# AITCS

# Development of Mobile Application for Applying Aquaponics Techniques in Farming Using Augmented Reality Approach

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**Abstract**: Aquaponics is integrated agriculture that blends aquaculture and hydroponics techniques with recirculating culture water to create 100% organic food sources while reducing wastewater generation. Currently, there are few available mobile apps for aquaponics, especially those that provide an augmented reality approach. Many of them require payment while others lack multimedia elements. As an additional learning tool to teach aquaponics utilising augmented reality, a mobile learning application is proposed. The objectives of this project is to design and develop the Aquaponics mobile application which employed multimedia elements using an augmented reality approach on the Android platform. Next is to perform functional testing and user acceptance testing on the target user. Multimedia Mobile Content Development is used as the methodology of the project. The application provides 8 topics of information, a video guide on building the aquaponics system and a 3D model to help the target users in visualizing the model. The functionality test result showed that all the functions work well as expected. The user acceptance test is done on 30 targeted users and the result showed more than 80% of positive responses which indicated the users are satisfied with the application. Future work can be done by adding more 3D model designs and interactivity in the AR session.

**Keywords**: Aquaponics, Mobile Application, Augmented Reality

## 1.    Introduction

Aquaponics is integrated agriculture that combines aquaculture and hydroponics techniques. The water used in this technique is recirculating. It starts from the fish tank, followed by the filter, the media bed and finally back to the fish tank. The complete cycle of the system provides a healthy growing environment for the fishes and plants as it is appropriately balanced [1]. There is a growth in demand for organic products [2] with the increasing concern of nutrition, health and quality of the food. The aquaponics system is a system that should be introduced widely to the public to fulfil the increasing demand as this system produces 100% organic food sources. It is different from Malaysia's Agriculture system to achieve the highest yield from the land which uses a lot of chemical products to assure yields

[3]. These chemical products are harmful to the environment and bring side effects to consumers. Besides the health issues, the self-sufficiency rate of vegetables in Malaysia in the year 2016, 2017, 2018 and 2019 are 51.51%, 46.64%, 44.56% and 44.63% respectively [4]. These data show that almost half a portion of the vegetables in Malaysia are imported to ensure that there is a sufficient vegetable supply. One of the programs that can solve this issue is the Urban Farming Program held by the Department of Agriculture [5]. The program is a campaign that encourages a community that consists of individuals and the community to grow vegetables and food crops for reducing living costs and producing enough, high-quality and safe food sources through their production of food. An aquaponics system can be one of the choices for this program where it does not require a large area to obtain high yields with two food sources which are vegetables and fish in a system.

In this era that is full of technology, augmented reality (AR) is the technique of mixing computer-generated data and a real-world environment [6]. It has been implemented in various sectors such as education, medical, games and navigation. These sectors that implemented AR have achieved a better quality or better user experience. AR usually can be categorized into marker-based AR and markerless AR. An interactive AR that allows the user to enlarge, rotate and view the object from various angles will provide a good experience for the user, especially for those who are unable to experience it in real life. Therefore, AR can be implemented in the agriculture sector to promote modern farming knowledge to the public, especially the younger generation. Nowadays, people can easily download any mobile application from Google Play Store. Based on the Hand Phone Users Survey 2018 by the Malaysian Communication and Multimedia Commission (MCMC) [7], the number of users of handphones has increased over the years. People use various mobile applications on handphones for communication, education, entertainment, shopping or even some useful information.

Based on the research done in the existing application in Google Play Store, there are not many applications that are developed with the content of aquaponics. The application existed with information contents are wordy, while the application existed with design contents are provided with images only. There is no application found that consists of both contents above. Moreover, there is the only application that includes Augmented Reality, but its function of the Augmented Reality (AR) does not function well as the model does not show on the screen. Therefore, after considering the existing problems, the application is proposed by providing the concept of the aquaponics system to the users and AR is applied in this application to allow users in viewing a basic aquaponics system that can be designed in their backyard or rooftop of a building. The objectives of this project are: (i) to design the aquaponics mobile application using an augmented reality approach, (ii) to develop the Aquaponics mobile application using the Android platform, and (iii) to perform functional testing and user acceptance testing on the target user.

The target users of this application are youth aged between 15 and 30. This application is to encourage and interest them in exploring deeper in this field. The application is designed entirely in English based. The application is allowed to operate on Android-based mobile. There are three modules in this application which are the learning module with 8 topics, the tutorial module that provides a video tutorial on building an aquaponics system and the marker-based AR module which displays the 3D aquaponics system.

This section discussed the background of the project. Section 2 discussed the literature review of the related work and existing applications. Section 3 explained the methodology used as well as the analysis and design. Then, the implementation and testing are explained in Section 4. Finally, the last section summarized the current work with advantages and limitations and suggestions for improvement.

## 2.    Literature Review

This section discussed the technology used in the development of the application and the research result of similar applications that are related to the application.

## 2.1 Aquaponics

Aquaponics is a system that has the concept of using the metabolic waste from the fish to be the fertilizer for the plant. This concept existed thousands of years ago in Asia and South America. The basic form of aquaponics is started in the late 1970s by the New Alchemy Institute and other North American and European academic institutions. In the 1980s, the integration of aquaculture and hydroponics achieved limited success. The improvement in system design, biofiltration and the identification of the optimal fish-to-plant ratios in the 1980s and 1990s has brought to the success of the aquaponics system [1].

Aquaponics is the integration of aquaculture and hydroponics. These two separate production systems are combined into one recirculating production system. In an aquaponic system, there are three living things involved in the system which are fish, bacteria and plants. In a conceptual understanding, the system is made up of a fish tank, filters and a media bed. The cycle of aquaponics started from the metabolic waste produced by the fish. The metabolic waste will generate ammonia in water that causes the water to be toxic to fish. The wastewater is pumped out from the fish tank into the filter which is made up of a mechanical filter and a biological filter. The water flows into the mechanical filter that filters out the solid waste and then moves into the biological filter which is the house for bacteria. There are two types of bacteria in the system which are ammonia-oxidizing bacteria to oxidize ammonia to nitrite and nitrite-oxidizing bacteria to oxidize nitrite to nitrate. The process is called the nitrification process. When the water flows out of the biological filter, it will be flown into the media bed. The dissolved nitrate in the water is absorbed by the plant as nutrients and the water is purified. Finally, the water returns to the fish tank. The living things in this complete cycle of the system keep a balanced and healthy environment for each other.

## 2.2 Augmented Reality

Augmented Reality (AR) is a technology that has been implemented in various sectors all around the world. It is a system that has the characteristics of combining real-world objects with the virtual object, interactive in real-world and registered in 3-D [8]. The sectors that have been implemented with AR included education, medical, entertainment and navigation. It is one of the technologies that can bring great improvement in these sectors. In general, AR can be categorized into two types which are marker-based AR and markerless AR.
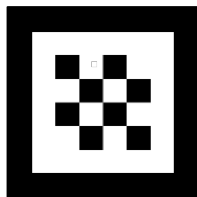


**Figure 1(a): Simple Marker**

**Figure 1(b): Sample Markerless AR [10]**

Marker-based Augmented Reality is a type of AR that depends on markers [9]. Markers are usually simple basic shapes made up of black squares on white backgrounds as shown in Figure 1(a), but other colours are allowed with the condition of being recognizable by the camera [10]. The feature of the marker is extracted and the virtual object will be displayed. Nowadays, there are several Software Development Kit (SDK) that provide the algorithms to extract the feature. An example of the existing SDK is AR SDKs.
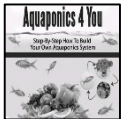
Markerless augmented reality is a type of AR that depends on localization technology and gyroscope [10]. It does not require a marker in displaying the virtual object. However, the virtual object will be

assigned with longitude and latitude. The Global Positioning System (GPS) will determine the position of the virtual objects and display the information to the users. The existing AR system that will display the furniture chosen by the user is one of the example products that use markerless augmented reality. Figure 1(b) is the sample of markerless AR which shows the information over a building.

## 2.3    Comparison of Existing Application and Proposed Application

There are a few mobile applications in Google Play Store that are developed with aquaponics content. Three applications that contain similar features to the proposed application are chosen to be compared in terms of the operating system, price, internet connection, content, AR-type, 3D model visualization, strength, and weakness as shown in Table 1. The chosen applications are "Aquaponics System" [11], "DIY Aquaponics Design" [12] and "AR Aquaponic" [13].

**Table 1: Comparison between existing application and proposed application**

| Feature | Aquaponics System | DIY Aquaponics Design | AR Aquaponics | Aquaponics |
|---|---|---|---|---|
| Operating System | Support Android 4.0 and above | Support Android 4.1 and above | Support Android 4.1 and above | Support Android 8.0 and above |
| Price | Free | Free | Need payment | Free |
| Internet Connection | No Internet connection needed | No Internet connection needed | Internet connection needed | No Internet connection needed |
| Content | Contains 45 topics for aquaponics | Contains 100 aquaponics designs | Stimulation of aquaponics in AR mode and 2D mode | Information, system building process and 3D AR model of the aquaponics system |
| AR-type | No AR applied | No AR applied | Marker-based | Marker-based |
| 3D model visualization | No 3D model visualization | No 3D model visualization | No 3D model visualization | Provide 3D visualization |
| Buttons | Not consistent in size | Consistent in size | Not consistent in size | Consistent in size |
| Audio | No audio provided | No audio provided | No audio provided | Background music in the video |
| Video | No video provided | No video provided | No video provided | Video provided as a tutorial |

## 3.    Methodology

Multimedia Mobile Content Development (MMCD) methodology is chosen for the development of the application to speed up the application development process and optimize mobile processing usage and data usage [14]. Figure 2 shows the MMCD model which contains the application idea creation stage, structure analysis stage, process design stage, main function development stage, and testing stage. Each stage is discussed in the following subtopics.
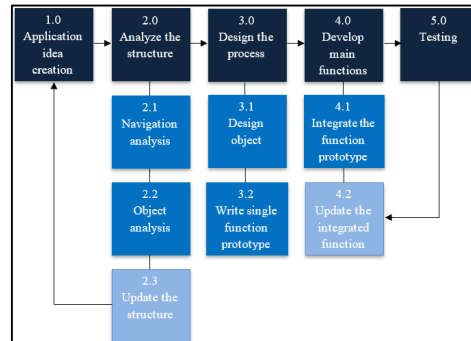


**Figure 2: Multimedia Mobile Content Development (MMCD) model [14]**

3.1    Application Idea Creation

Application idea creation is the first stage of MMCD methodology. In this stage, the needed information is collected and prepared before starting the design and development of the application. Table 2 shows the application idea creation checklist of applications. Besides, the user requirement analysis is tabulated in Table 3.

**Table 2: Application idea creation checklist**

| Item | Note |
|---|---|
| Type of application | • Mobile application |
| Target device | • Android mobile phone |
| Target users | • Youths aged between 15 and 30 |
| GUI (Graphical user interface) | • Home interface, Learning module, AR module, Tutorial module |
| Images | • Images of fishes and plants |
| Video | • Tutorial on building aquaponics system |
| Audio | • Background music in tutorial |
| AR | • Marker-based AR |
| Application synopsis | • Aquaponics is an application that provides the basic information of an aquaponics system which included a sample system, living things in the system, parts of the system, filter, the nitrification process, the materials to build up the system, fish selection and plant selection. It also provides a video tutorial on the building of an aquaponics system and an AR 3D model of the aquaponics system that is suitable for people who wanted to own a small-scale aquaponics system. |

**Table 3: User requirement analysis**

| Stakeholder | Role | Design Implications | Action Needed |
|---|---|---|---|
| Subject Matter Expert | Content consultant expert in the aquaponics field | Based on the interview,<br>• Simple user interface | • There are text and icon-based buttons used to ease the understanding of the navigation. |
| | | • Easy to navigate | • The application should contain back, previous, next and leave buttons.<br>• All buttons should have a consistent size.<br>• Avoid having complex navigation. |
| | | • Easy to learn | • A usage tutorial provided |
| | | • Reliable content, easy to understand | • The application should provide correct information about aquaponics. |
| General user | End-user of the system | Based on the questionnaire,<br>• Can be accessed anytime | • The application should function without the requirement of the Internet. |
| | | • Easy to use | • The application should provide easy-to-understand navigation. |
| | | • Free to download | • The application should be free to download and use without charging any price. |

## 3.2 Structure Analysis

The second stage of MMCD methodology is structural analysis. In this stage, two components of the application are conducted which are navigation analysis and object analysis. A content structure checklist is produced as shown in Table 4.

**Table 4: Content structure checklist**

| Item | Note | Item | Note |
|---|---|---|---|
| Layers design | Layer 1: Background images<br>Layer 2: Content<br>Layer 3: C# Scripting for Unity | Images | • Background image<br>• Fish images such as 'tilapia'<br>• Plants image such as 'tomato' |
| Video | Aquaponics system building steps | Audio | • Background music for video |
| Number of main GUI | Application logo | Sub GUI | None |

**Table 4: (Continued)**

| Item | Note | Item | Note |
|---|---|---|---|
| Frame design | Frame 1: Home Page<br>Frame 2: Learning module<br>Frame 3: Sample system<br>Frame 4: Living things in the system<br>Frame 5: Parts of the system<br>Frame 6: Filter<br>Frame 7: The nitrification process<br>Frame 8: Materials<br>Frame 9: Fish selection<br>Frame 10: Vegetable selection<br>Frame 11: AR module<br>Frame 12: Tutorial video<br>Frame 13: About<br>Frame 14: Quit pop-up | Menu and Navigation | • Start button<br>• Tutorial button<br>• AR button<br>• About button<br>• Back button<br>• Previous button<br>• Next button<br>• Cross icon button<br>• Quit button<br>• Yes button<br>• No button |

## 3.3 Process Design

Process design is the third stage of the MMCD methodology. In this stage, all the items in the content structure checklist as shown in Table 4 need to be prepared. There are two sub-components involved in this stage which are design objects and single function prototype scripting. The button design, content structure and flowchart are prepared. The storyboard is attached in Appendix A.

**Table 5: Button design**
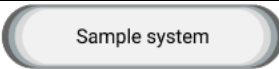
| Button | Description | Button | Description |
|---|---|---|---|
| TUTORIAL | • This is the tutorial button that navigates the user to the video display interface. | (back button icon) | • This is the back button that navigates the user back to the previous interface. |
| LEARN | • This is the learn button that navigates the user to the topic selection interface. | (quit button icon) | • This is the quit button. Navigate the user to the quit confirmation Interface. |
| VIEW AR | • This is the view AR button that navigates the user to the AR module. | Sample system | • This button existed in the topic selection interface, having a constant size with different words and colours to represent each topic. |
| ABOUT | • This is the about button that navigates the user to the about interface. | | |

**Table 5: (Continued)**

| Button | Description | Button | Description |
|---|---|---|---|
| YES | • This is the Yes button that appears on a quit confirmation interface which allows the user to quit the application. | ◁▷ | • This is the previous and next button that navigates the user within the topics. |
| NO | • This is the No button that appears on a quit confirmation interface which allows the user to stay in the application. | (fish) | • This type of button appears in the fish selection topic and plant selection topic having a constant size with different images and colours to represent each fish and plant. |
| ✕ | • This is the left button that allows the user to leave the topic detail interface. | | • The function of this button is to display the information about the fish and plants. |

The button is the element in the application to provide navigation within the application. The buttons that are designed for this application are simple and easy to understand. It is designed based on the design principle which is consistency. The buttons' design and their function description are shown in Table 5.
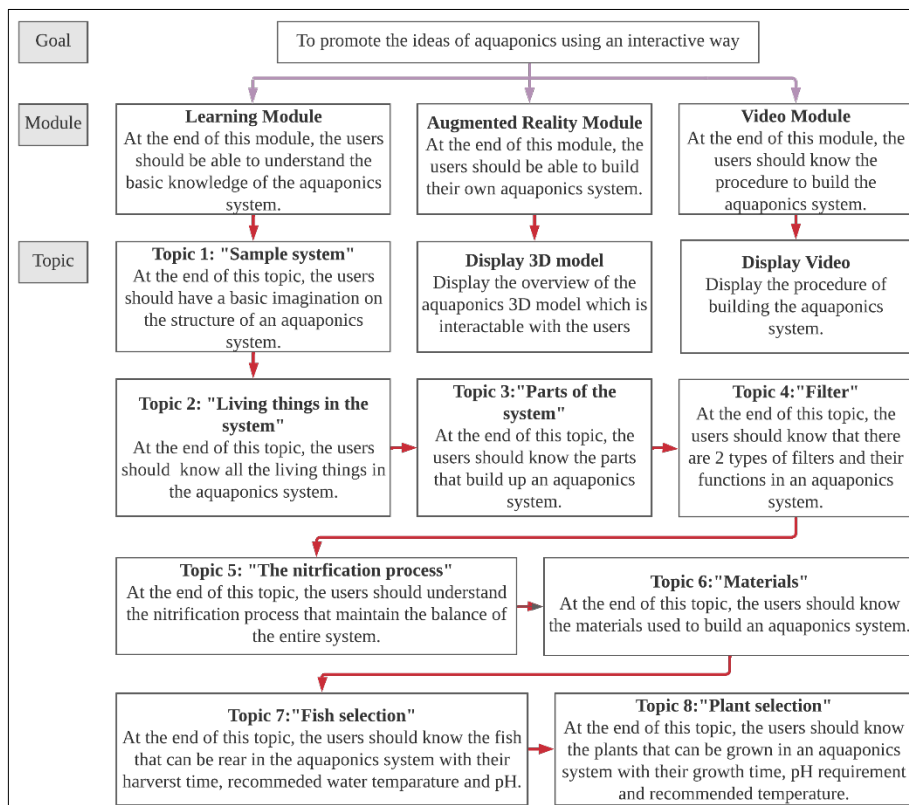


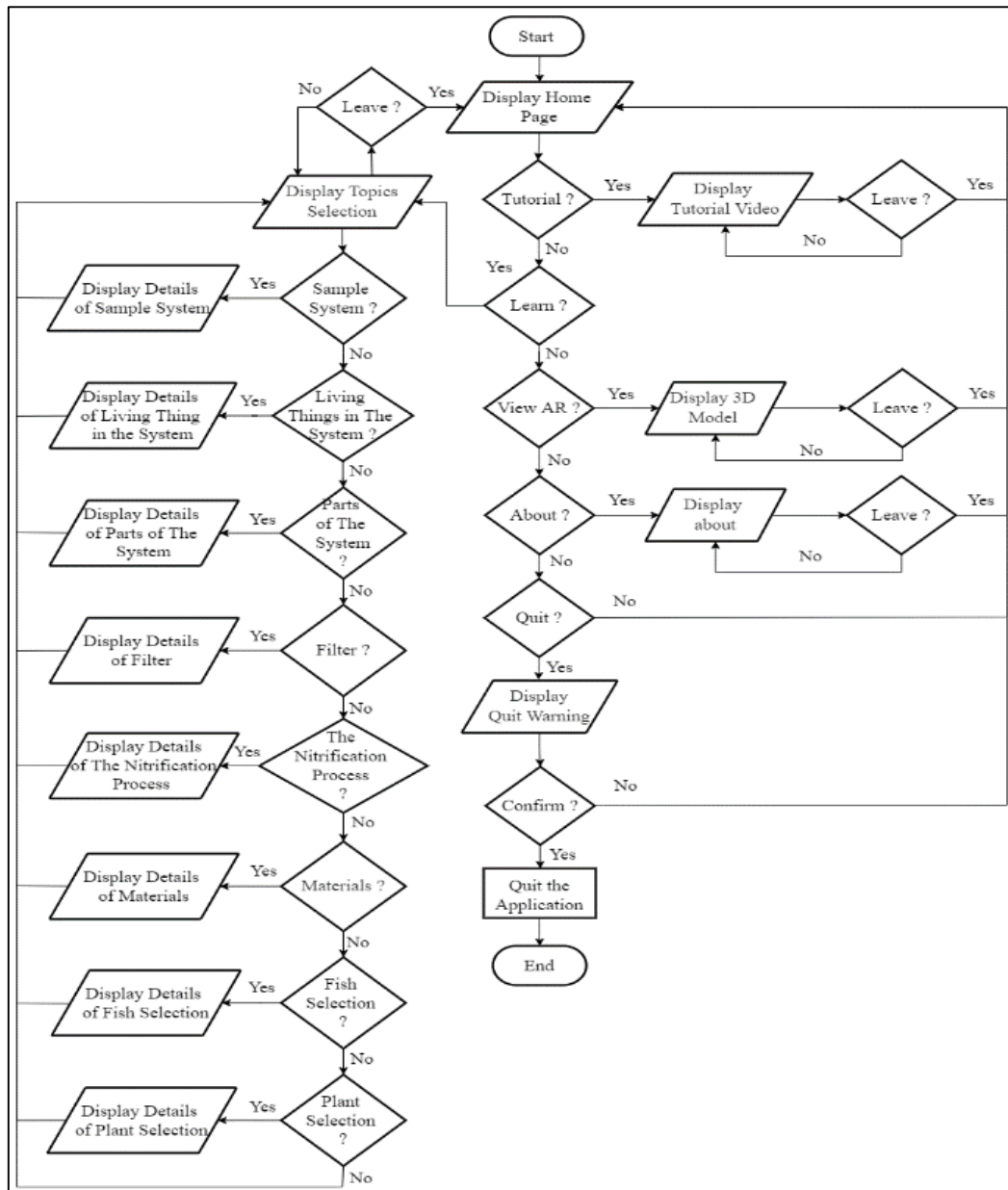**Figure 3: Content structure of Aquaponics**

**Figure 4: Flowchart of Aquaponics**

The content structure in Figure 3 outlined the goal, modules and topics that the user can learn from the application. The goal of developing the application is to promote the ideas of aquaponics using an interactive way. Besides, it shows that there are 3 modules in the application which are a learning module to learn the basic knowledge, an augmented reality module to allow the user to learn to build a simple aquaponic system by following the 3D model provided in the application and a video module to learn the procedure to build the aquaponics system. The topic is the part of the topics that are included in the module. There are 8 topics in the learning module which are sample system, living things in the system, parts of the system, filter, the nitrification process, the materials to build an aquaponics system, fish selection and plant selection. The flow chart in Figure 4 shows the detailed flow which included the main process and the sub-process in the application.

A single function prototype needs to be written in the design phase before the implementation stage. According to Figure 5, line 4 of the code snippet, the library that needs to be used is *UnityEngine.SceneManagement*. This library handles the object *SceneManager,* which involved the behaviour of *LoadScene* with parameters named "*Learn*", "*AR*", "*About*" and "*Home*".

```
using System.Collections;
using System.Collections.Generic;
using UnityEngine;
using UnityEngine.SceneManagement;

public class LoadScene : MonoBehaviour
{
    // Learning module
    public void LearnButton()
    {
        SceneManager.LoadScene("Learn");
    }

    // AR module
    public void ARButton()
    {
        SceneManager.LoadScene("AR");
    }

    // About module
    public void AboutButton()
    {
        SceneManager.LoadScene("About");
    }

    // Home page
    public void BackToHomeButton()
    {
        SceneManager.LoadScene("Home");
    }

    // Quit
    public void QuitApp()
    {
        Application.Quit();
    }
}
```

**Figure 5: Single function prototype of Aquaponics**

### 3.4    Main Function Development

Stage 4 of MMCD is the main function development stage. The main functions of this Aquaponics are the navigation between scenes or canvases, the play and pause of the video, and the AR session. These functions needed some setting or some scripting to be well-functioned. For the AR module, the scripting is focused on the functionality of the interactivity of the 3D aquaponic system model.
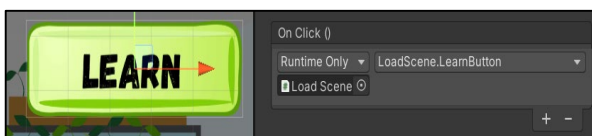
 

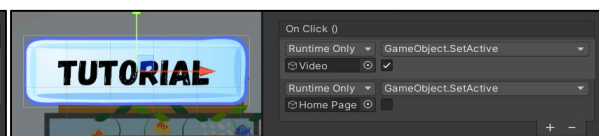**Figure 6(a): Navigation using script**        **Figure 6(b): Navigation using SetActive**

Figure 6(a) shows the navigation by assigning a method in a script. When the button is clicked by the user, the method is called and navigates to the respective interface. Figure 6(b) shows the navigation between canvases without using scripts. Besides, the play and pause buttons are shown and hidden on the interface by using the code as shown in Figure 7.

```
btnPause.gameObject.SetActive(true);
btnPlay.gameObject.SetActive(false);
```

**Figure 7: Hide and show the play and pause buttons**

```
public void BtnPlayVideo()
{
    if (videoIsPlaying)
    {
        VideoStop();
    }
    else
    {
        VideoPlay();
    }
}
```

```
private void VideoStop()
{
    videoIsPlaying = false;
    videoPlayer.Pause();
    btnPause.gameObject.SetActive(false);
    btnPlay.gameObject.SetActive(true);
}
```

```
private void VideoPlay()
{
    videoIsPlaying = true;
    videoPlayer.Play();
    btnPause.gameObject.SetActive(true);
    btnPlay.gameObject.SetActive(false);
}
```

**Figure 8(a): BtnPlayVideo method   Figure 8(b): VideoStop method      Figure 8(c): VideoPlay method**

Figure 8(a) shows the method that is called when the play or pause buttons are clicked. If the video is playing, the VideoStop method is called to pause the video as shown in Figure 8(b). If the video is in a paused state, the VideoPlay method is called to play the video as shown in Figure 8(c). Figure 9 is the Update method that controls the progress bar based on the frame of the video.

```
private void Update()
{
    if (videoPlayer.frameCount > 0)
    {
        float progress = (float)videoPlayer.frame / (float)videoPlayer.frameCount;
        progressBar.transform.localScale =
            new Vector3(progressBarWidth * progress, progressBar.transform.localScale.y, 0);
        knob.transform.localPosition = new Vector2(progressBar.transform.localPosition.x +
            (progressBarWidth * progress), knob.transform.localPosition.y);
    }
}
```

**Figure 9: Update method**

In the AR session, the marker is uploaded to the database in Vuforia. The Vuforia package 9.8.11 version and the database with Unitypackage format are downloaded and imported into Unity. An AR camera is added to the scene and repositioned to a suitable place while the original main camera is deleted due to duplication. Then, the license key of Vuforia is added to Unity to allow the camera to function as shown in Figure 10(a). The following steps are importing the 3D model into Unity, adding it to the scene, locating it on the image target and setting it as the child of the image target as shown in Figure 10(b).
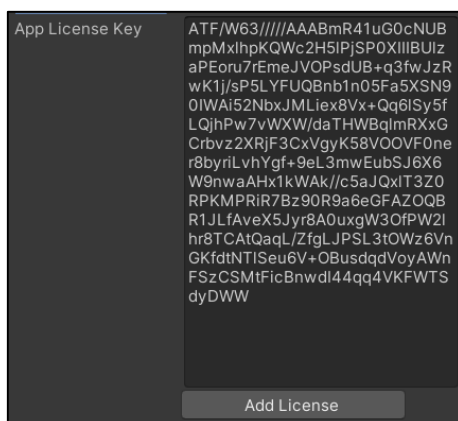


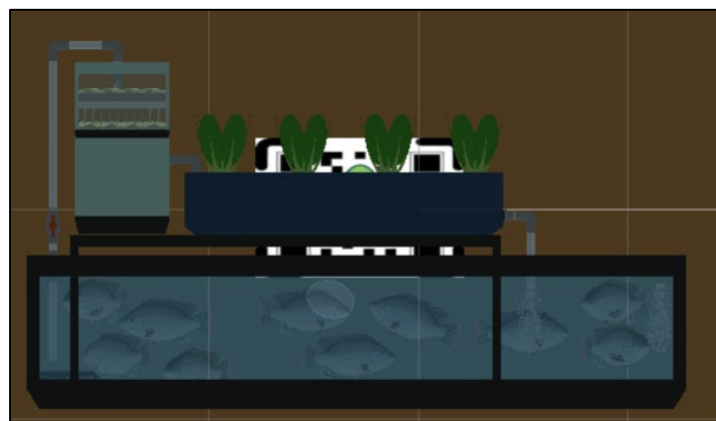**Figure 10(a): App license key**        **Figure 10(b): 3D model on image target**

```
// Count for 1 touch for rotation
if (Input.touchCount == 1)
{
    Touch touch = Input.GetTouch(0);

    // If touch, get initial position
    if (touch.phase == TouchPhase.Began)
    {
        initialPosition = touch.position.x;
    }

    // If touch moved, perform rotation
    if (touch.phase == TouchPhase.Moved)
    {
        if (initialPosition > touch.position.x)
        {
            transform.Rotate(Vector3.back, -rotateSpeed * Time.deltaTime);
        }
        else if (initialPosition < touch.position.x)
        {
            transform.Rotate(Vector3.back, rotateSpeed * Time.deltaTime);
        }
    }
}
```

**Figure 11: Rotation code segment**

Finally, there are some interactions applied to the model which are rotating and scaling the model. Figure 11 shows the code segment used to rotate the model while Figure 12 shows the code segment used to scale the model.

```
// Count for 2 touches for scale
if (Input.touchCount == 2)
{
    var touchZero = Input.GetTouch(0);
    var touchOne = Input.GetTouch(1);

    // If touchzero or touchOne is cancelled or ended
    if (touchZero.phase == TouchPhase.Ended || touchZero.phase == TouchPhase.Canceled ||
        touchOne.phase == TouchPhase.Ended || touchOne.phase == TouchPhase.Canceled)
    {
        return; //do nothing
    }
    //Get the distance between touchZero and touchOne
    if (touchZero.phase == TouchPhase.Began || touchOne.phase == TouchPhase.Began)
    {
        initialDistance = Vector2.Distance(touchZero.position, touchOne.position);
        initialScale = model.transform.localScale;
    }
    else // If touch is moved
    {
        var currentDistance = Vector2.Distance(touchZero.position, touchOne.position);
        var factor = currentDistance / initialDistance;
        model.transform.localScale = initialScale * factor; // Calculate new scale
    }
}
```

**Figure 12: Scaling code segment**

3.5     Testing

The last stage of the MMCD methodology is the testing stage. In this stage, there are two tests carried out which are the Alpha and Beta tests. Alpha test is the functional testing that is carried out by the developer to test whether the function runs properly. The beta test is the user acceptance testing that is carried out by the developer on the targeted user which are youth aged between 15 to 30. This stage is conducted to receive feedback from the users for future improvement.

## 4.     Results and Discussion

This section presents the results obtained from the testing process. The testing process is the process that starts after the application is completed. In this process, alpha testing and beta were carried out to ensure the application works properly. Alpha testing is done by the developer using a functional test while Beta testing is performed involving the targeted users after the development of the application is done using the user acceptance test.

4.1     Functional Test

Functional testing is a test carried out by the developer to check and test the functionality of the application. In this stage, if there is an error detected, the error will be solved to make sure it will be well functioned before releasing to the targeted users. The functional testing is done on all the functions of the buttons, the play and pause of the video, the generation of the 3D model and the interaction with the 3D model. The result of the functional testing is shown in Table 6, Table 7, Table 8, Table 9, Table 10 and Table 11.

**Table 6: Result of functional testing on Home page**

| Test | Expected Result | Actual Result |
|---|---|---|
| Learn Button | Navigates to the Topic's Selection interface | Works well as expected |
| Tutorial Button | Navigates to the Tutorial interface | Works well as expected |
| View AR Button | Navigates to the AR interface | Works well as expected |
| About Button | Navigates to the About interface | Works well as expected |
| Exit Button | Navigates to the Quit Confirmation interface | Works well as expected |

**Table 7: Result of functional testing on AR module**

| Test | Expected Result | Actual Result |
|---|---|---|
| Back Button | Navigates to the Home Page | Works well as expected |
| Scan Marker | Able to display the 3D model on the marker | Works well as expected |
| 3D Model can be Scaled and Rotated | Able to scale and rotate the 3D model | Works well as expected |

**Table 8: Result of functional testing in About**

| Test | Expected Result | Actual Result |
|---|---|---|
| Previous Button | Navigates to the previous information interface | Works well as expected |
| Next Button | Navigates to the next information interface | Works well as expected |
| Cross Icon Button | Navigates to the Home Page | Works well as expected |

**Table 9: Result of functional testing on Tutorial module**

| Test | Expected Result | Actual Result |
|---|---|---|
| Back Button | Navigates to the Home Page | Works well as expected |
| Play Button | Able to play the video | Works well as expected |
| Pause Button | Able to pause the video | Works well as expected |
| Video | Able to play the video when entering the interface | Works well as expected |
| Slider | Able to scale according to the frame of the video | Works well as expected |

**Table 10: Result of functional testing on Quit Confirmation interface**

| Test | Expected Result | Actual Result |
|------|-----------------|---------------|
| Yes Button | Able to quit the application | Works well as expected |
| No Button | Navigates to the Home Page | Works well as expected |

**Table 11: Result of functional testing on Learn module**

| Test | Expected Result | Actual Result |
|------|-----------------|---------------|
| Back Button | Navigates to the Home Page | Works well as expected |
| Sample System Button | Navigates to the Sample System interface | Works well as expected |
| Living Things in The System Button | Navigates to the Living Things in the System interface | Works well as expected |
| Parts Of the System Button | Navigates to the Parts of the System interface | Works well as expected |
| Filter Button | Navigates to the Filter interface | Works well as expected |
| The Nitrification Process Button | Navigates to the Nitrification Process interface | Works well as expected |
| Materials Button | Navigates to the Materials interface | Works well as expected |
| Fish Selection Button | Navigates to the Fish Selection interface | Works well as expected |
| Plant Selection Button | Navigates to the Plant Selection interface | Works well as expected |
| Previous Button | Navigates to the previous interface within the topic | Works well as expected |
| Next Button | Navigates to the next interface within the topic | Works well as expected |
| Cross icon Button | Navigates to the Topic's Selection interface | Works well as expected |

## 4.2    User Acceptance Test

The user acceptance test is a test that involved the target users after completing the application. The aim of this test is to get feedback from the target user who has experienced the Aquaponics application. In order to perform this test, a Google Form is released to 30 target users. In the Google Form, a link to access the Google Drive which contains the .apk file and the marker is included for the users. There are 3 sections in the Google Form. These sections are the AR background of the user, the user acceptance level and the functionality of the application. There is a different number of statements included in each section. Each of the statements is measured by a 5-point Likert scale ranging from "strongly disagree" to "strongly agree". The analysis is done on each question and shown in Figure 13, Figure 14, Figure 15 and Figure 16.
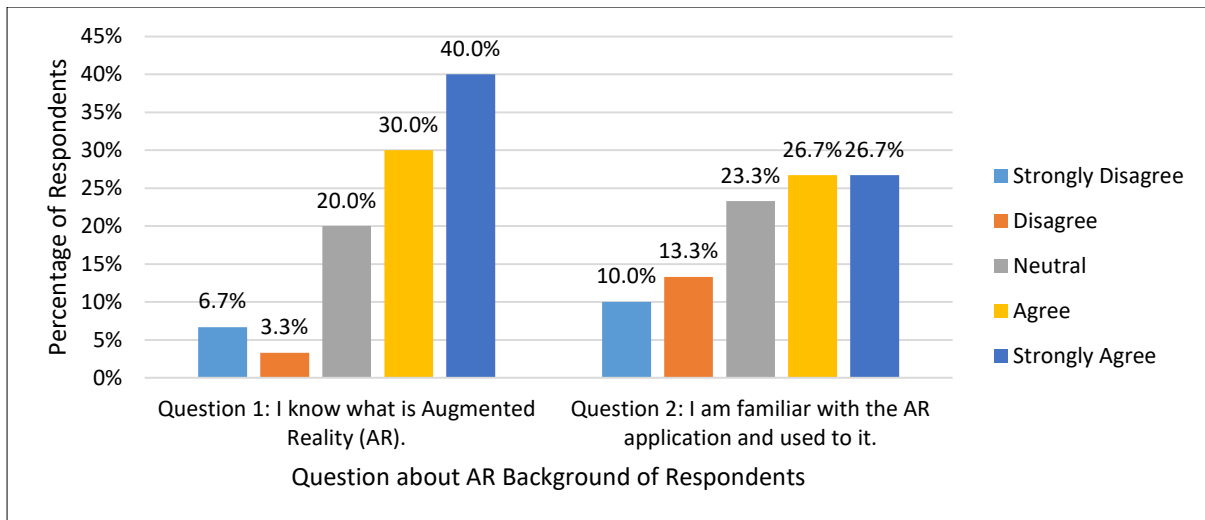
604

**Figure 13: AR background of Respondents**

Based on Figure 13, there are 2 questions were asked about the demography of the respondents. These 2 questions showed the AR background of the respondents. For Question 1, 70% of the respondents agreed that they know AR technology, 20% of the respondents felt neutral and 10% of the respondents disagreed that they know AR technology. For Question 2, only half of the respondents (53.4%) agreed that they are familiar with AR applications, 23.3% of them feel neutral and 13.3% of them are not familiar with AR applications.
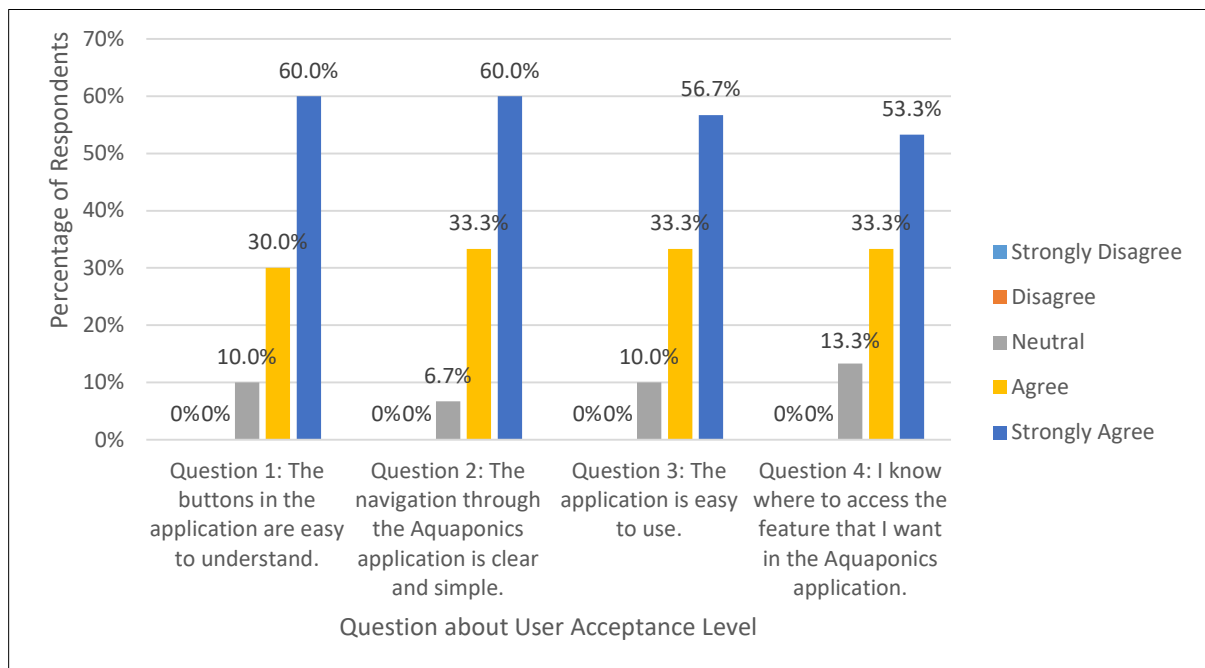


**Figure 14: Analysis of user acceptance level Q1 to Q4**

Figure 14 shows the first four questions of the user acceptance level. For Question 1 and Question 3, most of the respondents (90%) agreed that the buttons in the application are easy to understand and the application is easy to use while 10% of the respondents feel neutral on these 2 questions. For Question 2, 93.3% of the respondents feel that the navigation through the application is clear and simple while 6.7% of them feel neutral. Finally, for Question 4, 86.7% of the respondents agreed that they know where to access the features that they want in the Aquaponics application while 13.3% of respondents feel neutral on this question.
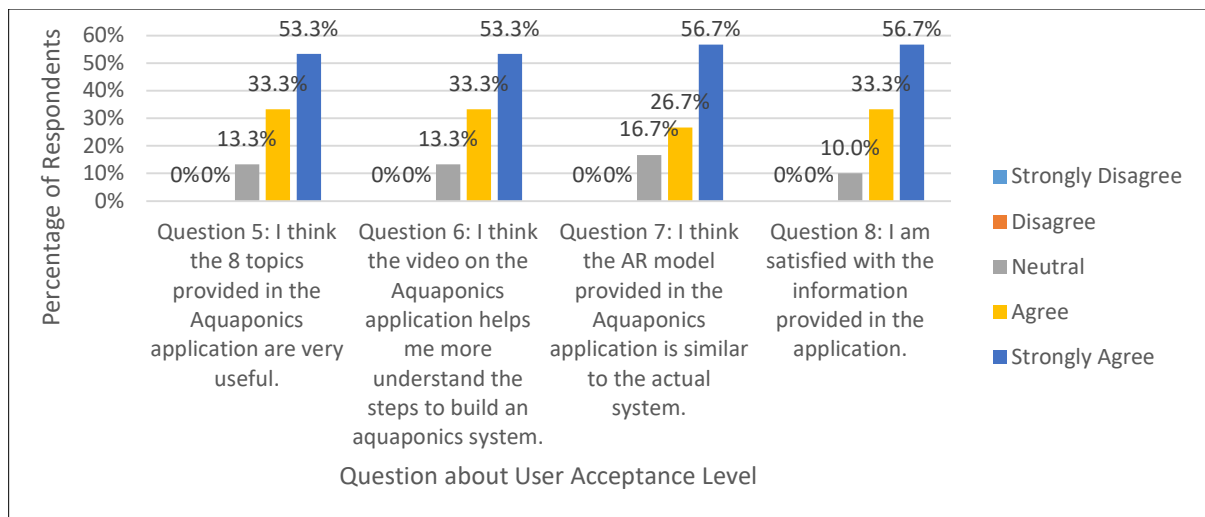
**Figure 15: Analysis of user acceptance levels Q5 to Q8**

Figure 15 shows the analysis of the user acceptance level for Question 5 to Question 8. Based on the figure, for Question 5 and Question 6, 53.3% of the respondents strongly agreed and 33.3% of the respondents agreed that the 8 topics provided in the application are very useful and the video on the application helps them more understand the steps to build on the aquaponics system. There are only 13.3% of the respondents feel neutral on these 2 questions. For Question 7, most of the respondents (83.3%) agreed that the AR model provided in the application is similar to the actual system while a small amount of them (16.7%) felt neutral. Finally, for Question 8, 90% of the respondents are satisfied with the information provided in the application while 10% of the respondents have a neutral opinion on this question.
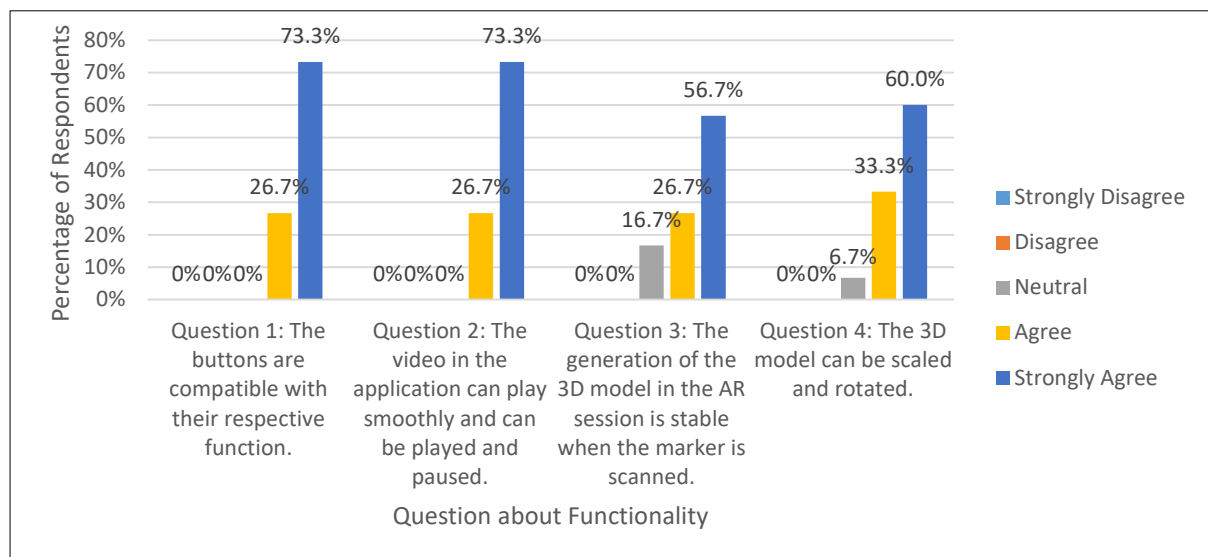


**Figure 16: Analysis of functionality**

Figure 16 shows the analysis of the functionality of the application. For Question 1 and Question 2, all of the respondents agreed that the buttons are compatible with their respective functions and the video in the application can play smoothly and can be played and paused. For Question 3, 83.3% of the respondents felt that the generation of the 3D model in the AR session is stable when the marker is scanned while 16.7% of them felt neutral. Finally, most of the respondents (93.3%) of the respondents agreed that the 3D model can be scaled and rotated while 6.7% felt neutral on this question.

**5.    Conclusion**

The Aquaponics application was successfully developed with three main modules. These modules are Learn module, Video module and AR module. The result of the user acceptance test has shown more than 80% of agreement rate for every question in the questionnaire.

The positive feedback received from the testing phase proved that the application is suitable to be introduced to the aquaponics system to the target user and the objectives are also achieved. There are a total of three objectives have been formulated to achieve the goals of this project. The first objective is achieved when AR is successfully implemented into the application. The second objective is achieved when the application exported from Unity is successfully installed in Android-based devices and can be used. Finally, the third objective is achieved when the functional test shows a positive result and the user acceptance test shows a result that is more than 80% of positive responses.

The advantages of the Aquaponics application were found after it had undergone the testing phase. These advantages are providing useful information to help the users easily get started with their aquaponics system with the provided information, providing the method for building an aquaponics system through video, has an AR session that provides users with more visualisation of the design of the aquaponics system, has an AR session that provides interaction such as rotation and scaling and has a high User Acceptance Level where the navigation and features of the application are simple and easy to understand.

Although Aquaponics applications have many advantages, the application also has some limitations. The limitations of Aquaponics application are providing only one sample model of the aquaponics system in the AR session, the interaction provided in the AR session is limited to rotating horizontally and scaling and the information provided regarding the aquaponics system is only a very basic knowledge for a beginner to start adopting the aquaponics system.

Based on the limitations that existed in the current Aquaponics application, some suggestions for improving the application are providing more sample models of the aquaponics system including small scale and large scale, adding more interaction to the AR session as well as adding more information on the problems that will be faced after the user had adopted the aquaponics system and the ways to solve the problems.

In conclusion, the overall development of the application is done successfully within a short time frame by following the Multimedia Mobile Content Development methodology. The high agreement rate from the user acceptance test has proven the success of the project. Therefore, it can be said that the three objectives of the project have been achieved.
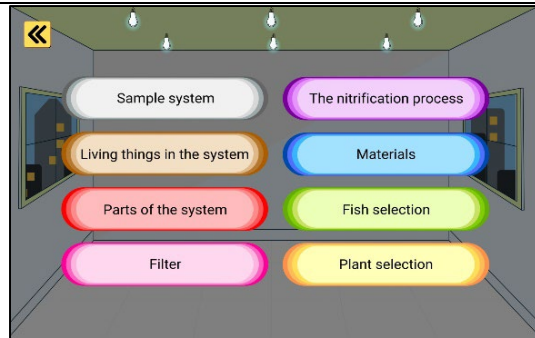
**Acknowledgment**

**Appendix A**

| Home Page Interface | Topics Selection Interface |
|---|---|
|  |  |

| Sample System Interface | Living Things in the System Interface |
|---|---|
|  |  |

| Parts of the System Interface | Filter Interface |
|---|---|
|  |  |

| The Nitrification Process Interface | Materials Interface |
|---|---|
|  |  |

| Plant Selection Interface | Plant Detail Interface |
|---|---|
|  |  |

| Video Display Interface | AR Model Display Interface |
|---|---|
|  |  |

| About Interface | Quit Confirmation Interface |
|---|---|
|  |  |
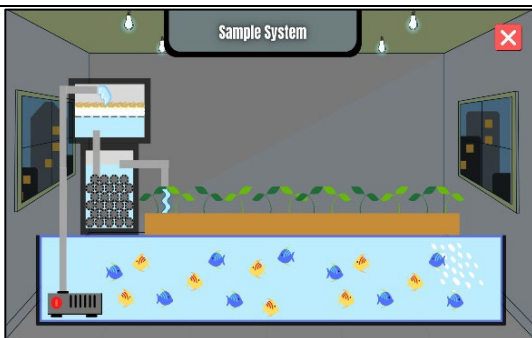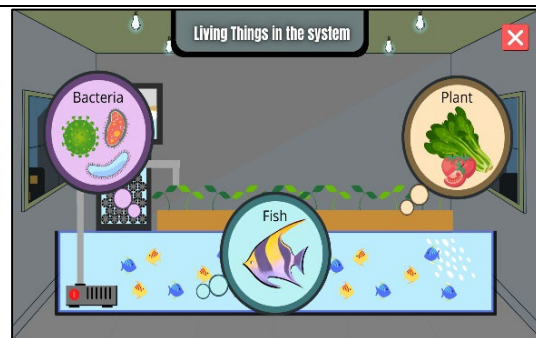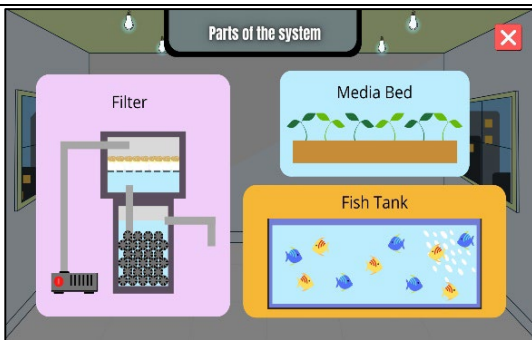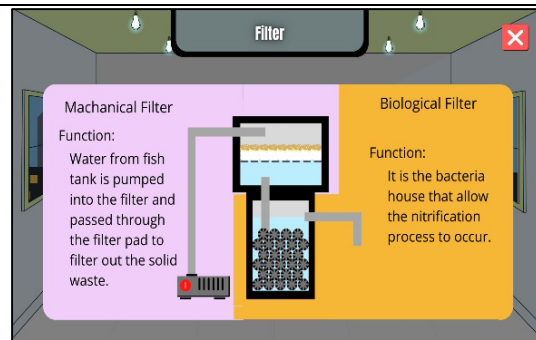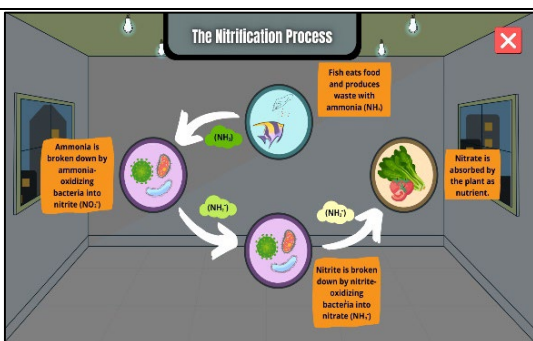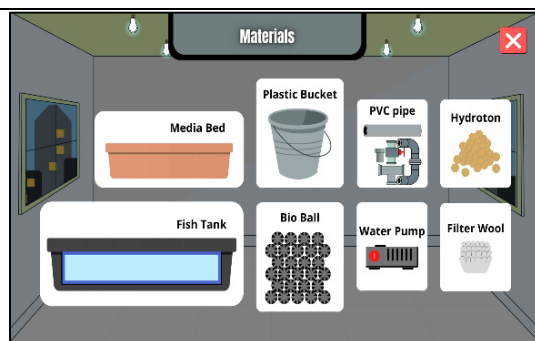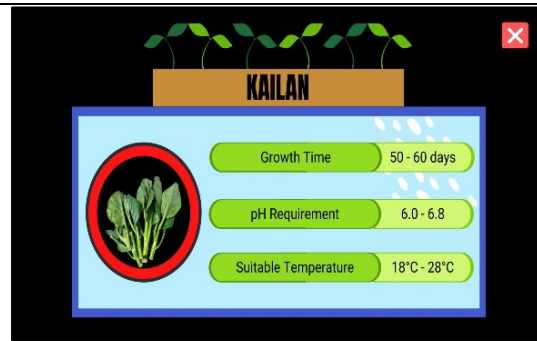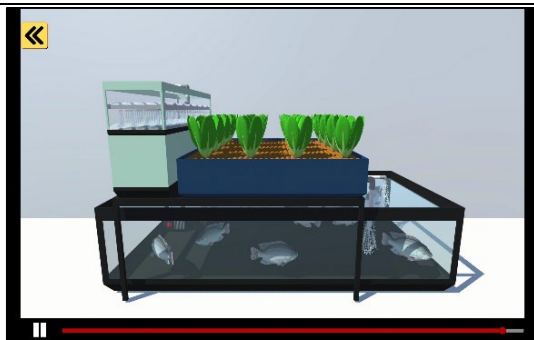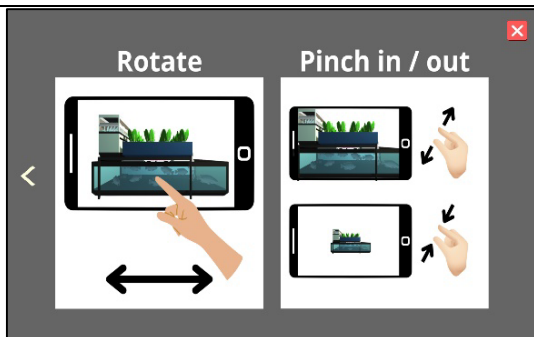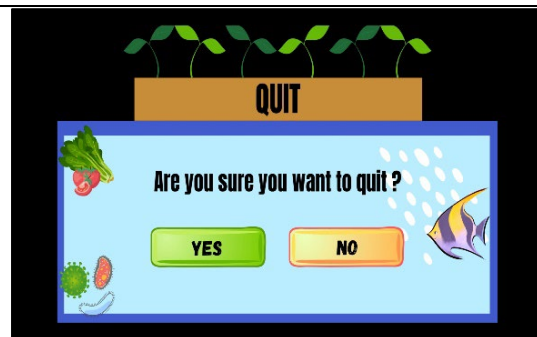
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