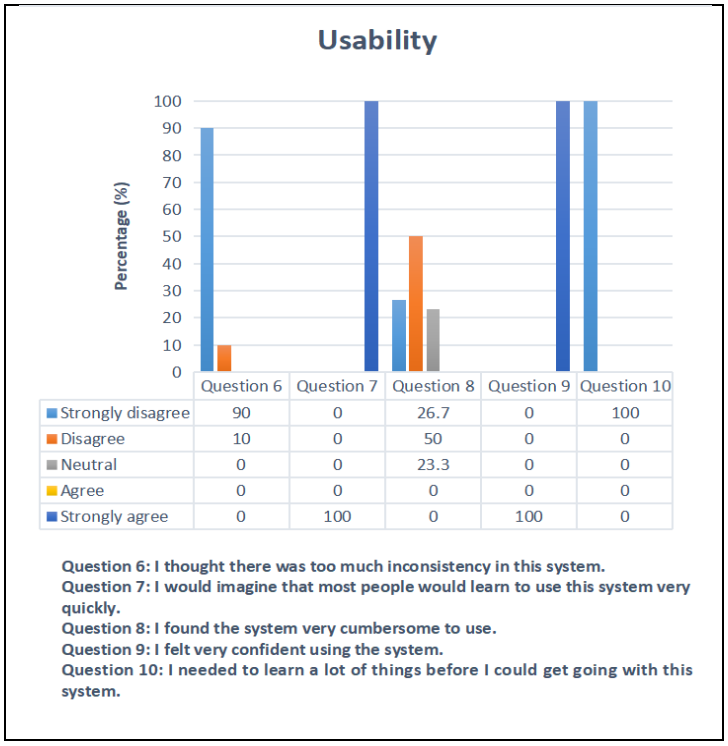



**Figure 6: Analysis of Usability (Question 6 - 10)**

The result can be obtained using the SUS formula for identifying the application's acceptability range. The sum of the respondents' scores for each question must be computed and divided by the total score for each question and multiply by 100% as illustrated in Figure 7.

| Respondent | Skor Item | | | | | | | | | | Odd items | Even items | SUS score (/100) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Q1 | Q2 | Q3 | Q4 | Q5 | Q6 | Q7 | Q8 | Q9 | Q10 | | | |
| R01 | 5 | 1 | 5 | 1 | 5 | 1 | 5 | 3 | 5 | 1 | 20 | 18 | 95 |
| R02 | 4 | 1 | 5 | 1 | 5 | 2 | 5 | 2 | 5 | 1 | 19 | 18 | 92.5 |
| R03 | 5 | 1 | 5 | 1 | 4 | 1 | 5 | 1 | 5 | 1 | 19 | 20 | 97.5 |
| R04 | 5 | 1 | 5 | 1 | 4 | 1 | 5 | 2 | 5 | 1 | 19 | 19 | 95 |
| R05 | 5 | 1 | 5 | 1 | 5 | 1 | 5 | 1 | 5 | 1 | 20 | 20 | 100 |
| R06 | 4 | 1 | 5 | 1 | 5 | 1 | 5 | 2 | 5 | 1 | 19 | 19 | 95 |
| R07 | 5 | 1 | 5 | 1 | 5 | 1 | 5 | 2 | 5 | 1 | 20 | 19 | 97.5 |
| R08 | 4 | 1 | 5 | 1 | 5 | 1 | 5 | 1 | 5 | 1 | 19 | 20 | 97.5 |
| R09 | 4 | 1 | 5 | 1 | 5 | 1 | 5 | 1 | 5 | 1 | 19 | 20 | 97.5 |
| R10 | 5 | 1 | 5 | 1 | 5 | 2 | 5 | 2 | 5 | 1 | 20 | 18 | 95 |
| R11 | 4 | 1 | 5 | 1 | 4 | 1 | 5 | 1 | 5 | 1 | 18 | 20 | 95 |
| R12 | 5 | 1 | 5 | 1 | 5 | 1 | 5 | 1 | 5 | 1 | 20 | 20 | 100 |
| R13 | 5 | 1 | 5 | 1 | 5 | 1 | 5 | 2 | 5 | 1 | 20 | 19 | 97.5 |
| R14 | 5 | 1 | 5 | 1 | 4 | 1 | 5 | 1 | 5 | 1 | 19 | 20 | 97.5 |
| R15 | 5 | 1 | 5 | 1 | 5 | 1 | 5 | 2 | 5 | 1 | 20 | 19 | 97.5 |
| R16 | 4 | 1 | 5 | 1 | 4 | 1 | 5 | 2 | 5 | 1 | 18 | 19 | 92.5 |
| R17 | 3 | 1 | 5 | 1 | 4 | 1 | 5 | 2 | 5 | 1 | 17 | 19 | 90 |
| R18 | 3 | 1 | 5 | 1 | 5 | 1 | 5 | 2 | 5 | 1 | 18 | 19 | 92.5 |
| R19 | 5 | 1 | 5 | 1 | 5 | 1 | 5 | 2 | 5 | 1 | 20 | 19 | 97.5 |
| R20 | 5 | 1 | 5 | 1 | 4 | 1 | 5 | 2 | 5 | 1 | 19 | 19 | 95 |
| R21 | 5 | 1 | 5 | 1 | 4 | 2 | 5 | 3 | 5 | 1 | 19 | 17 | 90 |
| R22 | 4 | 1 | 5 | 1 | 4 | 1 | 5 | 3 | 5 | 1 | 18 | 18 | 90 |
| R23 | 4 | 1 | 5 | 1 | 4 | 1 | 5 | 1 | 5 | 1 | 18 | 20 | 95 |
| R24 | 4 | 1 | 5 | 1 | 4 | 1 | 5 | 2 | 5 | 1 | 18 | 19 | 92.5 |
| R25 | 4 | 1 | 5 | 1 | 4 | 1 | 5 | 2 | 5 | 1 | 18 | 19 | 92.5 |
| R26 | 4 | 1 | 5 | 1 | 5 | 1 | 5 | 3 | 5 | 1 | 19 | 18 | 92.5 |
| R27 | 5 | 1 | 5 | 1 | 4 | 1 | 5 | 3 | 5 | 1 | 19 | 18 | 92.5 |
| R28 | 5 | 1 | 5 | 1 | 4 | 1 | 5 | 2 | 5 | 1 | 19 | 19 | 95 |
| R29 | 4 | 1 | 5 | 1 | 4 | 1 | 5 | 3 | 5 | 1 | 18 | 18 | 90 |
| R30 | 4 | 1 | 5 | 1 | 4 | 1 | 5 | 3 | 5 | 1 | 18 | 18 | 90 |
| | | | | | | | | | | | | Average Score | 94.58 |

2837.5

94.58333333

**Figure 7: Respondents' Score of Usability**

The result obtained is 94.58% and thus the application is acceptable since it falls in the acceptable range of the scale of the SUS score based on Figure 8. In my opinion, the result obtained is high because the students might not fully understand the meaning of the scale from 2 to 4. Thus, most of them only select strongly disagree and strongly agree when answering the Google Form.

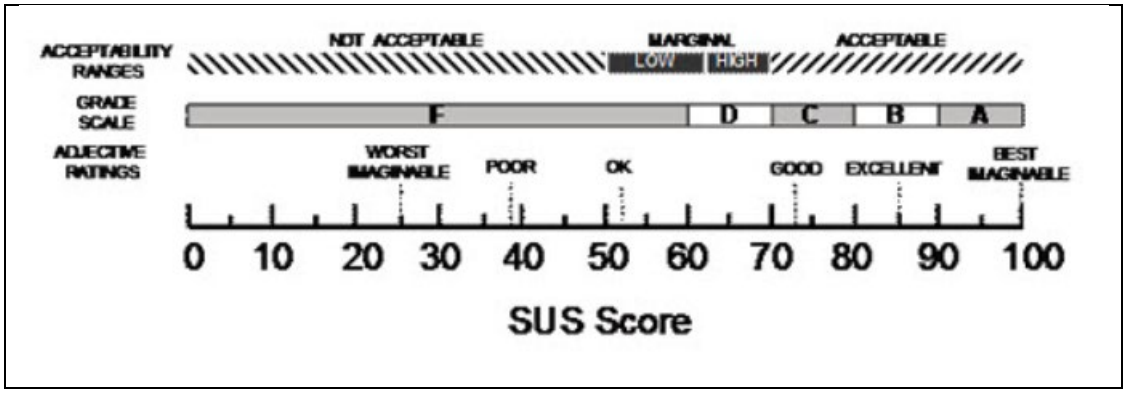



**Figure 8: SUS Score [18]**

## 5. Conclusion

In a nutshell, a microorganism learning application is designed for year 6 students in primary school named MicroWorld. The creation and accomplishment of the application development workflow are among the achievements and all the objectives are fulfilled. The respondents provide favorable feedback in accordance with the testing's findings. Thus, it can be stated that it is suitable, has the potential of acting as a learning tool for educating kids about microorganisms, and avoids the misconception that all microbes are harmful to human beings. In furtherance, as students often do experiments physically, a mix of augmented reality technology and multimedia features are employed in this application, giving users a fresh experience in conducting the experiment employing augmented reality technology. The integration of multimedia components including text, music, images, and animation in MicroWorld is another benefit. When developing the buttons, icons were chosen over words because the target audience was 12 years old. A voice-over will play when the description panel pops out, even if text elements have been used to indicate the name, kind, benefits, and drawbacks of each microbe. The text and audio components make it useful for users who prefer simply auditory, visual, reading, or a combination of the two learning styles, or who utilize all three. Consequently, it is advantageous for tri-modal and bi-modal learners. The buttons implemented in the MicroWorld application are also consistent, which will not confuse the users. Apart from that, the MicroWorld application's restrictions indicate that only sound effects will be played when answering quiz questions. If the user mutes the application, it will not be able to tell if the answer button the user hits is accurate or wrong. Along with that, just one set of test questions is offered. Moreover, it only allows for the support of Android-based smartphones rather than IOS-based smartphones, making it unfriendly to IOS users. Additionally, MicroWorld lacks an amusement module, such as a mini-game module, to let players decompress after completing the learning module and dense with the knowledge. Therefore, future work is making improvements to the answers checking method in the Quiz module, which includes adding a visual correct or incorrect effect in the Quiz module. Furthermore, offers the users a wider selection of quiz questions divided into three difficulty categories: easy, medium, and hard. It is further recommended that this application be made available for iOS. Last but not least, a mini-game module will be added.

## Acknowledgement

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## Appendix A

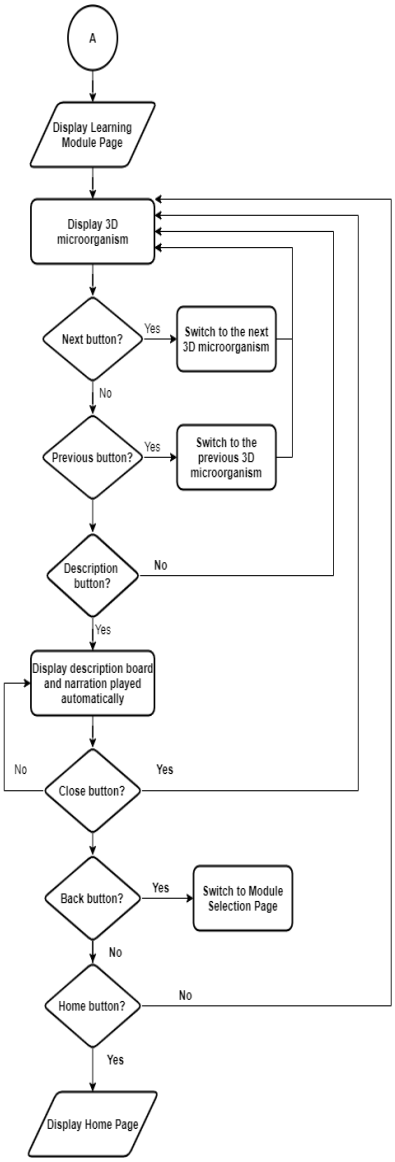



**Figure 9: Learning Sub-process flow**

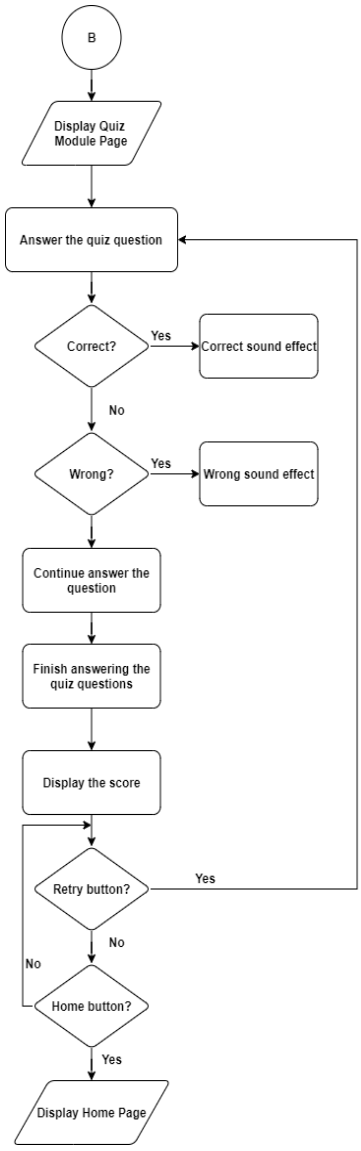



**Figure 10: Quiz Sub-process flow**

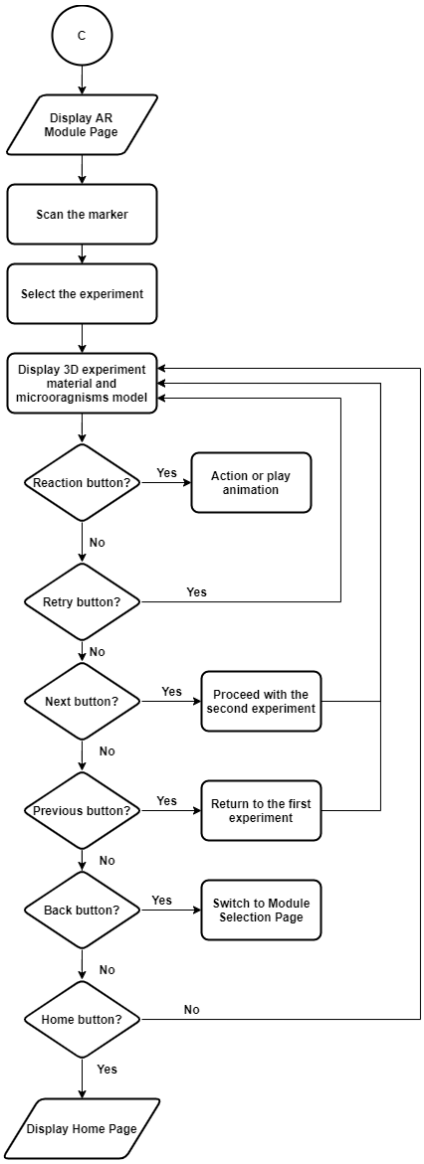
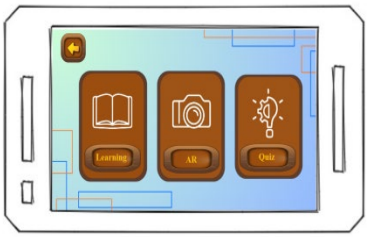
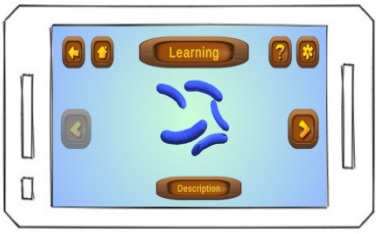
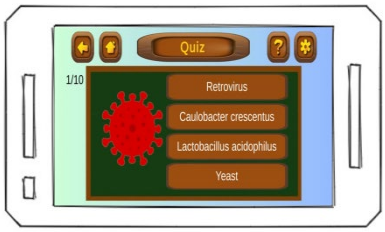
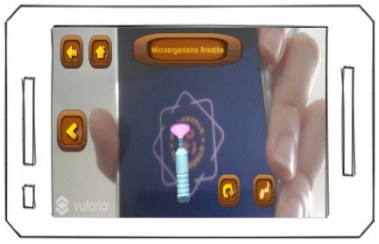



**Figure 11: AR Sub-process flow**

## Appendix B

**Table 9: Interface Design**

| Interface | Description | Interface | Description |
|---|---|---|---|
|  | This is the home page. |  | This is the exit page. |
|  | This is the credit page. |  | This is the settings page |
|  | This is the module selection page. |  | This is the learning module page. |
|  | This is the description board on the learning module page. |  | This is the quiz module page |
|  | This is the score at the end of the quiz module page. |  | This is the AR module page. |
|  | This is the first experiment after the user scans the marker. |  | This is the second experiment after the user scans the marker. |

## Appendix C

**Figure 10: Beta Testing**

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