LEARNING BIOSPHERE CYCLES IN O/L SCIENCE SYLLABUS USING AUGMENTED REALITY

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Dissertation submitted in partial fulfillment of the requirements for the B.Sc. Honors Degree in Information Technology

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DECLARATION

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ABSTRACT

Technology has become highly important today since it has brought numerous opportunities for every life and every field making day-to-day tasks much easier. Also, it is something that grows faster and quicker with various new advancements. When considering the field of education, technology has a huge impact on its growth and development. Augmented Reality is among these newest technologies which have unveiled major possibilities for various fields including education. Although there are many advantages that come with AR, still lots of people are unaware of it.

This paper is a contribution to emphasize how AR can be used to create an effective and interesting learning environment for the Ordinary Level students in Sri Lanka. It has mainly focused on introducing a new way of learning the topic, Biosphere Cycles which comes under the O/L syllabus with an AR mobile application. In order to explain the content of the topic more clearly and effectively, a marker-based approach is used to create the application. The paper discusses how the marker-based approach works, and the other methods which are been used for the development of the application. Moreover, it describes how effective an AR application is for the students, the advantages they can gain, the feedback of the students which was obtained by handing over the application to them, and how the application can be commercialized. It also discusses the similar applications and studies which were carried out to underline the benefits of using AR. Therefore, the overall attempt of this paper is to highlight the importance of using AR for the development of education in Sri Lanka.

Keywords: Augmented Reality, Biosphere Cycles, Mobile Learning System

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LIST OF ABBREVIATIONS

Abbreviation	Description
AR	Augmented Reality
OL	Ordinary Level
PC	Personal Computer
GCE	General Certificate of Education

1. INTRODUCTION

1.1. BACKGROUND AND LITERATURE SURVEY

Augmented Reality has been widely used in various fields such as Medical training, Design, and Modelling, Tourism Industry, Education, Repair & Maintenance, etc. One of the main reasons for using AR is its inability to display physical objects using 3D models. It enhances the perception of the user; provides a better understanding of the interaction of the real-world objects by visualizing them virtually. These virtual objects demonstrate information which is complicated for the users to detect or observe directly by themselves. This information transmitted by virtual objects can help users in performing their tasks. In the education field, both the processes of teaching and learning can be developed and enhanced by applying AR. As an example, examining or studying animals would be more interesting and productive if the animals can be directly observed in an environment where they roam freely and naturally. Even though it is true, there can be situations where it is impossible to watch animals in a natural environment or at least in a zoo, because of its cost, distance, and time. But with augmented reality, it is possible to bring the real-life experience of observing the natural behaviors of the animals. The inability of observing the extinct animals using AR can also be shown as an example to emphasize its capabilities and potential. Moreover, studying monotonous subjects such as Science would be more interesting if the processes and scenarios in the textbook can truly be seen.

Applying AR for education would immensely support to improve the learning process because AR has the potential to change the traditional classroom-based learning to distance learning. Since the learning process should be all about creativity and interaction, it is not mandatory for teachers to always be there in the classroom to guide students. Besides, the ultimate goal of the learning process is to make students interested and motivated in a subject, and AR has the capability of doing that. Therefore, many researchers have put their efforts into topics such as learner motivation and engagement in learning using AR.

Rita Layonaa, Budi Yuliantob, and Yovita Tunardi together have carried out a study to develop an AR application for human body anatomy learning in order to make it easier for students to understand the content clearly. For collecting data for the research, a questionnaire has been distributed among 48 junior and senior high school students of a higher education institution in Jakarta, Indonesia. As mentioned in the research, this application enables students to learn human body anatomy with 3D object interaction, and previously it was taught using textbooks and mannequin, and therefore, students have faced difficulty in understanding its content. As a solution, this application has provided a three-dimensional practice form for the students to visualize the anatomy of two-dimensional body shape [1].

Similarly, in another study, it shows that learning human anatomy with an AR mobile application is more beneficial to students than learning it using textbooks. This study has mainly focused on highlighting the importance of AR for the medical students to learn human anatomy, and in order to gain data for the evaluation, a survey has been conducted with 30 medical students in Indonesia. Through the evaluation, the research has successfully proved that AR is one of the best technologies which can be used to improve the level of education. [2]

Another research has been conducted to develop an AR mobile application to learn railway transportation. As mentioned in this research, this AR application has been tested among 18 users, and as per the results gained from the testing process, the AR application has made its users teach boring and difficult subjects more interestingly [3]. Moreover, another research has indicated how to apply augmented reality technology using a marker-based approach in an E-learning system for transmitting virtual objects into real-world scenes. According to this research, there are two approaches for transmitting virtual objects into the real world scene: Marker-based and Monitor-based registration approaches. Finally, the research has indicated that a subject which is explained using several pages can be eliminated by replacing it with a small marker [4].

V. Camilleri and M. Montebello have emphasized in their research that the industrial-age approach has added barriers between the “classroom” setting and the real world, and AR is one of those powerful technologies which can break these barriers. Moreover, the following advantages of AR have been mentioned in the research [5].

- Flow in balancing inactivity and challenge.
- Repetition allowing learners to repeat their experimentation until they are satisfied with the outcomes.
- Experimentation in encouraging learners to try and learn in the process.
- Experience is more engaging than other digitally mediated technologies.
- Doing through practice.
- Observing through an essential communication platform.
- Motivation is stimulated by the people’s own active part.

Similarly, the benefits and the detriments of AR regarding e-learning has been emphasized by Kamalika Dutta in her study. This research has explained several relevant aspects which are needed to be considered in order to identify the true benefits of the AR technology in order to improve the learning processes. The main purpose of this study has been to encourage people to do more future research regarding AR for educational settings. It has also included a summarized research work that is related to AR for e-learning. Following Fig.1 shows the summarized research work [6].

Researcher	Application	Content	Participants
Woods et al., 2004	Multiple AR Exhibits such as SOLAR System, Black Magic Kiosk, Volcano Kiosk, EyeMagic Storybook.	Science and History Museum exhibits.	Museum Visitors
Kaufmann et al., 2002, 2006, 2007	Construct3D	Mathematics and Geometry	Several groups consisting of 6 students each
Schmalstieg and Wagner 2007	medien.welten	History	19 students (aged 12-15)
Squire, Klopfer et al., 2007	Environmental Detectives	Environmental Engineering Education	58 University students 18 High school students
Juan et al., 2008	AR Human Body System	Learning letters and words	32 Primary School Students (aged 5-6)
Arvanitis et al., 2009	CONNECT	Science	5 students with disabilities
Pérez-López et al., 2010	3 Desktop AR Applications and HUMANAR library	Human digestive and circulatory systems	Students (aged 10-11)
Juan et al., 2011	Games: ARGreenet and BasicGreenet	How to recycle	38 children (aged from 8 to 13 years)
Chen et al., 2011	Desktop PC AR Application	Engineering Graphics Courses	35 engineering-major students
Martín et al., 2012	EnredaMadrid	History	65 people (aged over 36 years)
Tarng and Ou 2012	Butterfly Ecological Learning System	Science	60 elementary school students
Kose et al., 2013	Mobile AR Application	Computer Science courses	200 Computer Science University Students
Santos et al., 2013	AR X-ray	K-12 Education	Pilot user study: 23 Students (aged 5-15) Second user study: 47 students (aged 11-16)
Blanco-Fernández et al., 2014	REENACT	Human History	61 University Students
He at al., 2014	Mobile AR English learning software	English Vocabulary	40 Pre-School children
Munoz et al., 2014	Gremlings in My Mirror	Logical Mathematics Skills	20 students from a school for children with special needs

Figure 1: A summarized research work on AR for e-learning

Apart from the above-mentioned studies, another study has presented four applications developed using augmented reality for e-learning; two have focused on the collaborative work of students and the other two on biology and geography. As mentioned in the paper, the use of images, 3D models, sounds, and animations are the important factors in AR which get the attraction from the students, and it is more effective than the classical teaching methods. The paper has explained further that these augmented elements allow students to retain new information more easily, and tests designed as games contribute to reducing their stress. This paper has mainly focused on indicating the use of augmented reality in order to improve the communication and collaboration skills between children, especially autistic children, and the game-based evaluation of pupils in various teaching areas, allowing for a stress-free testing environment [7].

Moreover, there is a study which was conducted by two researchers from the University of Moratuwa in order to implement a mobile application for enhancing the Sinhala learning experience for children. According to their study, with this application children can learn letters, vocabulary, and use letters interactively in real-world scenarios. Also, it is mentioned that with the survey results obtained by preschool teachers and children, 85% of them have given positive feedback about the application [8].

According to the above-mentioned facts, it is apparent that AR is one of the most effective and powerful technologies which can be used to improve the field of education. Although, in Sri Lanka, this technology is not being used to enhance the education of our children. Therefore, implementing an AR application can be highly important in Sri Lanka, and it can surely be useful to obtain educational advancements and encourage the students for learning.

1.2. RESEARCH GAP

As mentioned above, various studies have been carried out to highlight the relationship between e-learning and AR, and how this emerging technology can be used to improve the field of education. Also, many e-learning related AR applications have been implemented and tested among students, and they have proved that AR is an effective way to increase student motivation to study. Even though there are many studies and implemented AR applications for e-learning, these applications are still not being used in schools, universities, or other higher educational institutes. Therefore, it is also important to consider the commercialization aspect as well.

For Sri Lanka AR is a new concept, especially in the field of education. There are very few attempts have been made on AR-based e-learning, and none of these studies are focused on learning Science with AR. While considering the educational system in Sri Lanka, O/L Examination takes an important place in a student's life since it can decide his or her future path. Therefore, it would be a huge benefit if they have a better and effective way to learn difficult subjects in the O/L syllabus, such as Science. Science is a subject with many complex topics which has made it difficult to understand without proper explanations. Under the topic "**Biosphere"** in the Science syllabus, there are two main biochemical cycles: The carbon cycle and the Nitrogen cycle. In order to gain a better understanding of these cycles, reading the textbook will not be enough. Therefore, as an effort of making it easy for O/L students to learn these two biochemical cycles, this study has mentioned an Augmented Reality mobile application.

Even though there are no other similar AR mobile applications for Science in the local context, there are few related studies in other countries. The following Table.1 is a summarized comparison that shows the gap in order to emphasize the importance of the newly implemented application.

Table 1: Comparison between the New Product and the Existing Applications

Existing Research and Applications	Ability to visualize the textbook objects using 3D models	Audio Support	Provides both Sinhala and English Audios	Relevant to the O/L Syllabus
Augmented Reality Mobile Application to Enhance Sinhala Learning Experience for Children [8]	✓	✓	Sinhala Only	✗
Anatomiar [2]	✓	✗	✗	✗
GeoAR [7]	✓	✗	✗	✗
Digital Anatomy [1]	✓	✗	✗	✗
Spellbound [4]	✓	✗	✗	✗
ARBio [7]	✓	✓	English Only	✗
New Product	✓	✓	✓	✓

1.3. RESEARCH PROBLEM

Currently, there is only a traditional learning approach to learn the topic **"Biosphere"** in the O/L Science syllabus. Students can only learn these cycles using the textbooks, and therefore, there can be several reasons for the inability of most of the students to understand this topic. Those reasons can be mentioned as follow.

- Science is a monotonous subject
- Reading the textbook can be boring
- Difficult to understand the real processes of the biochemical cycles using 2D images and text descriptions

Due to the above-mentioned reasons, learning biosphere cycles can be a less interesting task for the students, and it could cause them to score low grades for Science in the O/L examination.

Table 2: O/L Science Results in 2018 *[9]*

Grade	School Candidates		Private Candidates		Total	Percentage
	Amount	Percentage	Amount	Percentage		
A	24453	7.83	643	2.99	25096	7.52
B	21689	6.94	750	3.48	22439	6.72
C	65220	20.88	2941	13.66	68161	20.42
S	99833	31.96	5814	27.01	105647	31.64
W	101148	32.38	11380	52.86	112528	33.70
Total	312343	100.00	21528	100.00	333871	100.00

The above Table 2 shows the O/L Science results in 2018, and it is a valid proof to indicate that most of the students have gotten lower grades: S and W grades for Science. This can be mitigated by improving student motivation for learning. Therefore, as a solution, an AR mobile application has been implemented to teach two main biochemical cycles in the Science syllabus:

Carbon cycle and Nitrogen Cycle. Using this application students can view a 3D model of each cycle to obtain a better understanding of how these cycles actually work. Also, there is an option in this application for students to select the language they prefer to learn. They can choose either Sinhala or English, and accordingly, audio description is played in the background of the 3D model.

1.4. RESEARCH OBJECTIVE

1.4.1. MAIN OBJECTIVE

The main objective of this research is to implement a mobile application using Augmented Reality to provide necessary knowledge about the biosphere cycles in the O/L Science textbook.

1.4.2. SPECIFIC OBJECTIVES

- Generating 3D models for the 2D cycle images in the textbook to make studying more effective and interesting.
- Providing audio support in both Sinhala and English languages since most Sri Lankan schools are Sinhala medium.
- Motivating students to learn the cycles, since operating a mobile application is less time consuming than reading a textbook.
- Making the user interfaces more attractive and user friendly since the application is designed targeting the O/L students.

2. METHODOLOGY

2.1. METHODOLOGY

2.1.1. PLANNING

As the initial phase of implementing the application, a literature study was performed regarding the augmented reality developments in different fields and decided to focus on applying AR in the field of education. Then, it was examined how this combination between AR and education can be useful for the betterment of the students. Especially, on how it can provide the required learning materials which should also be satisfying the visualization need. Since the application was planned to develop in a way where students can learn the **Biochemical cycles in the O/L Science syllabus**, visualization was a major aspect. Therefore, it was planned to develop the application using the following technologies.

- **Vuforia**

  Vuforia is an augmented reality software development kit (SDK) for mobile devices that enables the creation of augmented reality applications. It uses computer vision technology to recognize and track planar images and 3D objects in real-time. This image registration capability enables developers to position and orient virtual objects, such as 3D models and other media, in relation to real-world objects when they are viewed through the camera of a mobile device. The virtual object then tracks the position and orientation of the image in real-time so that the viewer's perspective on the object corresponds with the perspective on the target. It thus appears that the virtual object is a part of the real-world scene [10]. The following Fig.2 shows the Vuforia trademark.

Figure 2: Vuforia Logo

- **Unity**

  Unity is a cross-platform game engine developed by Unity Technologies, first announced and released in June 2005 at Apple Inc.'s Worldwide Developers Conference as a Mac OS X-exclusive game engine. As of 2018, the engine had been extended to support more than 25 platforms. The engine can be used to create three-dimensional, two-dimensional, virtual reality, and augmented reality games, as well as simulations and other experiences. The engine has been adopted by industries outside video gaming, such as film, automotive, architecture, engineering, and construction [11].

Figure 3: Unity Logo

- SketchUp

  SketchUp is a 3D modeling computer program for a wide range of drawing applications such as architectural, interior design, landscape architecture, civil and mechanical engineering, film, and video game design. It is available as a web-based application, SketchUp Free, a freeware version, SketchUp Make, and a paid version with additional functionality, SketchUp Pro. SketchUp is owned by Trimble Inc., a mapping surveying and navigation equipment company. There is an online library of free model assemblies (e.g. windows, doors, automobiles), 3D Warehouse, to which users may contribute models. The program includes drawing layout functionality, allows surface rendering in variable "styles", supports third-party "plug-in" programs hosted on a site called Extension Warehouse to provide other capabilities (e.g. near photo-realistic rendering), and enables placement of its models within Google Earth [12].

Figure 4: SketchUp Logo

Moreover, during the literature survey, it was identified that there is no implemented O/L Science related AR applications. Therefore, it was crucial to gather and analyze the necessary customer requirements for the development of the application.

2.1.2. REQUIREMENTS GATHERING AND ANALYSIS

As previously mentioned, in order to gather and analyze the requirements an online survey was conducted among Grade 11 students. It was a questionnaire with 12 questions which was focused on discovering the difficult subject contents for the students. Another purpose of the questionnaire was to gain information about how many students are familiar with using new technologies and how much they prefer to learn using AR technology. The results of the study revealed that the majority of students who can get a decent grade, encounter problems in learning several principles of science because of the complexity in its content. Also, the study indicated that most students prefer to learn these contents with the aid of AR. Moreover, they have highlighted that it would be a huge benefit for them if they could visualize the biochemical cycles in the textbook using 3D models. Therefore, as a solution, it was concluded to implement an AR mobile application to encompass these highlighted topics in the O/L Science.

2.1.3. DESIGN

According to the analyzed requirements, it was important to implement a user-friendly, content related application which should also be suitable for students to use. Therefore, as the first step of the designing phase, it was mandatory to create a use case diagram and a flow chart in order to understand how the implementation of the application should take place. An architectural diagram was also created for the ease of implementation. It is one of the best practices to consider creating diagrams before starting the implementation since it can save both money and time. Following Fig.5, Fig.6 and Fig.7 respectively show the use case diagram, flow chart, and the high architectural diagram.

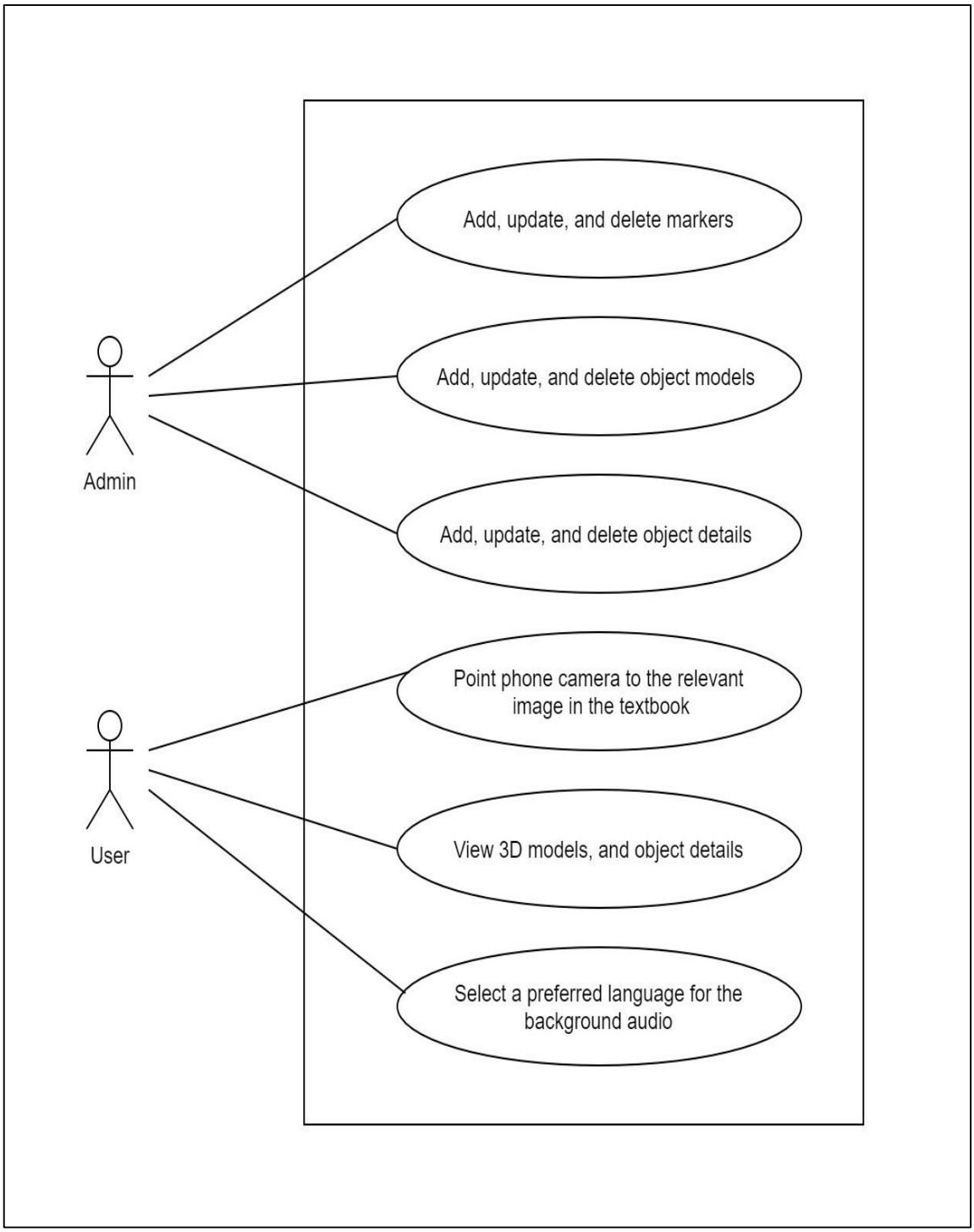

Figure 5: Use Case Diagram of the System

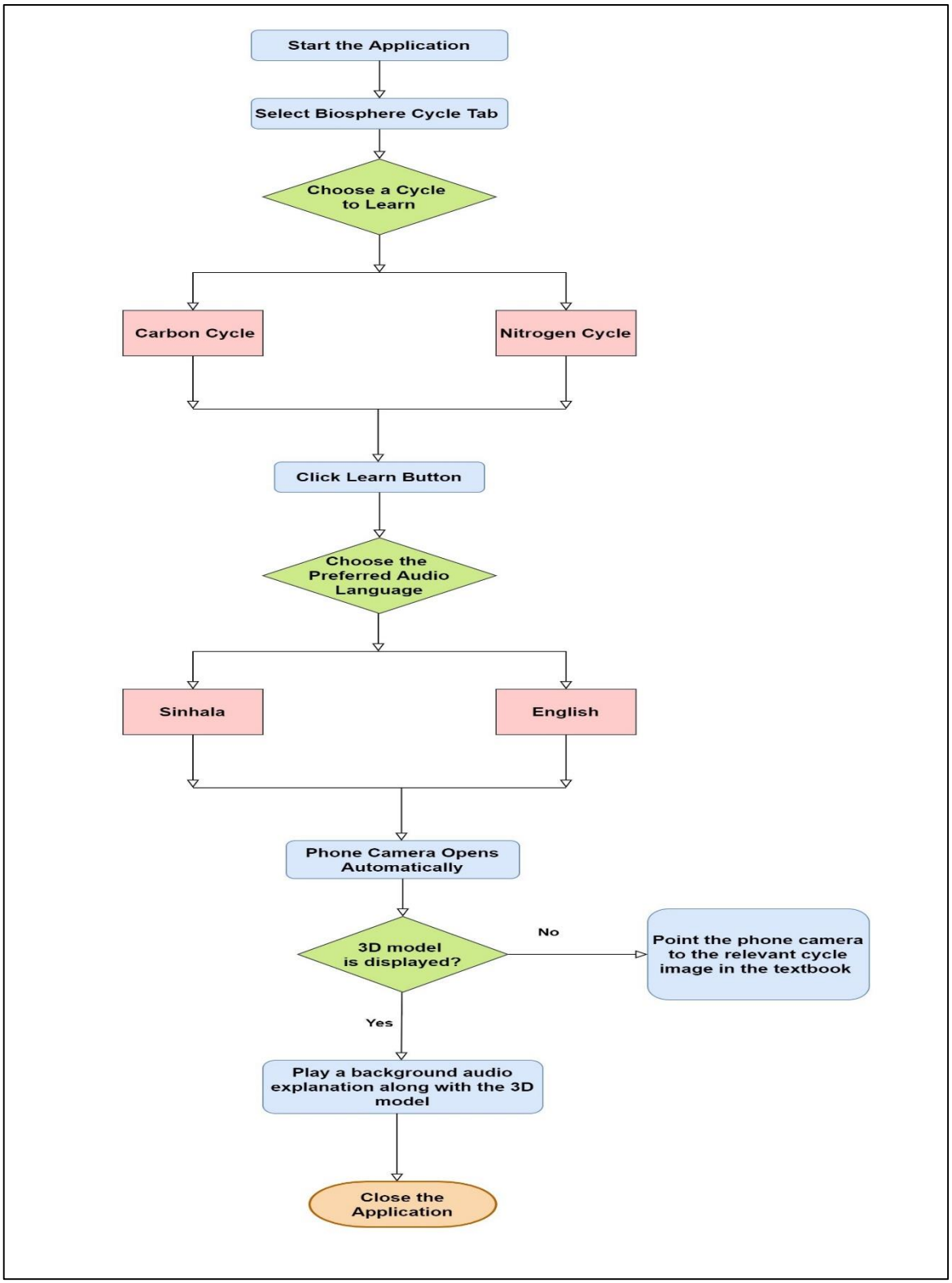

Figure 6: Flow Chart for the System

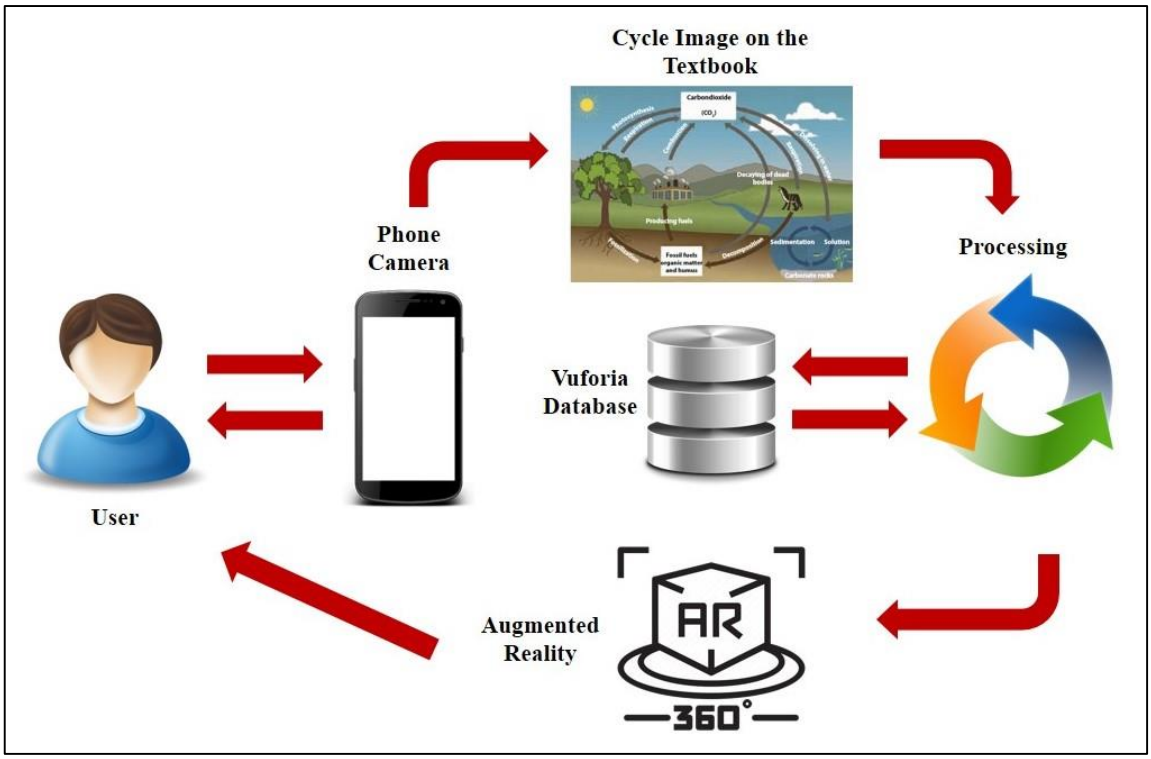

Figure 7: High Architectural Diagram of the System

As shown in Fig.7, when the user points the camera to the cycle image in the textbook, it will be identified as the marker in the Vuforia database. Images of the Carbon cycle and the Nitrogen cycle in the textbook have already been captured and stored in the Vuforia database as the markers. Therefore, the database can identify these textbook images through the phone camera. One of the major advantages of this is that users do not need to be bothered about downloading the markers. All they have to do is to point their phone cameras to the relevant cycle image in the textbook which they prefer to learn. Following Fig.8 and Fig.9 shows the textbook cycle images which are stored in the Vuforia database as the markers.

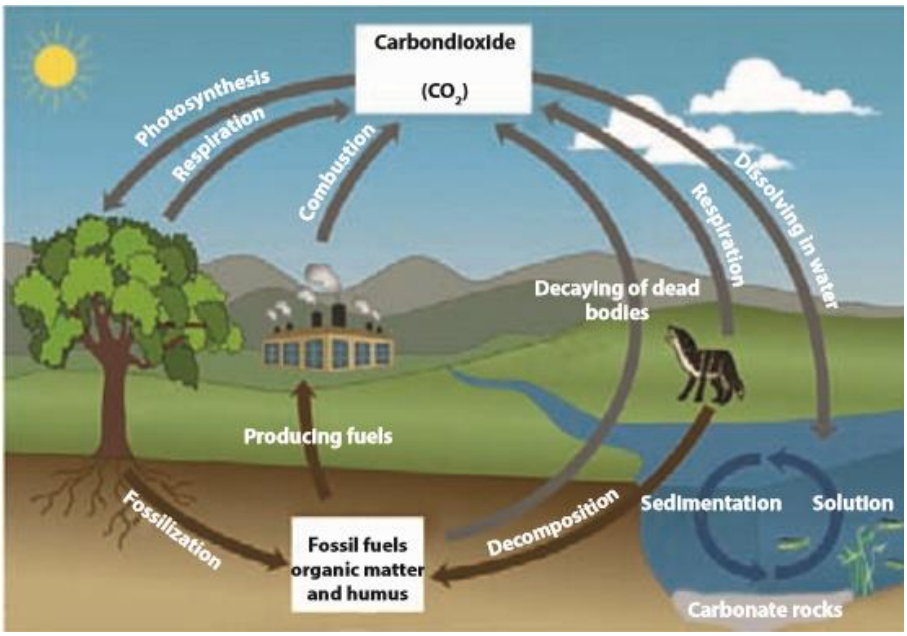

Figure 8: Carbon Cycle Image as in the Textbook

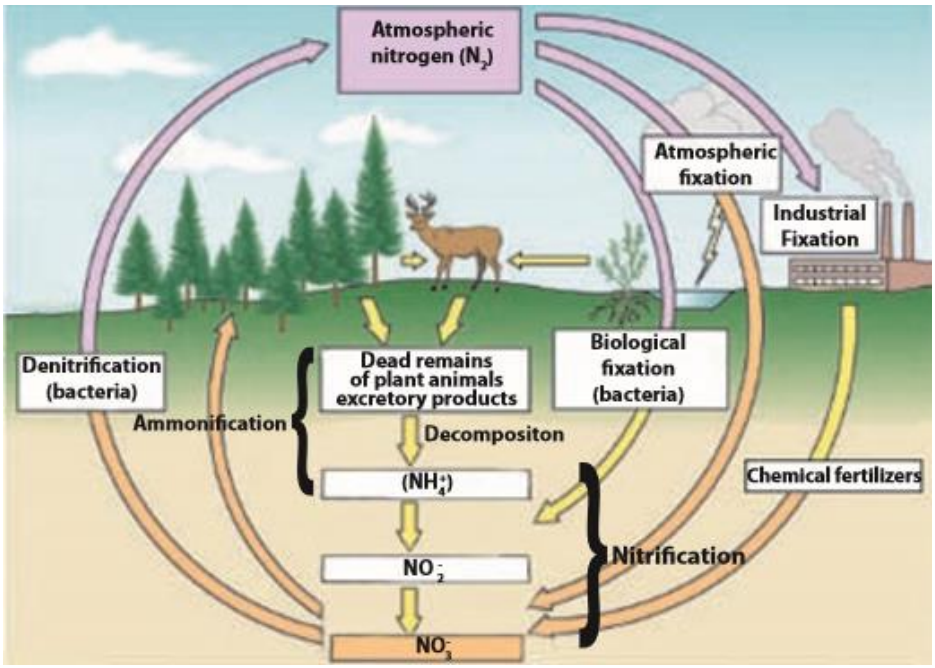

Figure 9: Nitrogen Cycle Image as in the Textbook

2.1.4. VUFORIA CONFIGURATION

In order to store the above images in the Vuforia database, there are few steps to be considered. First, it is needed to login to the Vuforia Developer Portal and for the new users they have to create a developer account, and it is freely available for anyone. After that, a license key should be obtained. Following Fig.10, Fig.11 and Fig.12 show the necessary steps to obtain a free license key.

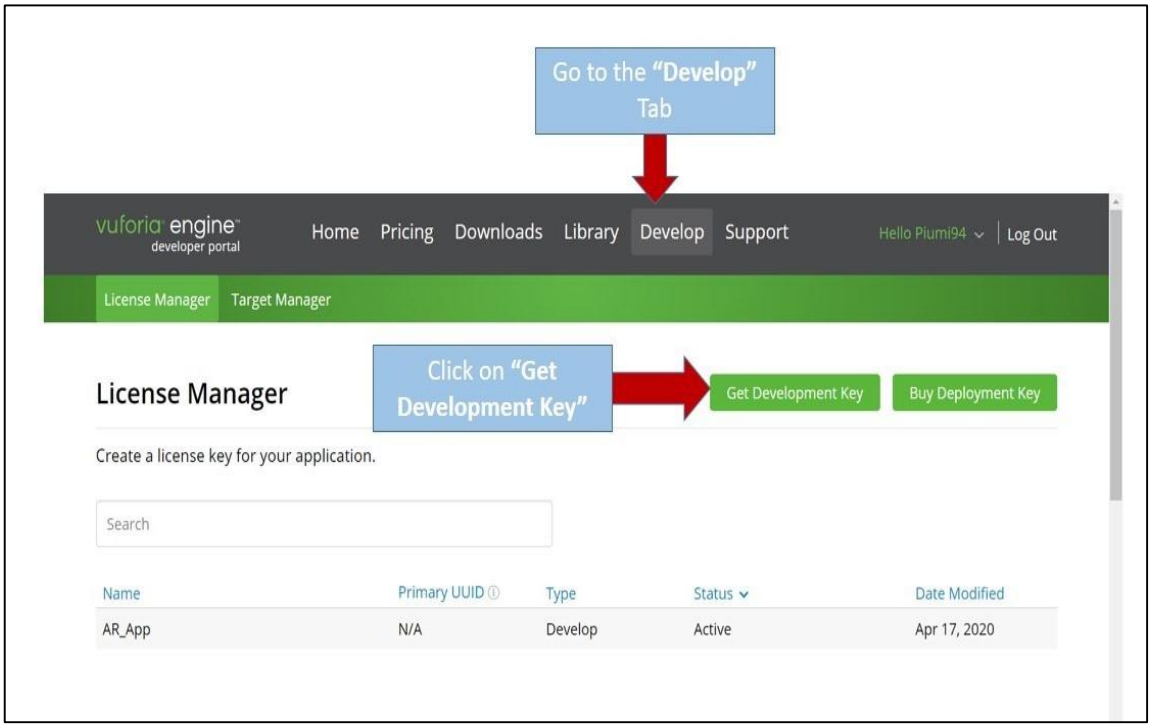

Figure 10: License Manager Window

As shown in the image, after visiting the License Manager window, the *Get Development Key* button should be selected. Then it gets redirected to another window as shown in the following Fig.11.

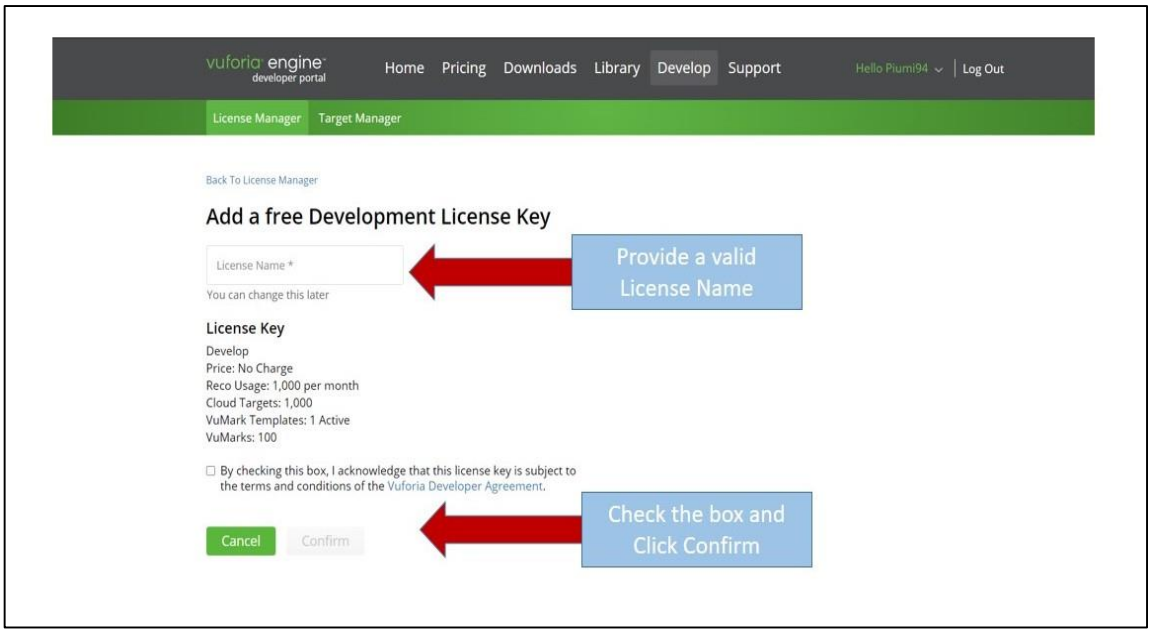

Figure 11: License Key Window

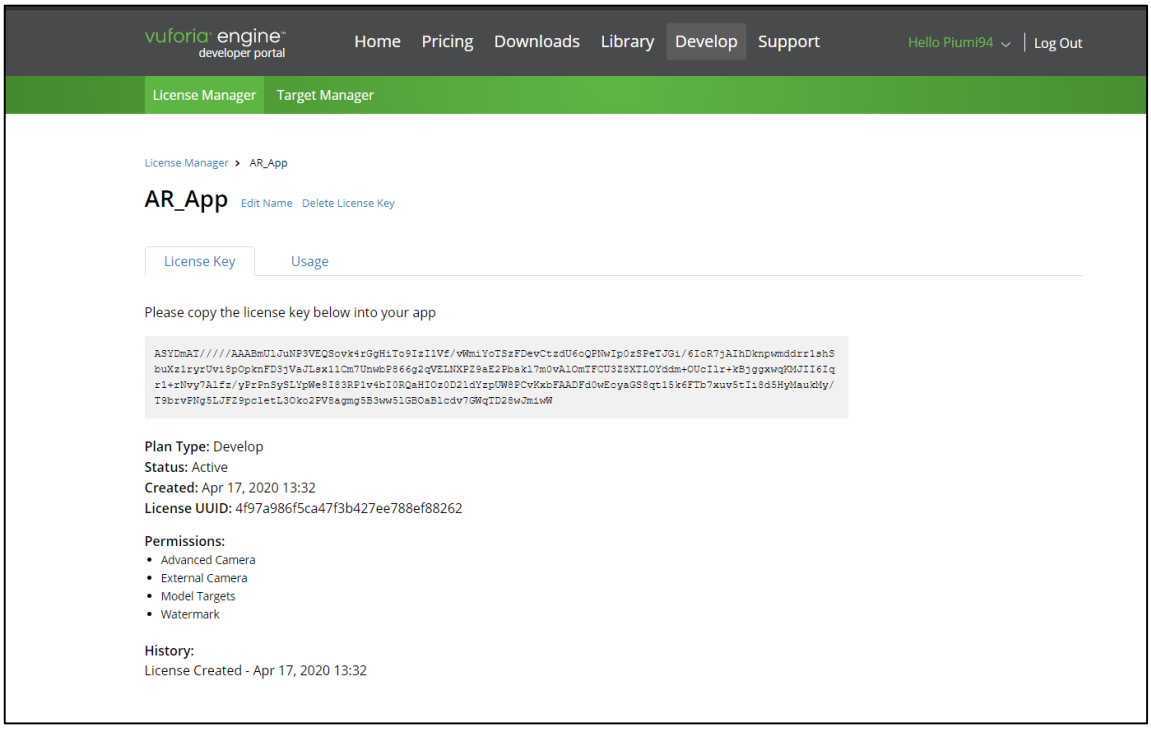

Figure 12: Generated License Key

According to the steps shown in the above images, a License key can be generated. This license key needs to be added to the Unity application. In order to do that a Unity project should be created. After installing Unity into the PC, a new Unity project should be created. For the development of this application Unity 2018.4.20f1 version was installed. Fig.13 and Fig.14 show the necessary steps to create a Unity project.

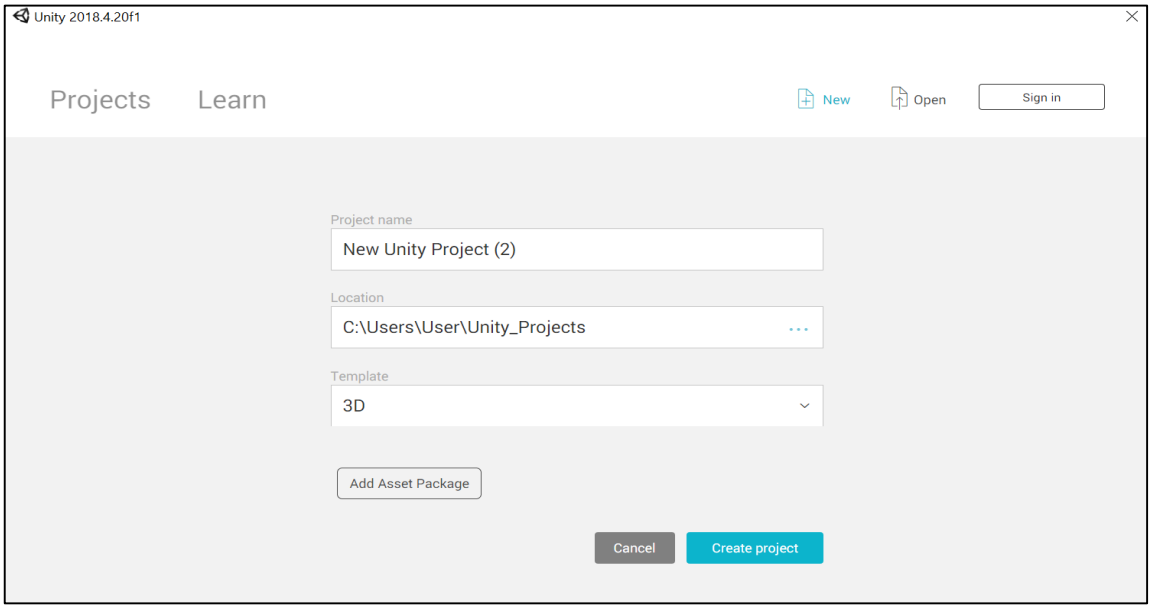

Figure 13: Creating a Unity Project

A preferred project name and a location can be given, and after that, the Unity project gets created. Following Fig.14 shows the initial appearance of the newly created Unity project.

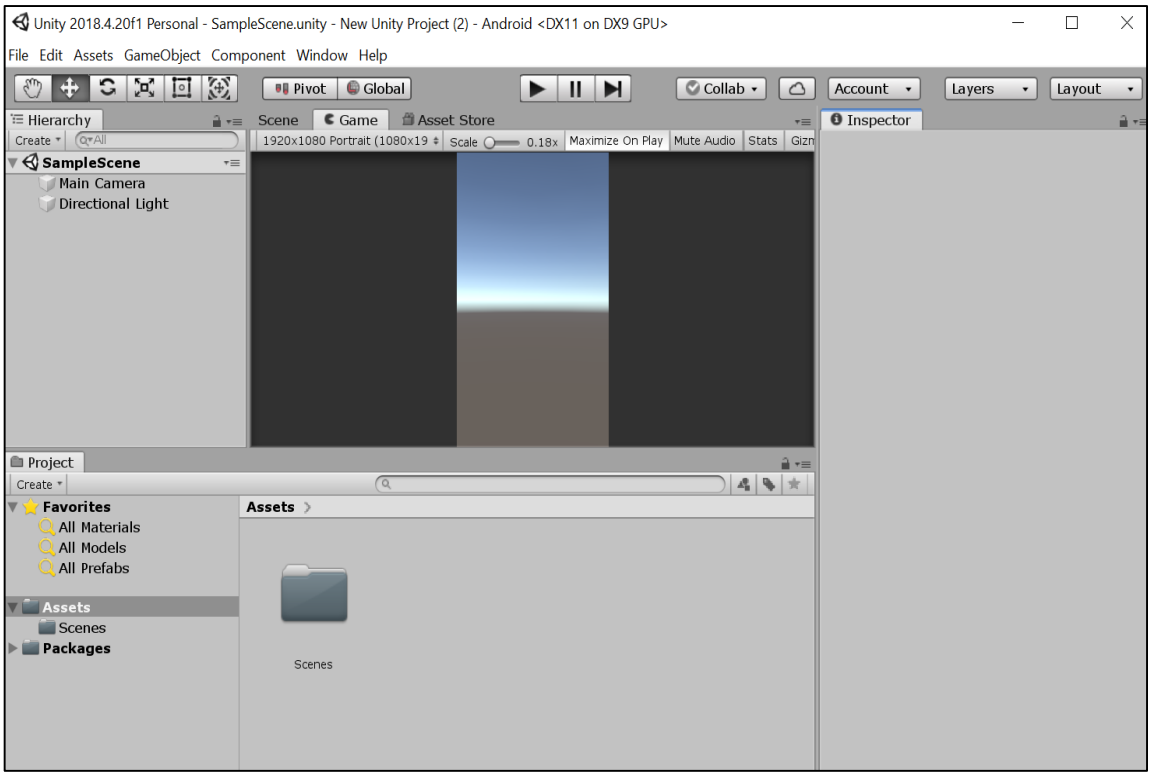

Figure 14: Initial View of the Unity Project

To create an AR application few changes should be made to the Unity project. Those changes can be mentioned as follows.

1. Click the GameObject tab.
2. From the dropdown select Vuforia Engine.
3. Then select AR Camera.

After that, a window will be prompted asking to import Vuforia assets and it should be imported in order for the AR camera feature to work. It will take only a few seconds to import the assets. The above-mentioned steps are indicated by the following Fig.15 and Fig.16.

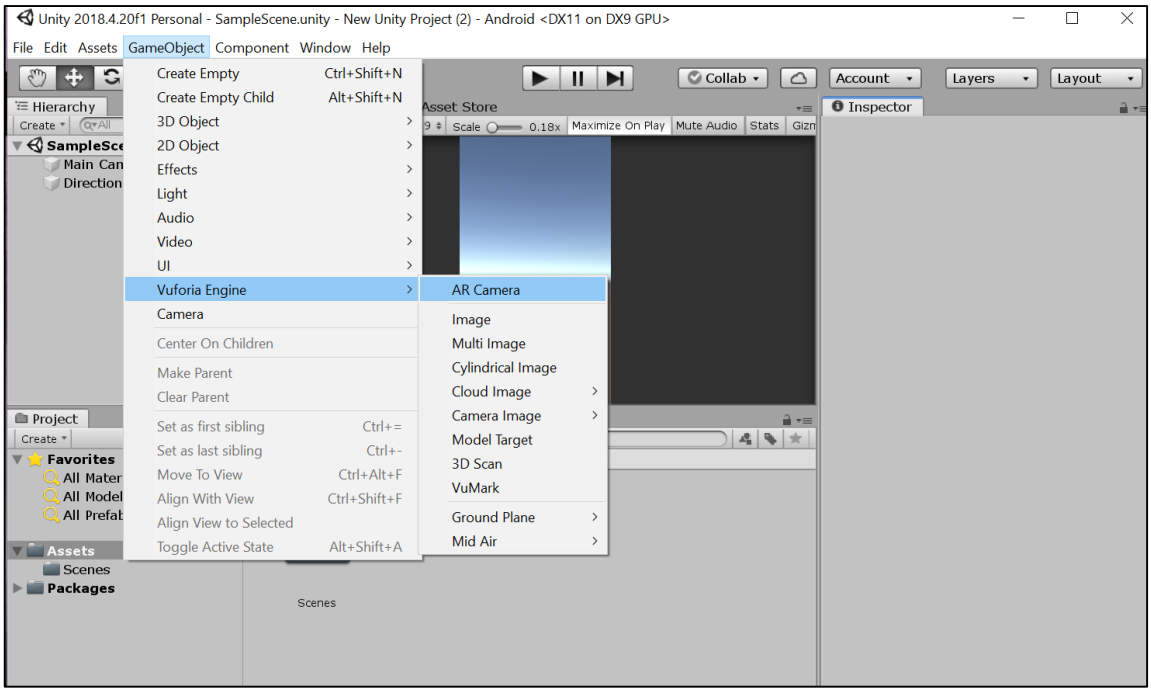

Figure 15: Selecting the AR Camera Option

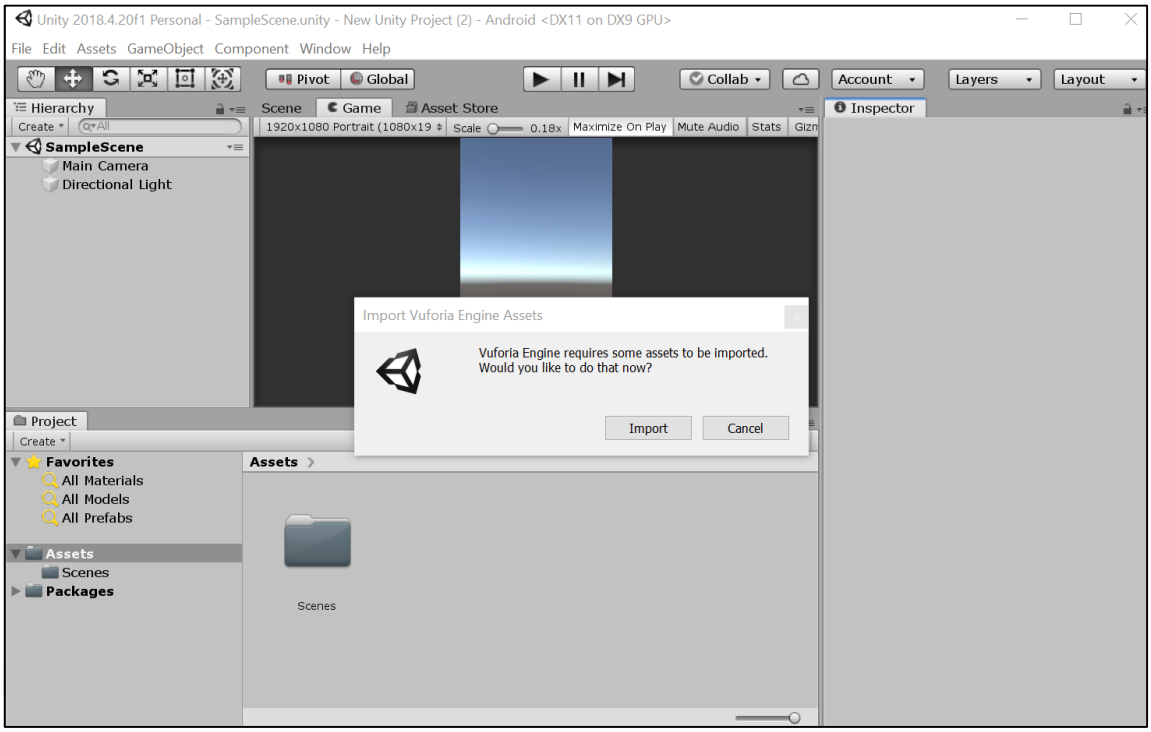

Figure 16: Importing the Vuforia Assets

After importing the AR camera, the main camera is not needed, and therefore, it should be deleted from the project. Then, as the next step, an image target should be added. The purpose of having an image target is to represent the images that the Vuforia engine can detect and track. The Engine detects and tracks the image by comparing extracted natural features from the camera image against a known target resource database [13]. Following Fig.17 shows how to add an image target to the project.

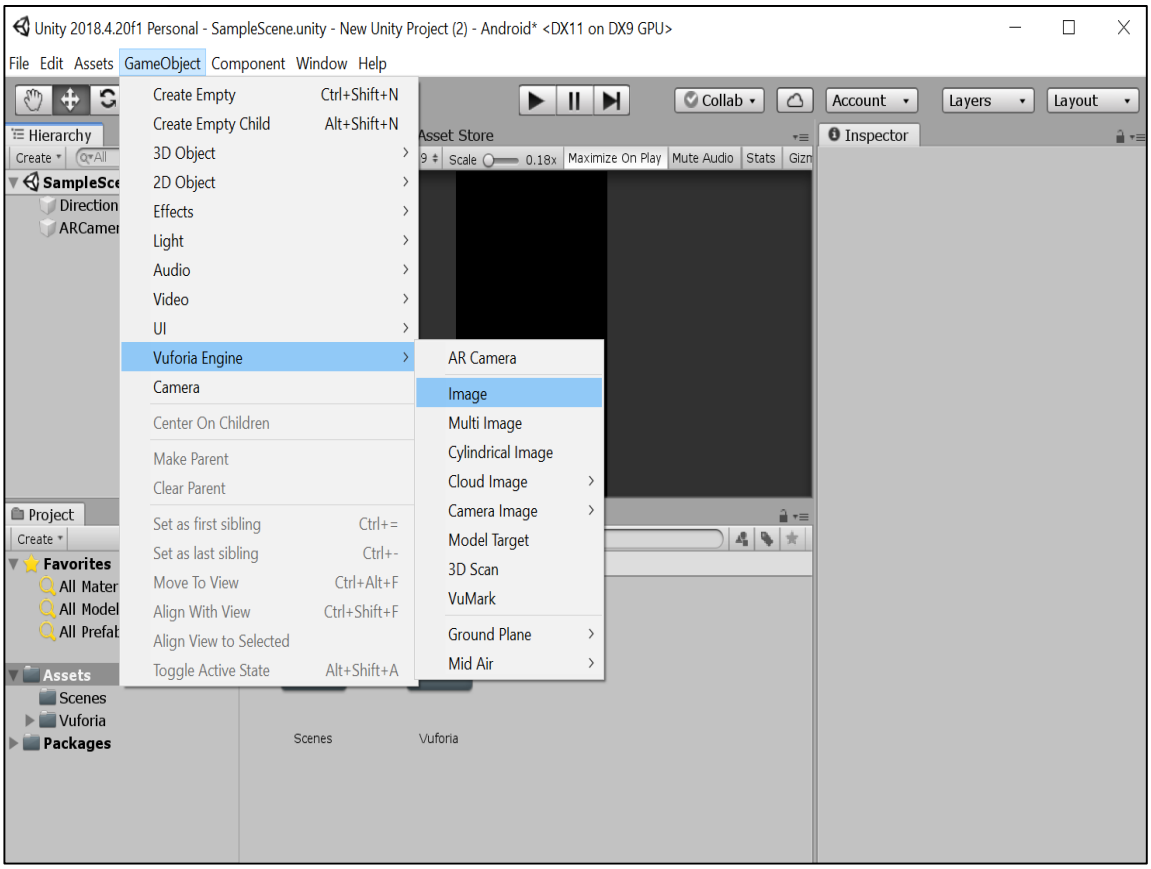

Figure 17: Adding an Image Target

As previously mentioned, it should also be imported in the same way that the AR camera has been imported. *The image* option under the *Vuforia Engine* should be selected from the *GameObject* tab, and then the Image target will be imported into the project. Fig.18 shows the project view after these imports.

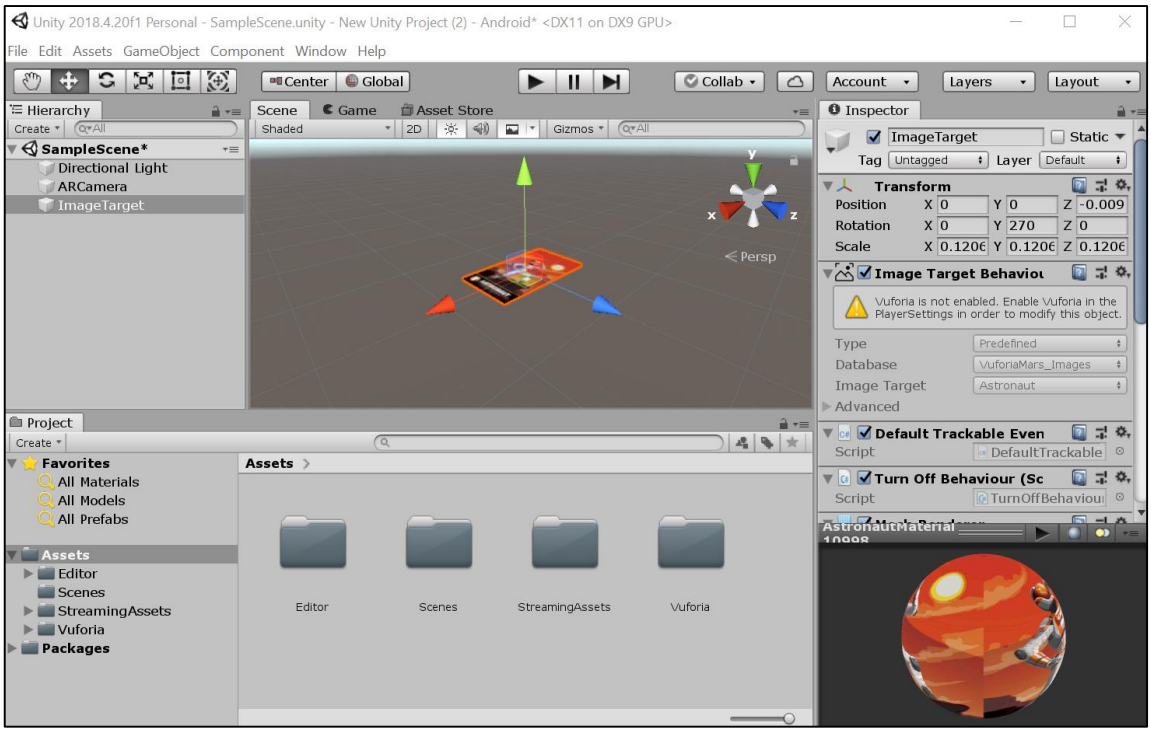

Figure 18: Project View after the Imports

The image target shown here is a default Astronaut image which is in a predefined Vuforia database called VuforialMars_Images. As shown in the above Fig.18 there can be situations where it shows a warning in the *Inspector* window on the right side of the project window saying that "**Vuforia is not enabled**. **Enable Vuforia in PlayerSettings in order to modify this object.".** To resolve this issue following steps should be taken.

1. Go to File -> Build Settings -> Player Settings
2. Then go to XR Settings
3. From the window, select Vuforia Augmented Reality

Following Fig.19, Fig.20 and Fig.21 indicate the above-mentioned steps.

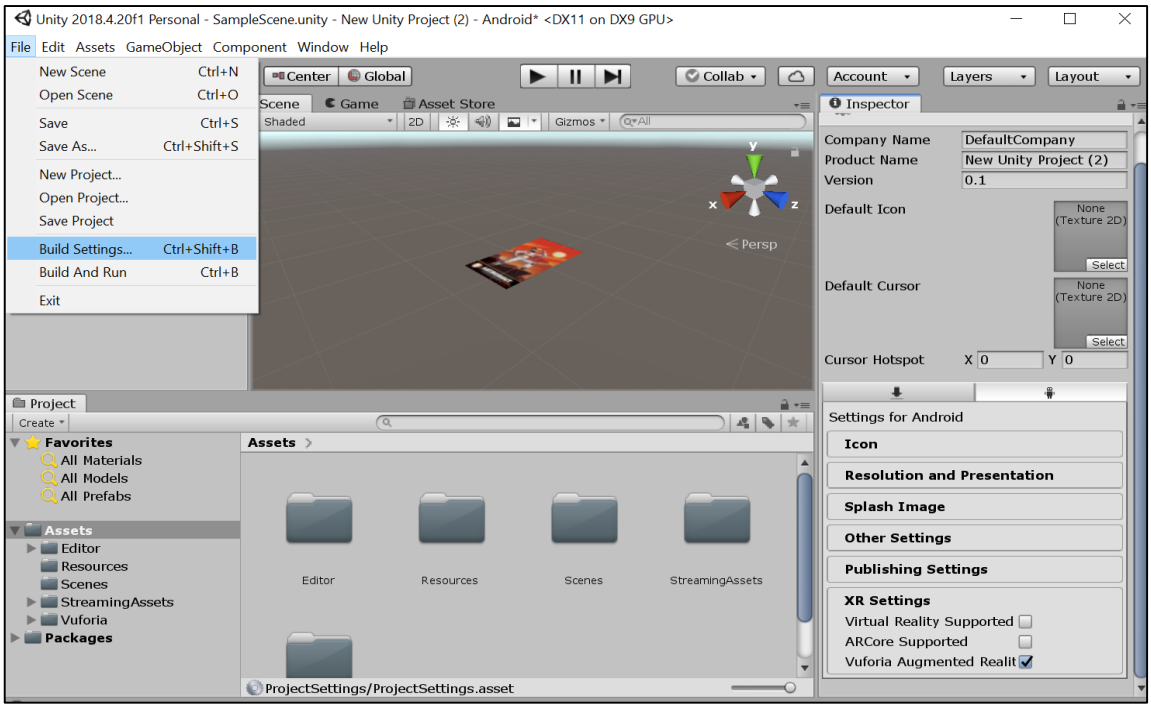

Figure 19: Go to Build Settings

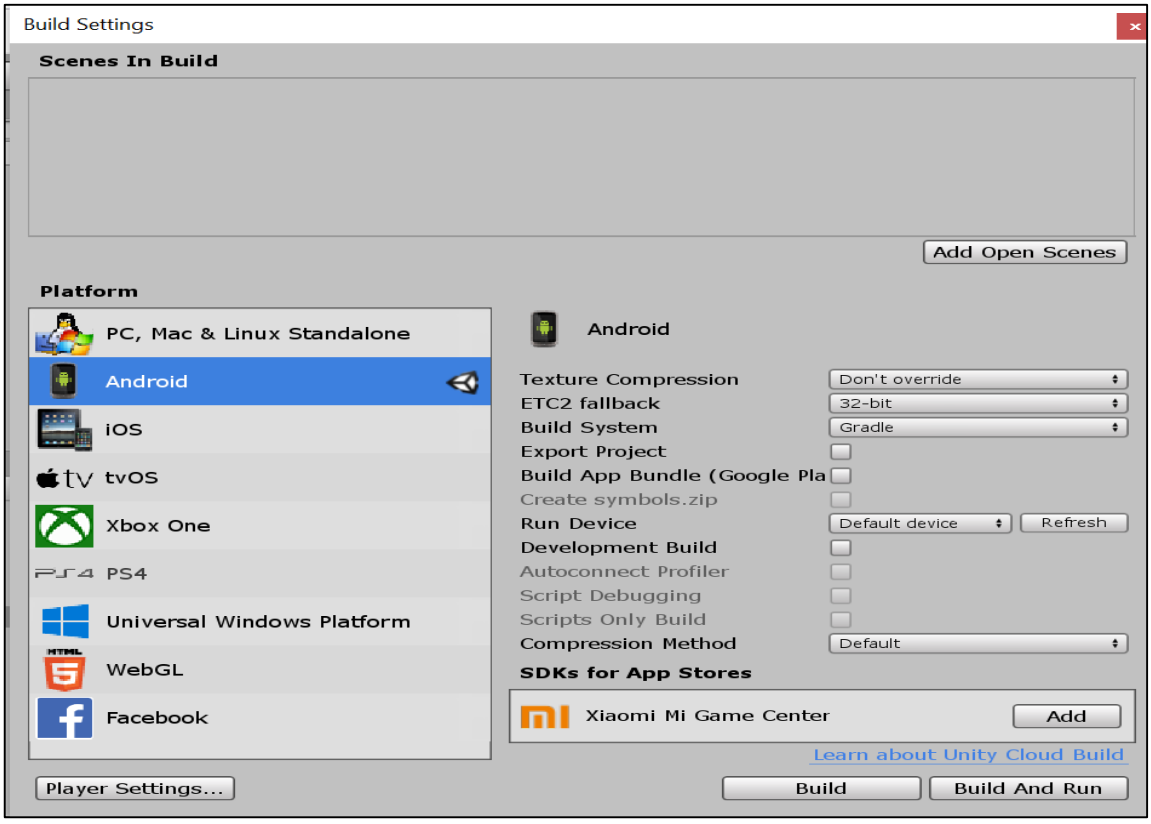

Figure 20: Build Settings Window

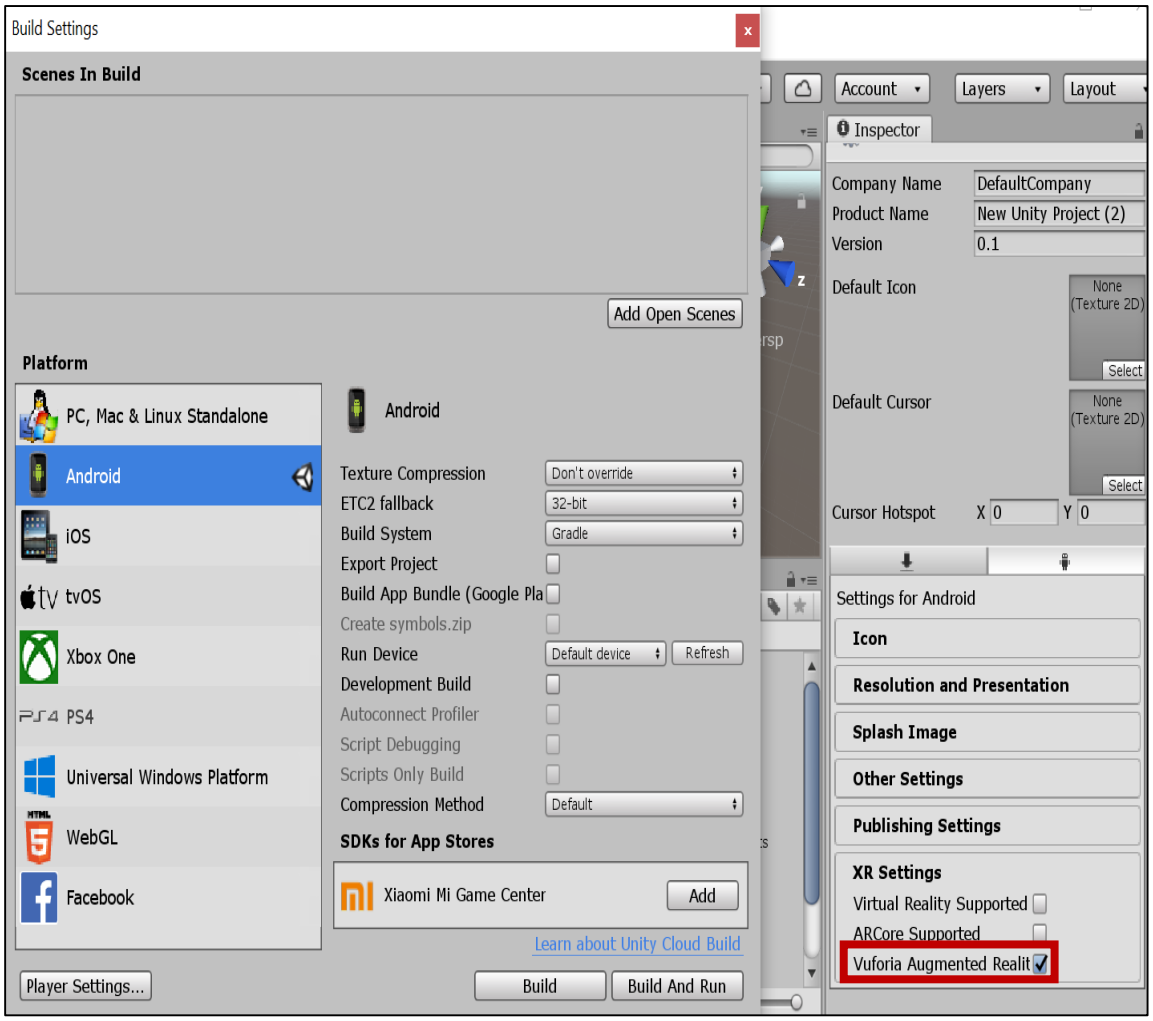

Figure 21: Select Vuforia Augmented Reality under XR Settings

After following the necessary steps Vuforia becomes enabled. Then, as previously mentioned, in order to add the Vuforia License key to the project, the image target should be selected from the assets list on the left side of the window, and from the *Inspector* window *Add Target* button should be clicked (Fig.22). It will redirect to the Vuforia AR Platform where the License key was generated after been logged in as shown in Fig.23.

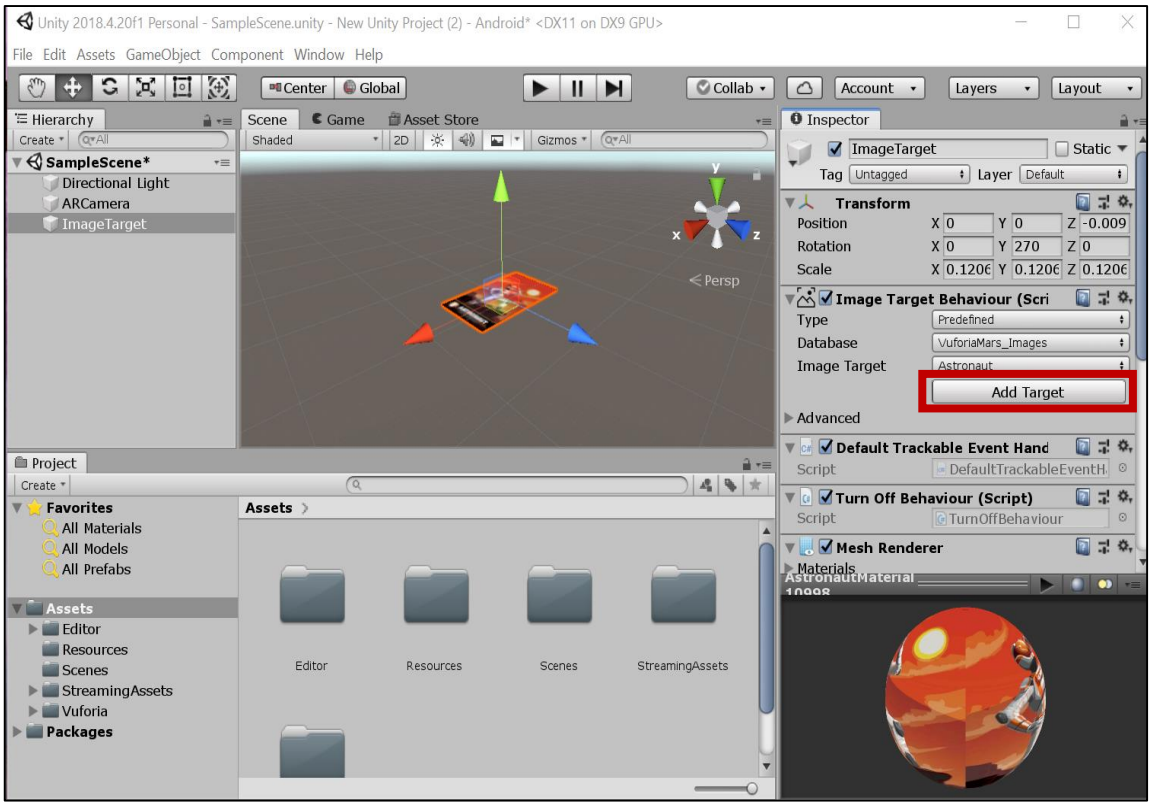

Figure 22: Add Target Button in the Inspector Window

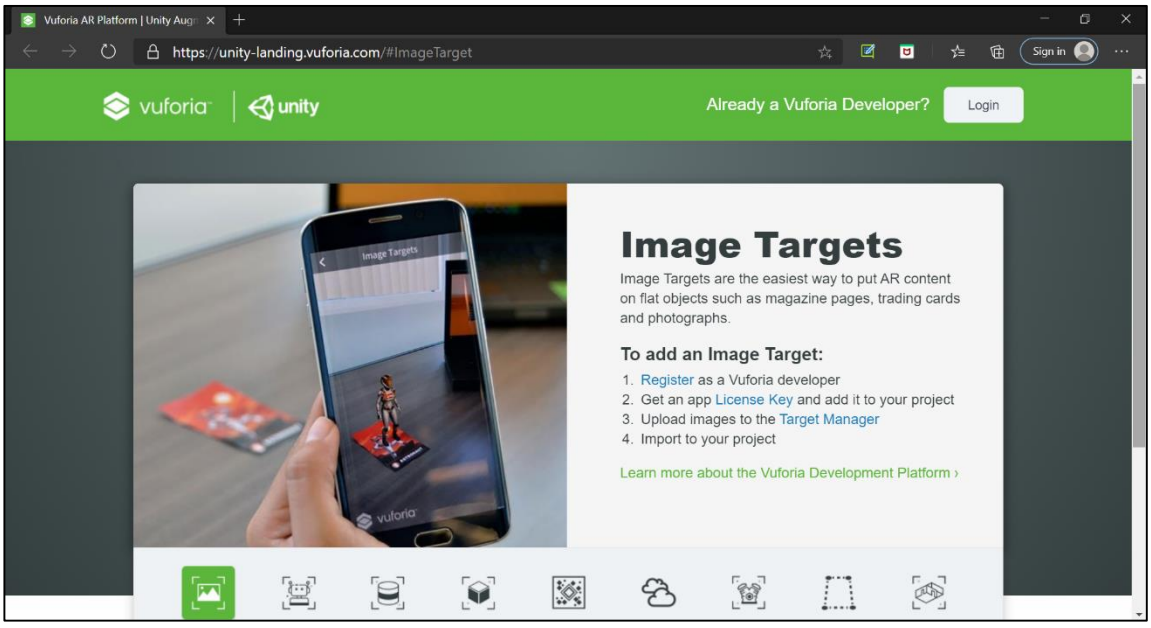

Figure 23: Vuforia AR Platform Window

Then as in the Fig.12 generated License key should be copied and added to the Unity project. Once the key is been copied Unity project should be opened and the AR camera should be selected from the assets list on the left side of the window. Then, from the Inspector window, the *Open Vuforia Engine Configuration* button should be clicked as highlighted in Fig.24.

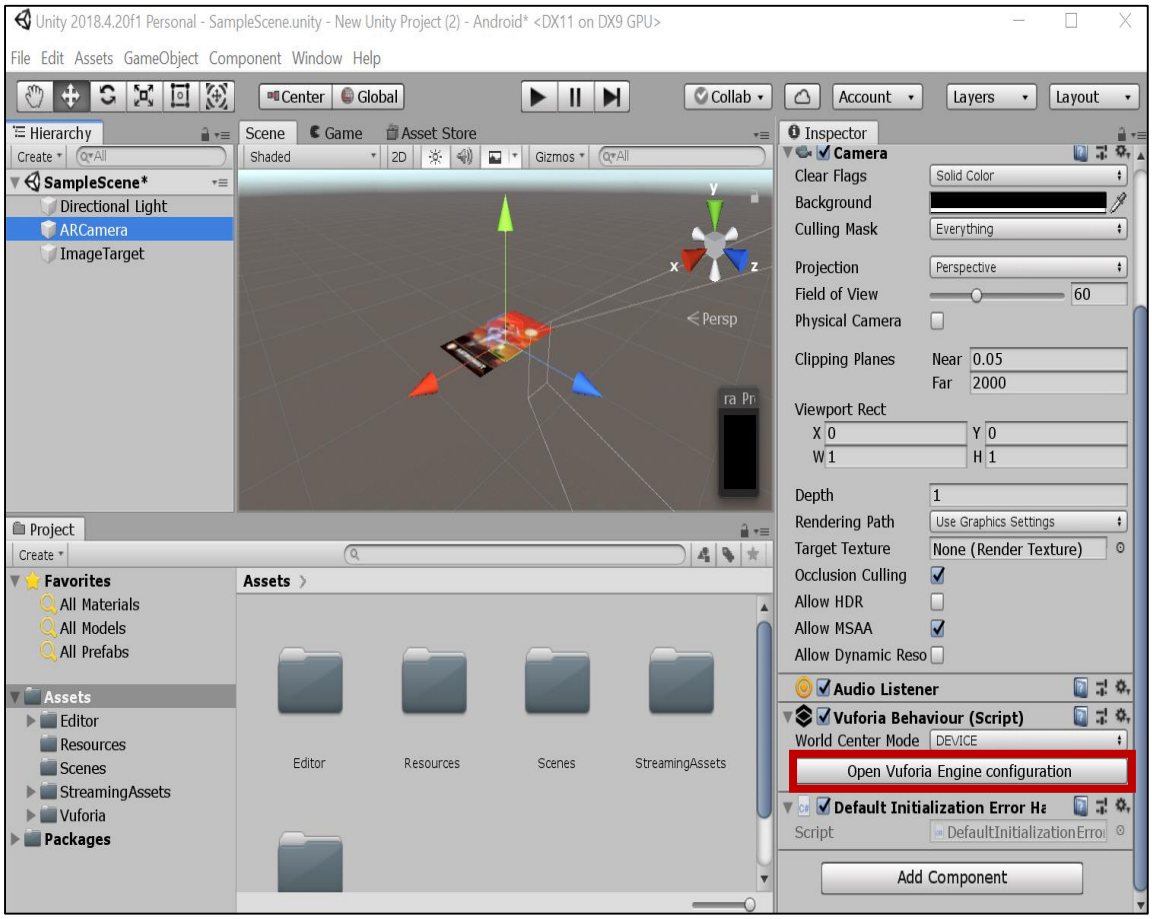

Figure 24: Open Vuforia Engine Configuration Button

After that, the License key should be pasted in the provided App License Key space as shown in the following Fig.25.

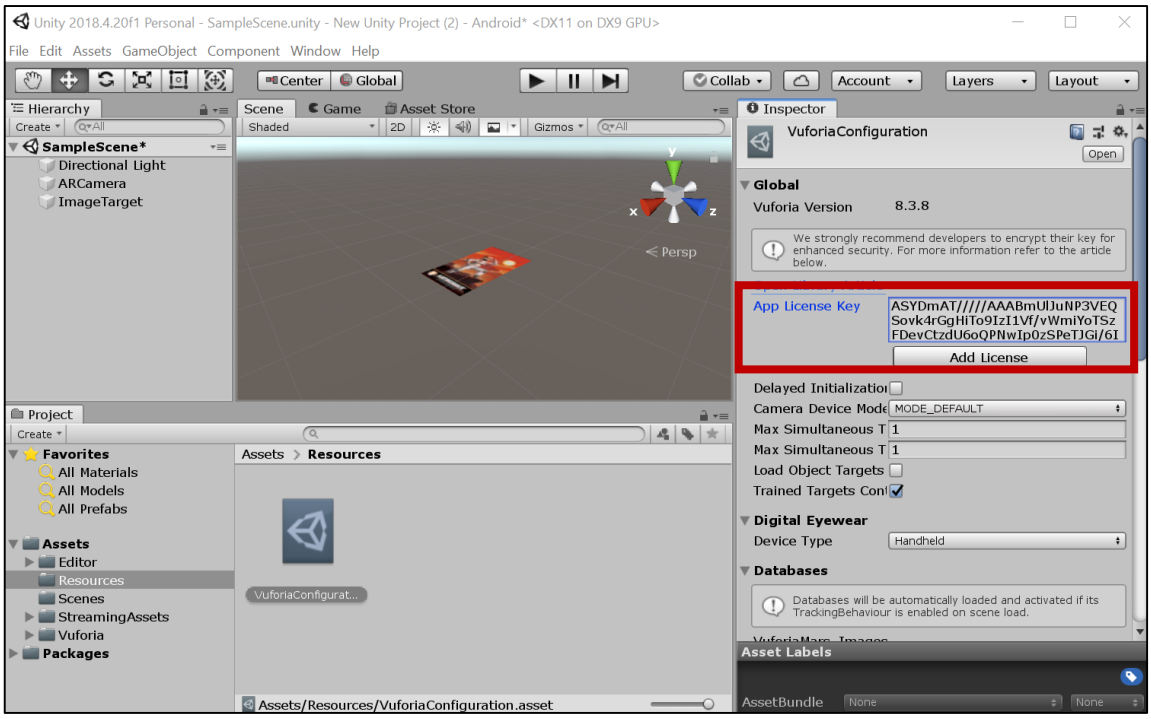

Figure 25: Provided Space to add the App License Key

Then the Vuforia Portal should be visited and the Target Manager tab should be selected to create or modify a database. Fig.26 shows the Target Manager window.

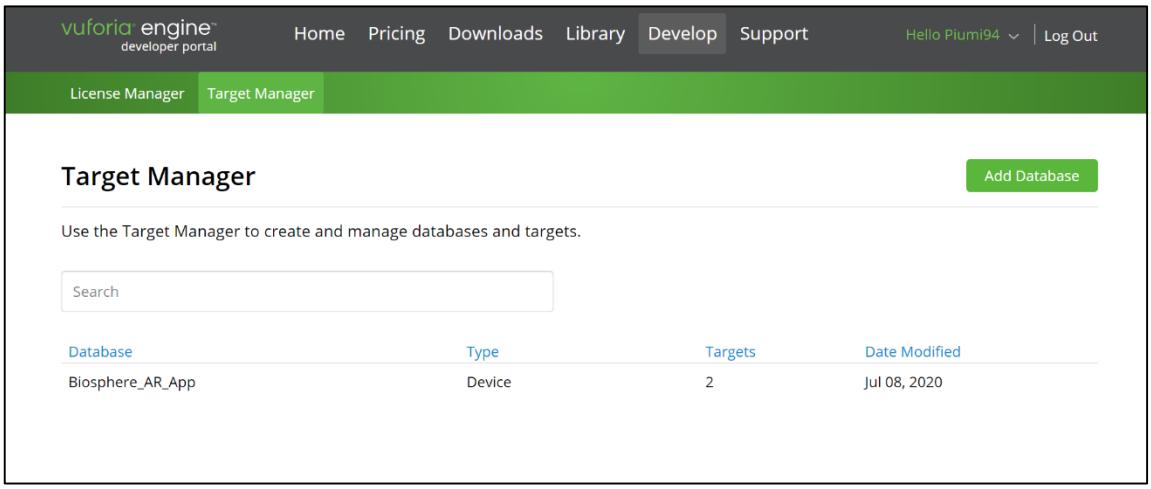

Figure 26: Target Manager Window

To create a new database the *Add Database* button should be clicked and then the following window will be displayed as shown in Fig.27.

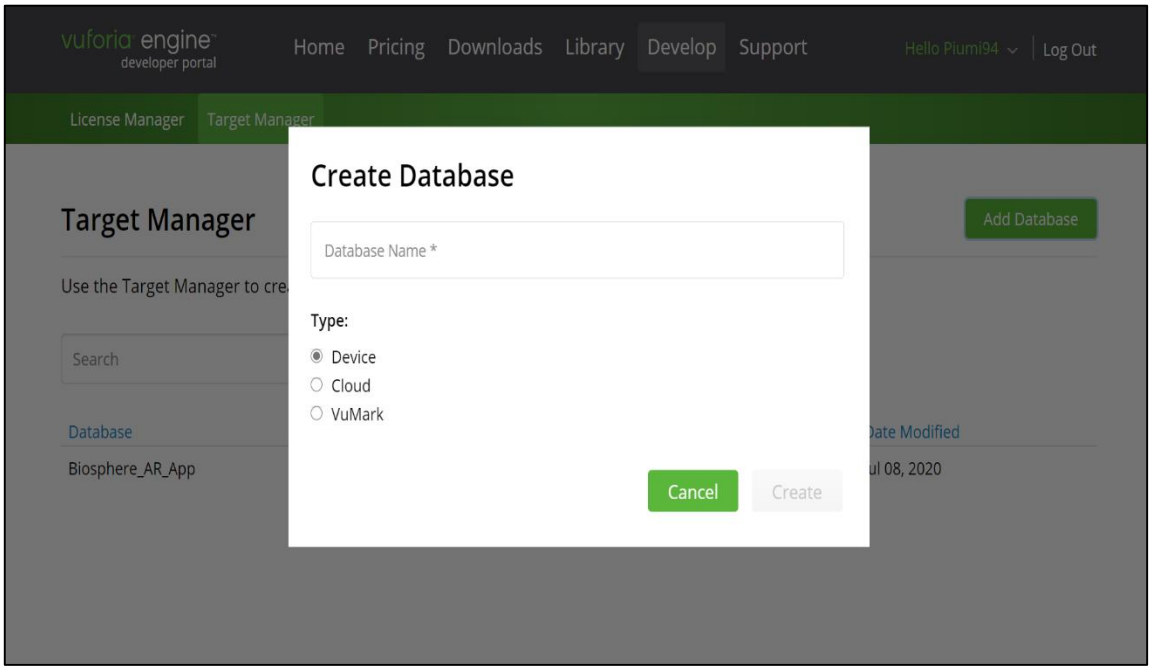

Figure 27: Create Database Window

After providing a preferable database name and clicking on the *Create* button, the database will be successfully created (Fig.28). Now, it is allowed to add the previously mentioned Fig.8 and Fig.9 cycle images captured by the textbook to the database as the target images by clicking the *Add Target* button as indicated in Fig.29. After adding the target images, a rating is given to each image to show how suitable these target images for the application (Fig.30).

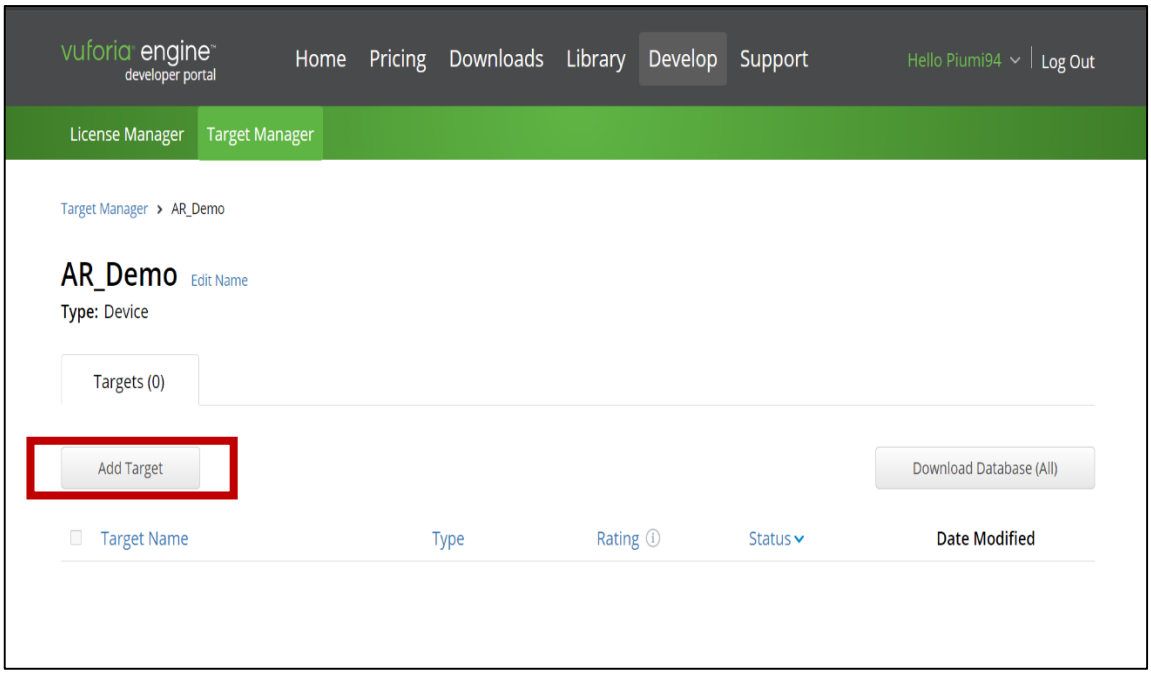

Figure 28: Newly Created Database

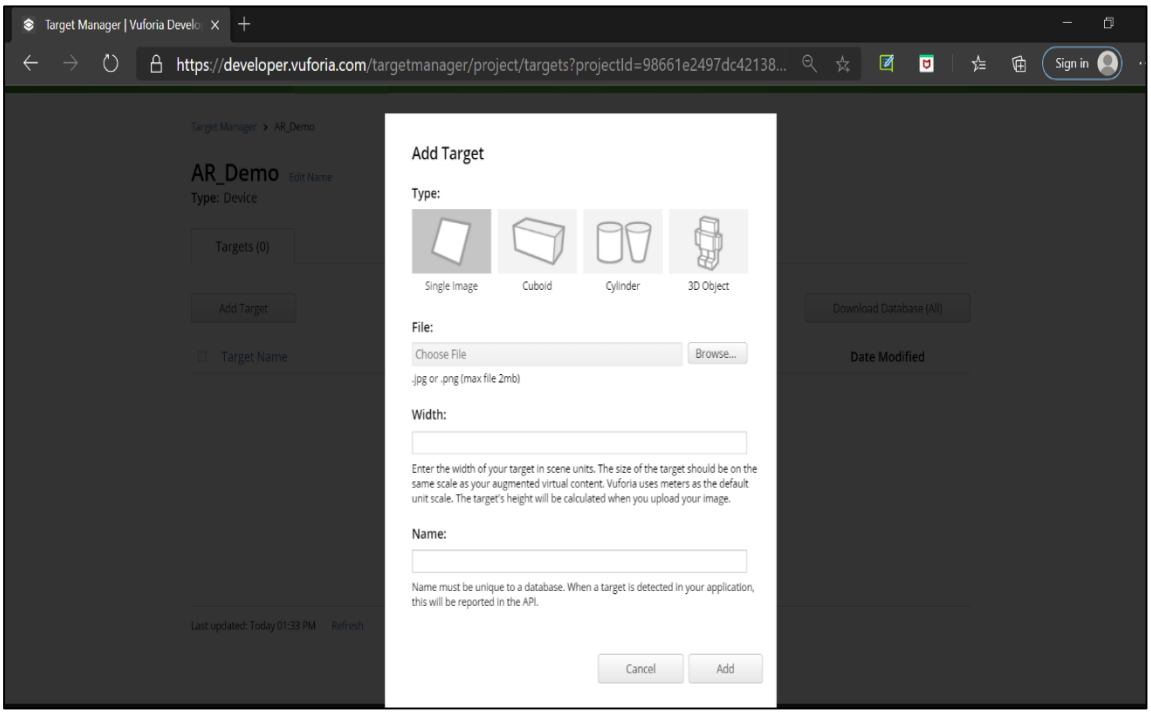

Figure 29: Add Target Window

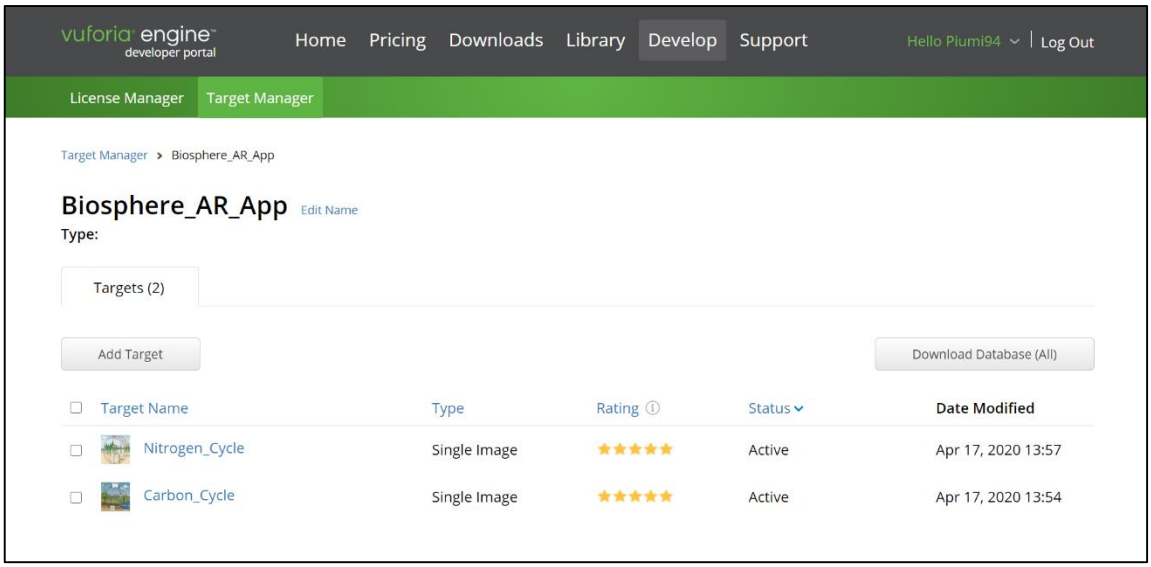

Figure 30: Target Image Ratings

Then the database should be downloaded and imported into the Unity Editor as shown in the following Fig.31 and Fig.32.

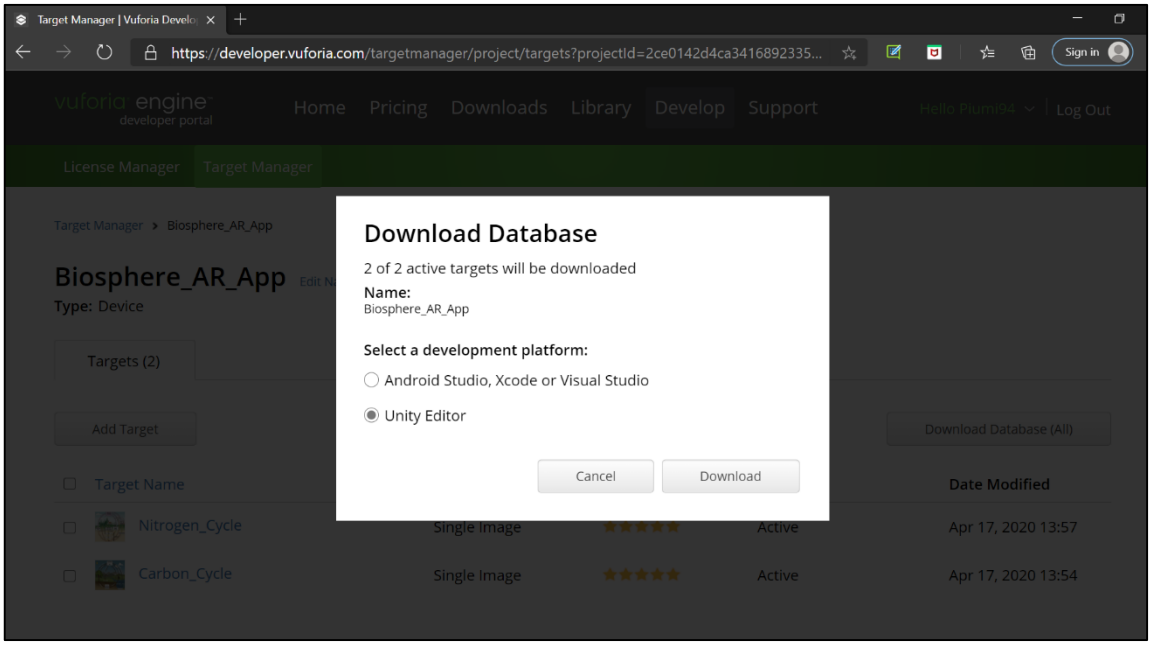

Figure 31: Database Download Window

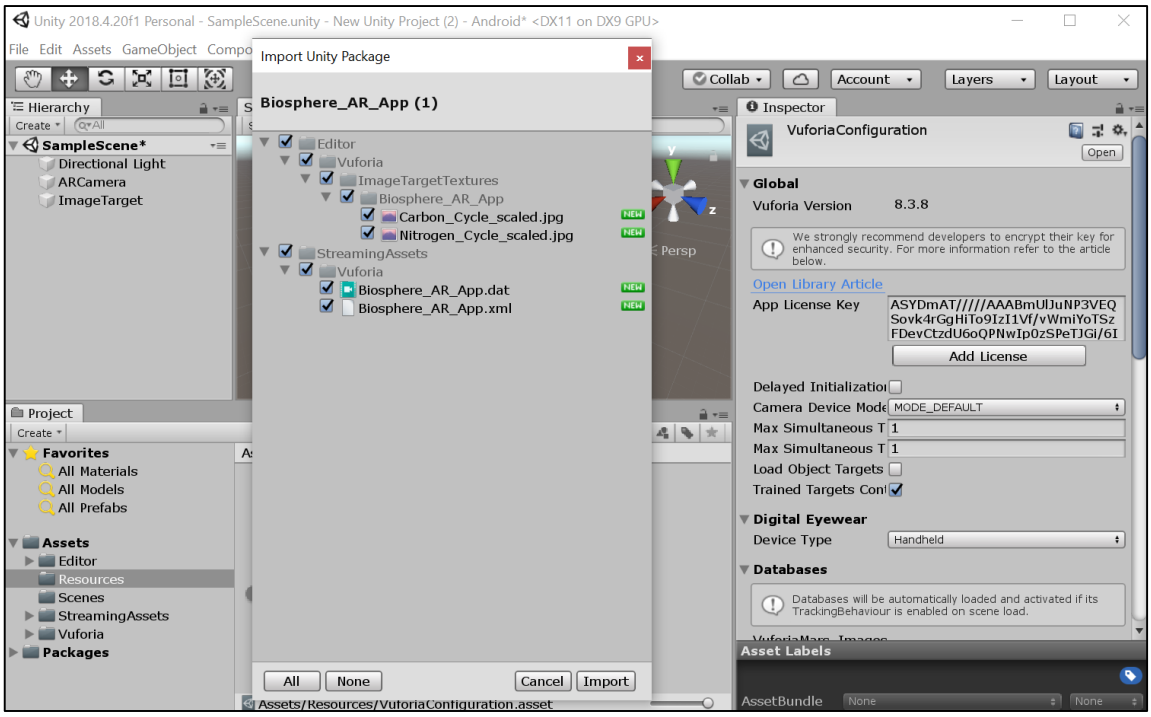

Figure 32: Importing the Database to the Unity Editor

Now it is allowed to select and add a preferred image to the image target instead of the Astronaut image in the *VuforiaMars_Images* database for the application since the newly created database can be accessed by the Unity project (Fig.33 and Fig.34).

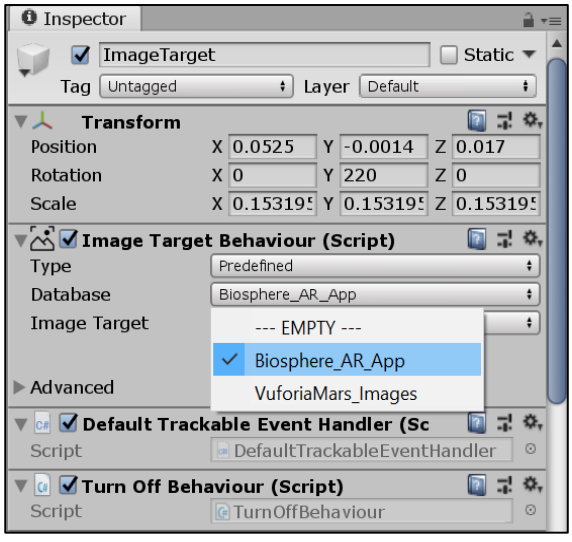

Figure 34: Selecting the New Database

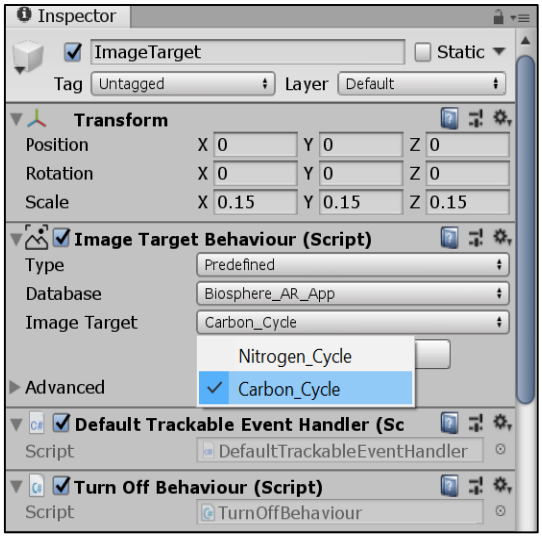

Figure 33: Selecting the Preferred Image

2.1.5. USER INTERFACE DESIGNING

Since this AR application was designed to use by the O/L students it was highly important to design attractive and user-friendly interfaces. Therefore, while designing the interfaces few factors had to be considered such as colors, images, font size, and font style, etc. After a considerable amount of analyzing it was decided to design the following main user interface as shown in Fig.35.

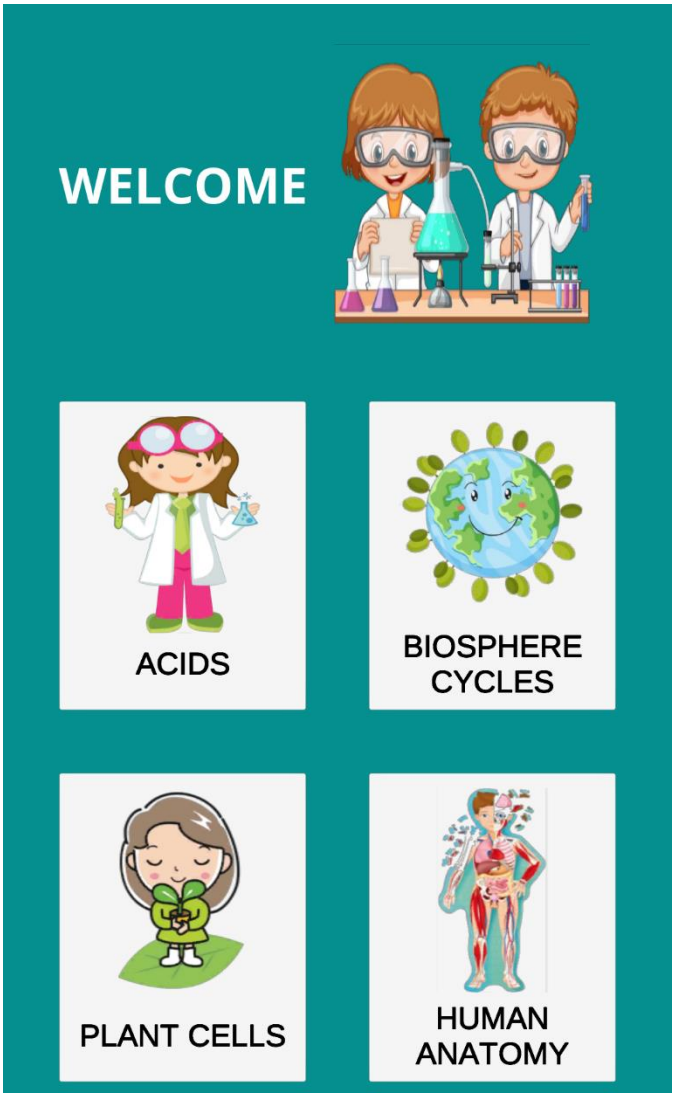

Figure 35: Main User Interface

Apart from being attractive, it was important to design the user interfaces considering the usability of the application. Therefore, the following interfaces were created in order to teach the Biosphere cycles effectively. While creating these interfaces simplicity was considered since it could make the application more user-friendly. Also, it could save the time of both the developers and the users since it requires to give fewer instructions and support on how to use the application. Students can view the biosphere cycle interface when they click on the biosphere cycle tab on the top right corner of the main interface. Following Fig.36 shows the biosphere cycle interface.

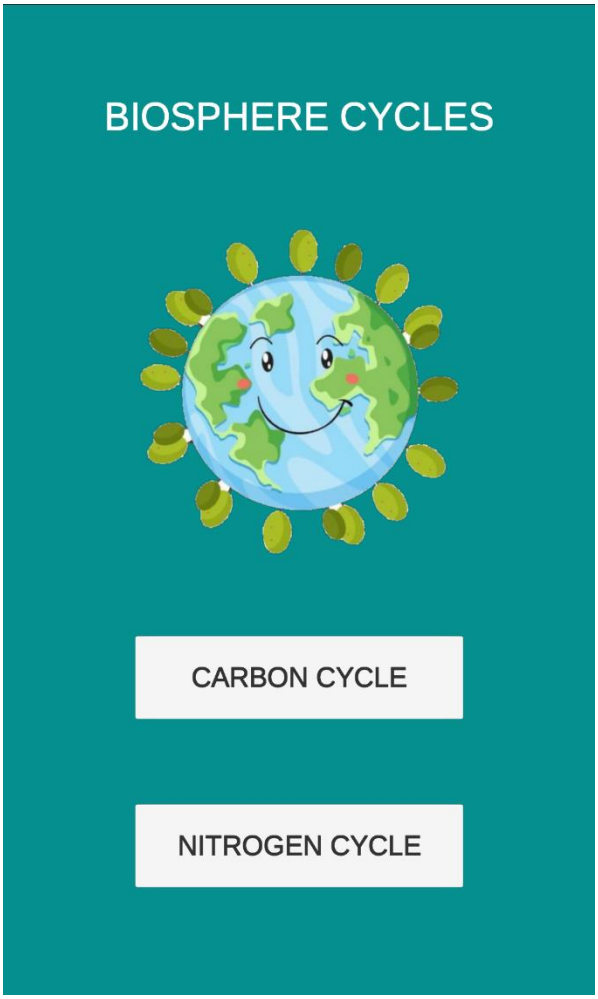

Figure 36: Biosphere Cycle Interface

Using this interface students can select any cycle according to their preference of learning. If the Carbon cycle is selected then the interface will look like Fig.37, and if the Nitrogen cycle is selected the interface will look like Fig.38, which shows the Nitrogen cycle interface.

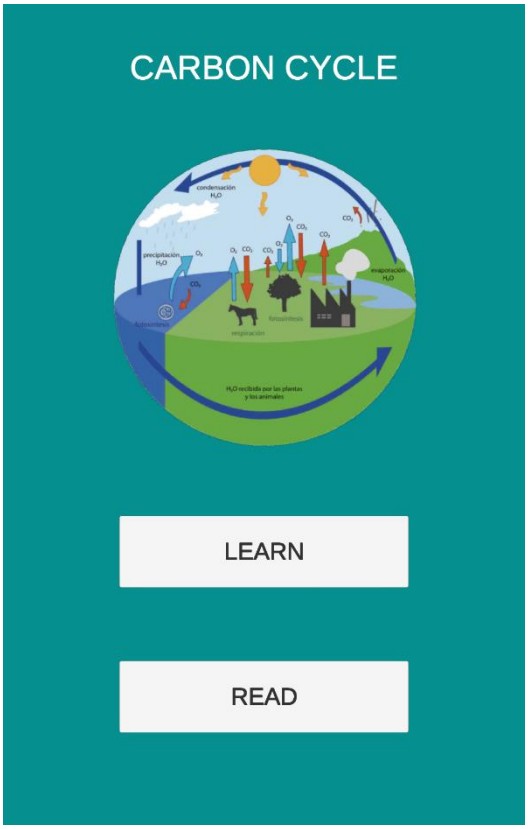

Figure 37: Carbon Cycle Interface

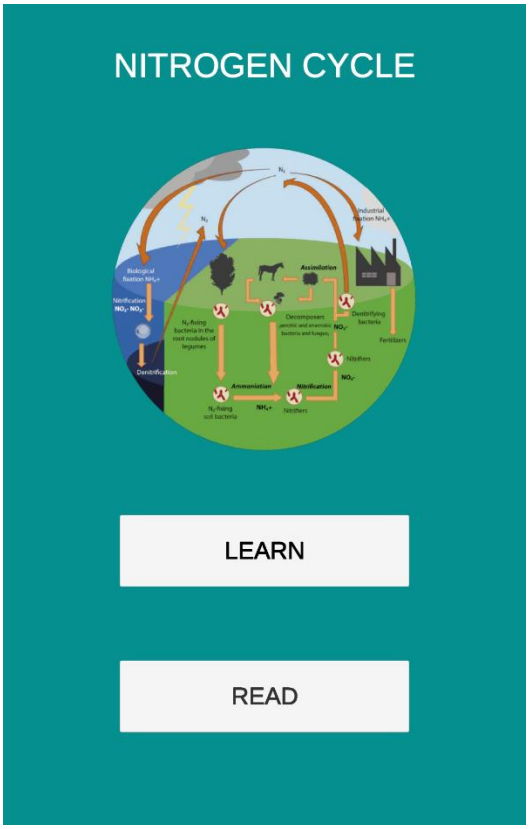

Figure 38: Nitrogen Cycle Interface

Both these interfaces will display the same interface after the *Learn* button is clicked. It is the interface that allows the students to choose a preferred language to be played in the background audio (Fig.39). It was decided to include both Sinhala and English as the audio languages to the application since most Sri Lankan schools are Sinhala medium-based. Also, it would be helpful for the students who go to English medium schools because the

application allows them to hear the same content in Sinhala if there are any ambiguous content under the topic.

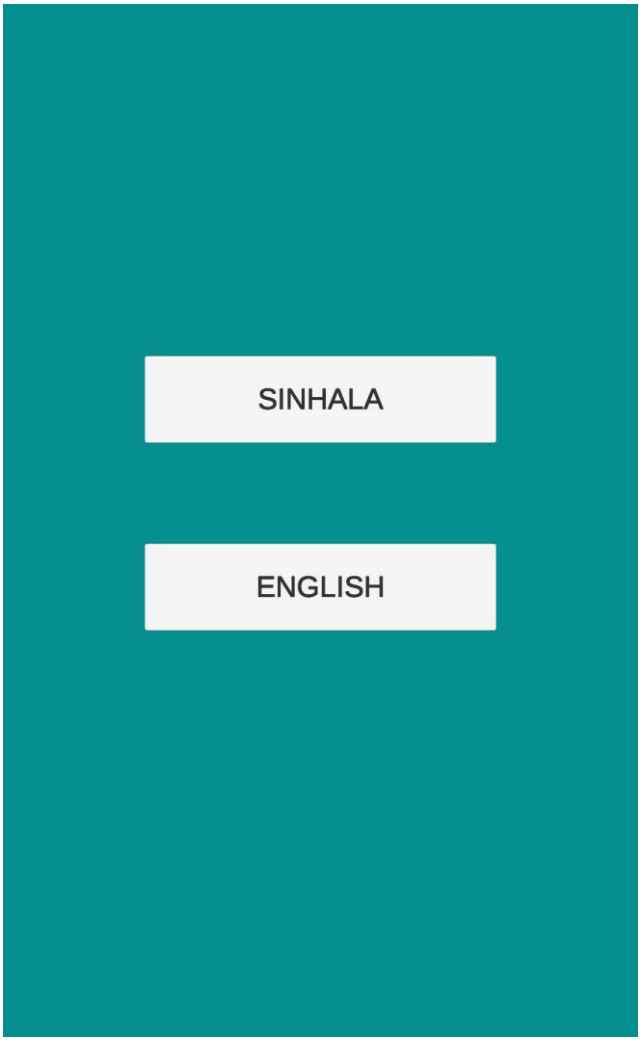

Figure 39: Language Selection Interface

After selecting one of these languages the phone camera will be automatically opened, and a 3D model will be displayed along with a background audio explanation according to the selections of the user from the above-mentioned interfaces. Moreover, the application facilitates the students to read the notes relevant to the cycles. They can read the notes when the *Read* button in the Carbon cycle interface (Fig. 37) and the Nitrogen

cycle interface (Fig. 38) is clicked. The following Fig. 40 and Fig. 41 respectively indicate the interfaces which include the notes relevant to the Carbon cycle and the Nitrogen cycle.

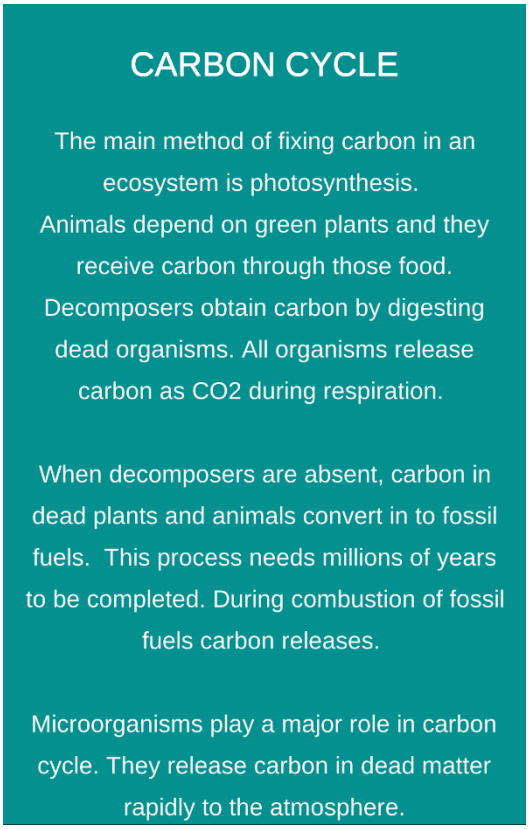

Figure 41: Relevant Notes for the Carbon Cycle

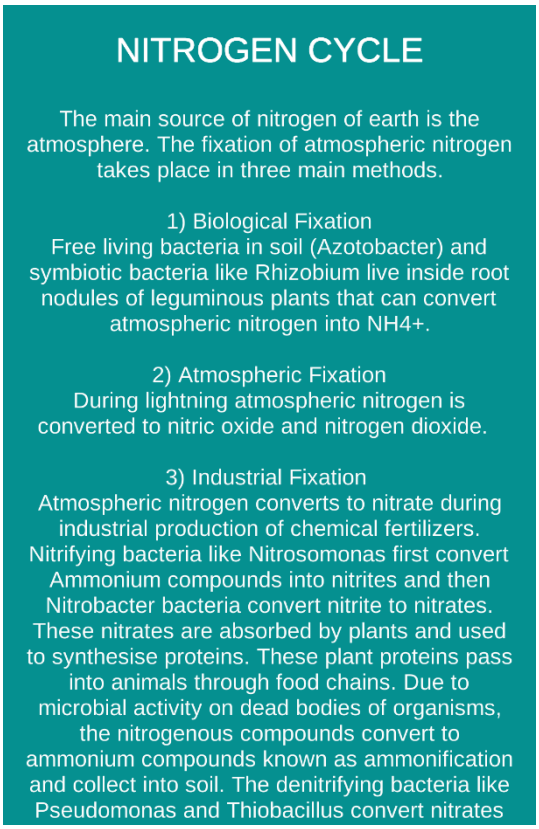

Figure 40: Relevant Notes for the Nitrogen Cycle

2.2. COMMERCIALIZATION ASPECTS OF THE PRODUCT

This application was implemented focusing on the O/L Science students, and therefore, they will be the end-users of this application. But apart from them, this application can also be useful for Science teachers since they can use the application to teach the students. Even though the application has been implemented for the school classroom teaching and learning, this application can also be beneficial for the outside private class teaching and learning. Moreover, currently, there is no implemented AR mobile application for O/L Science students, so that this application can be commercialized easily.

Furthermore, this application is based on one of the newest technologies available in the world. The main advantage of using Augmented Reality is that it is not only a technology but a huge opportunity that can open up numerous possibilities for every field, especially for the educational field. Therefore, an AR application holds an enormous business value. While referring to other existing research and applications related to e-learning, it was evident that student motivation for learning can be improved by adding an interactive and practical approach to the learning process. AR is the best available solution for the moment to make it becomes true since it can easily create a more effective and productive learning environment for the students.

Also, the use of mobile phones has highly increased in every country including Sri Lanka. Today, almost all teenagers and adults know how to use a mobile phone. Therefore, another value has been added to the application since it is a mobile application. Moreover, this application facilitates students to learn the concept of Biosphere cycles using a 3D model visualization while listening to audio playing in the background explaining the important details about the cycles. Another value has been added to the application since it allows this background audio to be played in two languages; Sinhala and English. Since most Sri Lankan schools are Sinhala medium schools, the application could satisfy a large number of users.

2.3. TESTING AND IMPLEMENTATION

There are several risks associated with implementing a new system if it is not tested accordingly in every phase. Some of these risks can be mentioned as follows.

- The final product can be divergent from the user expectations
- Time and cost can be wasted
- The product can be dysfunctional at the end or in the middle of the implementation

Therefore, any software product must be tested in order to improve consistency, performance, usability, etc. Considering these circumstances, the application was tested from the beginning of the development process to ensure that every component is error-free and working properly as it is expected to be working. For this purpose Unit testing and Integrated testing were carried out. The following test cases were used to carry out the testing process for the biosphere cycle component.

Table 3: Test Case Table 01

Test Case ID	01
Test Description	Checking whether the Carbon cycle interface is displayed when the Carbon cycle button is clicked
Pre-condition	User should select the Biosphere Cycle tab
Steps	1. User clicks the *Carbon Cycle* button from the Biosphere cycle interface
Expected Output	Displaying the Carbon cycle interface
Actual Output	Displaying the Carbon cycle interface

Table 4: Test Case Table 02

Test Case ID	02
Test Description	Checking whether the camera gets opened automatically when a preferred language is selected.
Pre-condition	User should select the Biosphere Cycle tab
Steps	1. The user clicks on the *Carbon Cycle* button. 2. The user clicks on the *Learn* button. 3. The user selects a language.
Expected Output	The camera gets opened automatically
Actual Output	The camera gets opened automatically

Table 5: Test Case Table 03

Test Case ID	03
Test Description	Checking whether the Carbon cycle 3D model is displaying when the marker is detected.
Pre-condition	User should select the Biosphere Cycle tab
Steps	1. The user clicks on the *Carbon Cycle* button. 2. The user clicks on the *Learn* button. 3. The user selects a language.

	4. The camera gets opened and the user points the camera to the 2D carbon cycle image in the textbook.
Expected Output	The 3D model of the Carbon cycle is displayed properly.
Actual Output	The 3D model of the Carbon cycle is displayed properly.

Table 6: Test Case Table 04

Test Case ID	04
Test Description	Checking whether the Nitrogen cycle 3D model is displaying when the marker is detected.
Pre-condition	User should select the Biosphere Cycle tab
Steps	1. The user clicks on the *Nitrogen Cycle* button. 2. The user clicks on the *Learn* button. 3. The user selects a language. 4. The camera gets opened and the user points the camera to the 2D Nitrogen cycle image in the textbook.
Expected Output	The 3D model of the Nitrogen cycle is displayed properly.

Actual Output	The 3D model of the Nitrogen cycle is displayed properly.

Table 7: Test Case Table 05

Test Case ID	05
Test Description	Checking whether the Sinhala audio explanation is played when the Sinhala language is chosen.
Pre-condition	User should select the Biosphere Cycle tab
Steps	1. The user selects a cycle to learn. 2. The user clicks on the *Learn* button. 3. The user clicks on the *Sinhala* button. 4. The camera gets opened and the user points the camera to the relevant cycle image in the textbook.
Expected Output	Sinhala audio is playing properly along with the 3D model.
Actual Output	Sinhala audio is playing properly along with the 3D model.

The following Fig.42 and Fig.43 show how the application will display the 3D models of the Carbon cycle and the Nitrogen Cycle if the application is properly working.

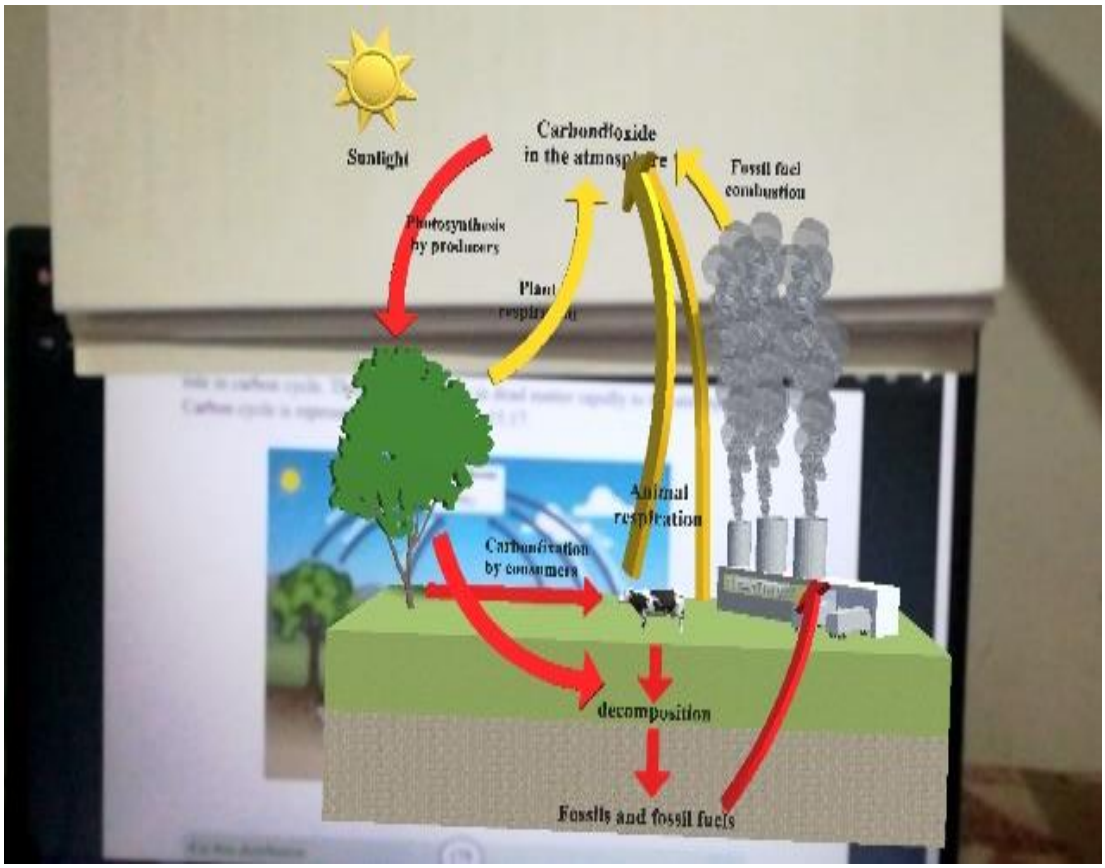

Figure 42: Carbon Cycle 3D Model

The phone camera gets automatically open after choosing a preferred language from the interface. After that, the student has to point the camera to the relevant cycle image in the textbook in order to visualize the 3D models of the cycles. Also, the audio description will be played in the background according to the language selected by the student.

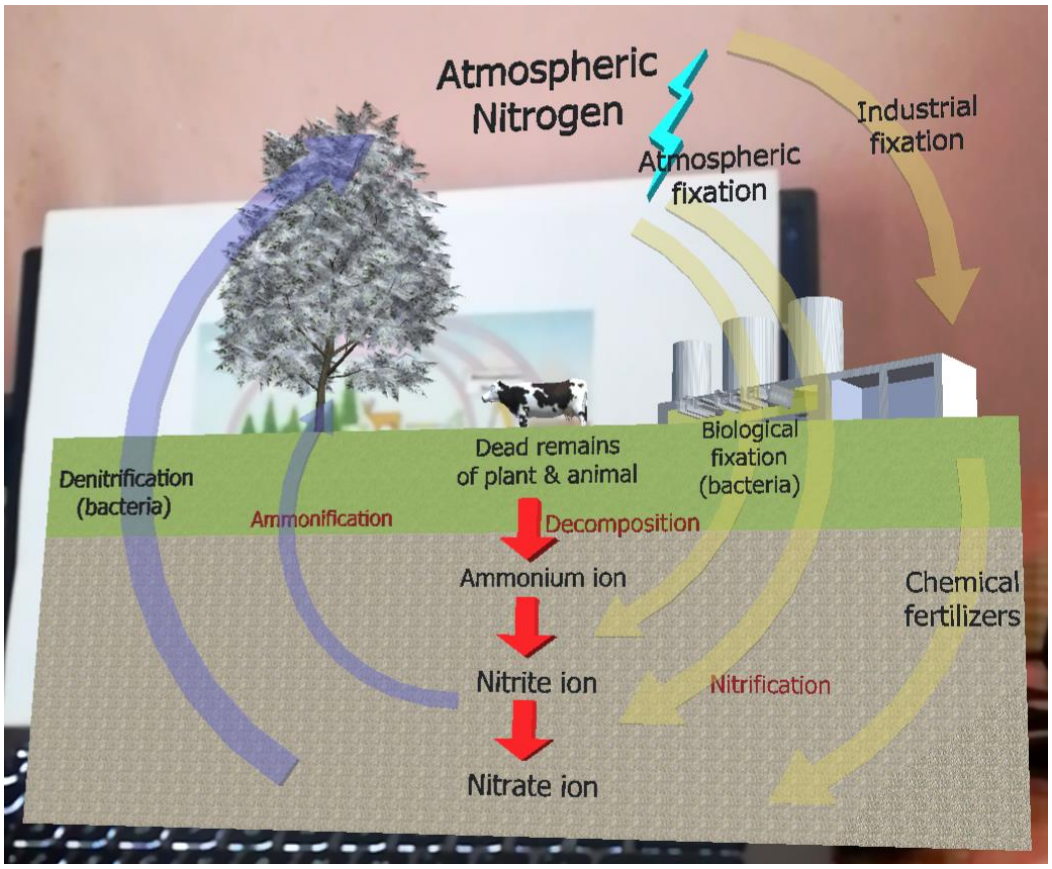

Figure 43: 3D Model of the Nitrogen Cycle

3. RESULTS AND DISCUSSION

3.1. RESULTS

The main aim of implementing this AR mobile application is to teach the **Biosphere Cycles** for the O/L students with the hope of making the learning environment interesting and effective for the students. Also, it is expected to improve the O/L Science results of the students. Therefore, it was important to find out how end-users feel about the Biosphere section of the application. For this application, end-users are students and teachers. The following graphs (Fig.44 and Fig.45) show how they have given their feedback regarding the application.

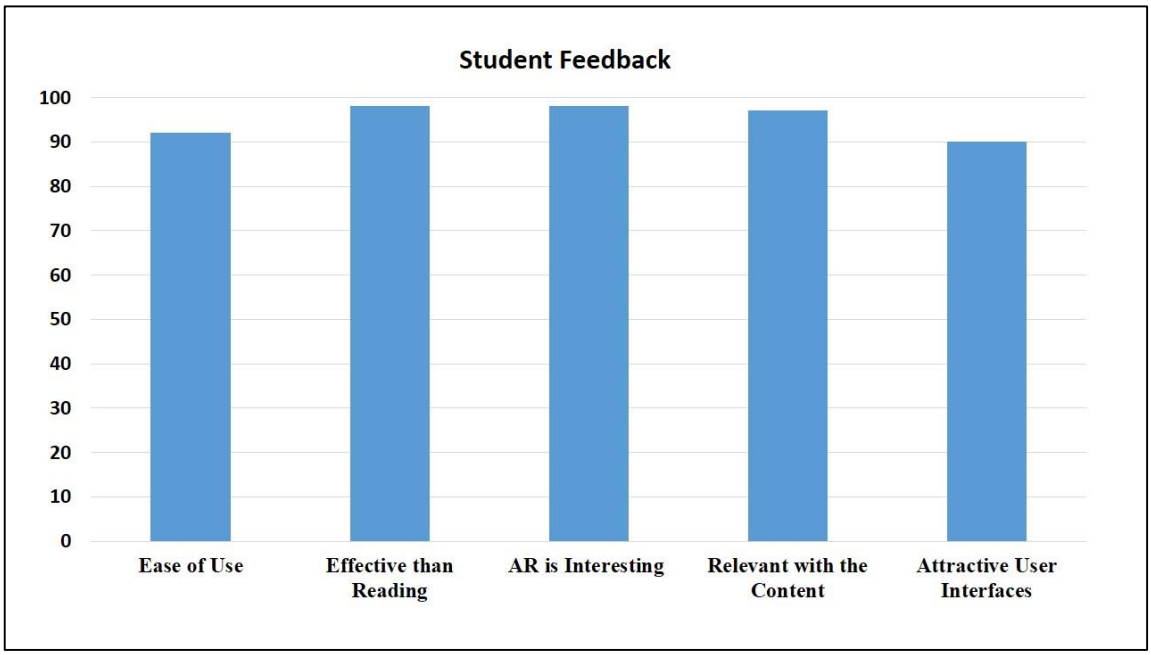

Figure 44: Student Feedback

According to the graph, it is clear that most students prefer to use this application since most of them have given positive feedback. 98% of the students have mentioned that AR is an interesting technology to work with. Also, the same percentage of students have mentioned that it is effective to use AR for learning

rather than reading the textbook. 92% of them have indicated that the application is easy to use, while 90% of the students have mentioned that the user interfaces are attractive. Furthermore, it is highlighted by 97% of the students that the content of the application is relevant to the textbook content

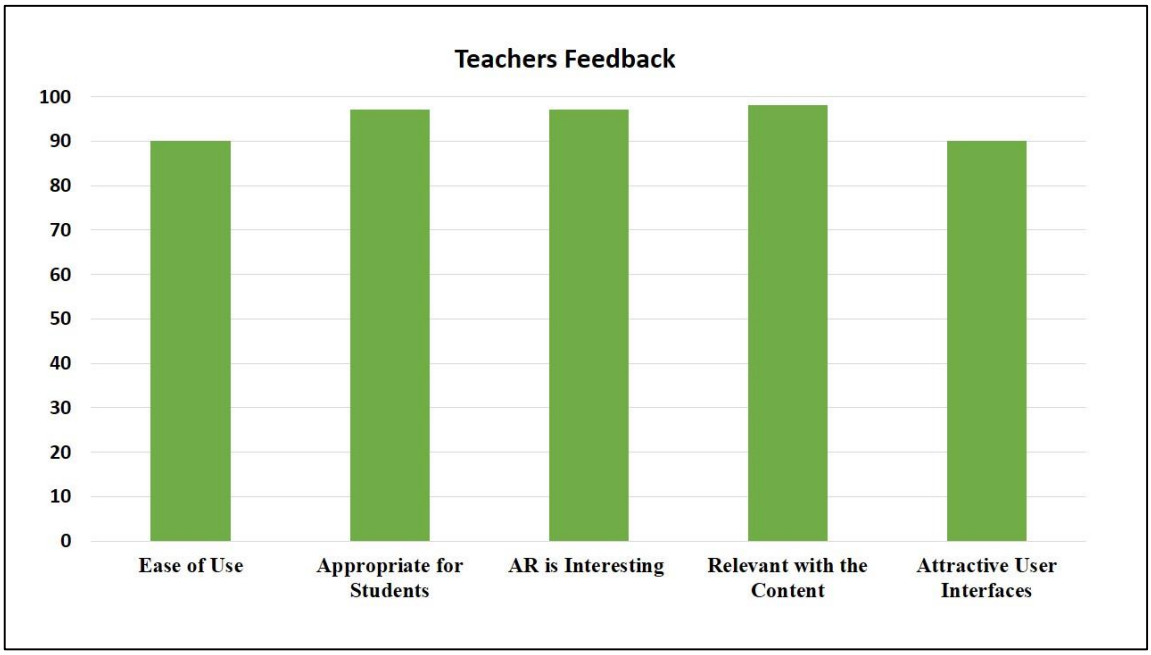

Figure 45: Teachers Feedback

According to the above graph, 97% of the teachers have mentioned that the application is appropriate for the students and therefore, they can recommend it as a useful application for their students to use as learning material. From their feedback, they have indicated that the application can support them to achieve the desired learning objectives. Also, the same percentage of teachers have highlighted AR as an effective learning technology. When they were asked to give their feedback about the relevancy of the application content with the textbook content, 98% of them have mentioned that the application has successfully aligned with the subject content. Moreover, 90% of the teachers have mentioned that the application is easy to use, and it has attractive interfaces

that will make students interested in the application. When considering the overall responses given by the teachers and the students, it is proved that the application can be used as a useful learning technique to learn the Biosphere cycles in the O/L syllabus and also to improve the Science results of the students.

3.2. RESEARCH FINDINGS

This application was implemented to provide a better learning environment for the O/L students. While the application was being developed it was important to conduct a study to find out the actual requirements of the end-users. Therefore, a questionnaire was distributed among thirty Grade 11 students to determine the areas which they find difficult in the **Biosphere** topic in the Science syllabus. The following Fig.46 shows the obtained data from the students.

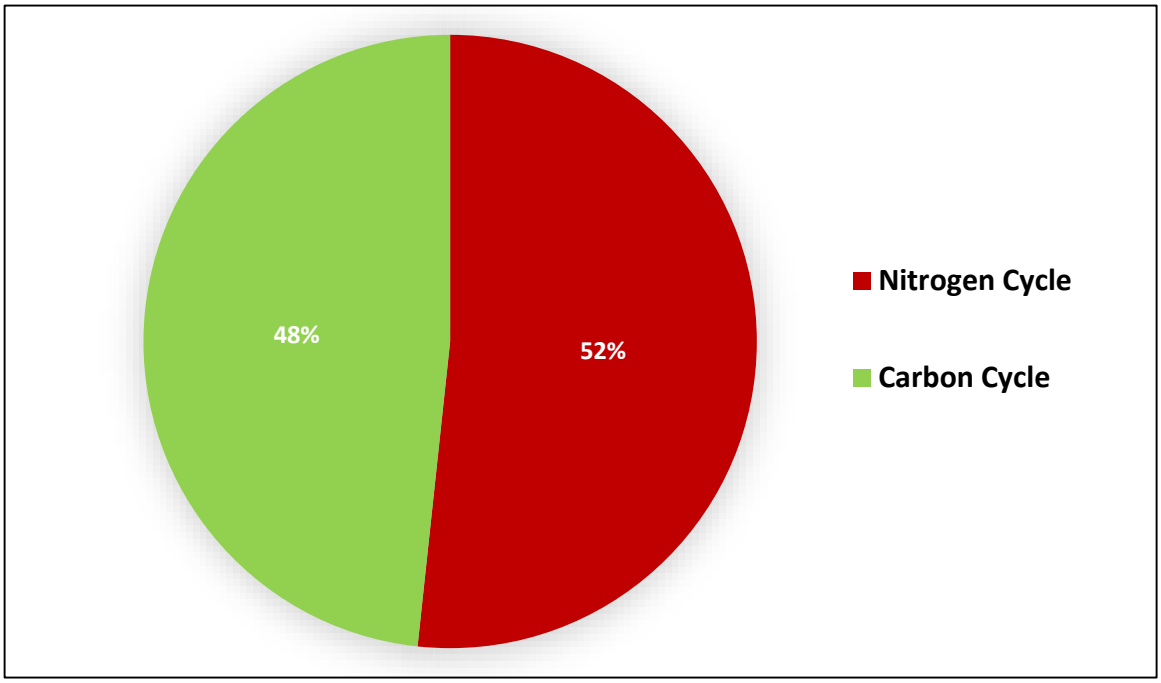

Figure 46: Difficulty in Understanding the Biosphere Cycles

According to the research findings, it was evident that an AR mobile application should be implemented in order to teach and learn these main Biosphere cycles in the Science syllabus.

3.3. DISCUSSION

The study and the results obtained by the end-users indicated that Augmented Reality is one of the best technologies which can be applied to the field of education. It was the main reason for developing an AR mobile application to enhance student motivation and interest in learning the topic **"Biosphere Cycles"**. Almost all the students are willing to learn this topic using the implemented AR application since it can make learning bored or difficult topics such as **"Biosphere"** more interesting, impressive, and it gives motivation for the students to learn more and more. Furthermore, AR can change traditional classroom-based learning to distance learning while giving more advantages and benefits. Therefore, developing an AR mobile application for learning O/L science topics is an immense opportunity for a country like Sri Lanka.

4. CONCLUSION

The developed product is an AR mobile application to support teaching and learning science for G.C.E O/L students in Sri Lanka by overcoming the drawbacks in the traditional classroom teaching methods. The application has used an augmented reality-based approach with the hope of making it effective and more interactive for the students to learn the syllabus. The key concepts in the topic Biosphere were considered for this research as it was determined by the survey results that most students have faced difficulties while learning these cycles. By analyzing the survey results and the evaluation of the developed application, it was proved that learning Biosphere cycles using AR is a better way of learning. Also, they indicated that the final product would be more effective for O/L students to grab even more advanced concepts in the topic Biosphere by using the application rather than reading the textbook. Moreover, this application would be a tremendous support for students with a low level of reading capabilities since it provides audio support.

5. REFERENCES

[1] R. Layona, B. Yulianto and Y. Tunardi, "Web based Augmented Reality for Human Body Anatomy Learning," in *3rd International Conference on Computer Science and Computational Intelligence 2018*, Jakarta, 2018.

[2] M. H. Kurniawana, S. D. and G. Witjaksono, "Human Anatomy Learning Systems Using Augmented Reality on Mobile Application," in *3rd International Conference on Computer Science and Computational Intelligence 2018*, Jakarta, 2018.

[3] H. Pranoto and F. M. Panggabean, "Increase The Interest In Learning By Implementing Augmented Reality : Case studies studying rail transportation," in *4th International Conference on Computer Science and Computational Intelligence*, Jakarta, 2019.

[4] F. K. Algarawi, W. A. Alslamah, . A. A. Alhabib, A. S. Alfehaid and D. M. Ibrahim, "Applying Augmented Reality Technology for an E-Learning System," *International Journal of Computer and Information Engineering*, vol. 12, pp. 151-156, 2018.

[5] V. Camilleri and M. Montebello, "ARieL: Augmented Reality in interactive e-Learning," November 2008.

[6] K. Dutta, "Augmented Reality for E-Learning," Aachen, 2015.

[7] A. Iftene and D. Trandabăț, "Enhancing the Attractiveness of Learning through Augmented Reality," in *International Conference on Knowledge Based and Intelligent Information and Engineering Systems*, Belgrade, 2018.

[8] W. A. U. Y. S. Wickramasinghe, "A Mobile Application with Augmented Reality to Enhance Sinhala Learning," University of Moratuwa, Moratuwa, 2015.

[9] "Department of Examinations, Sri Lanka," [Online]. Available: https://www.doenets.lk/statistics. [Accessed 25 January 2020].

[10] Wikipedia, "Vuforia Augmented Reality SDK," [Online]. Available: https://en.wikipedia.org/wiki/Vuforia_Augmented_Reality_SDK. [Accessed October 2019].

[11] Wikipedia, "Unity (game engine)," [Online]. Available: https://en.wikipedia.org/wiki/Unity_(game_engine). [Accessed October 2019].

[12] Wikipedia, "SketchUp," [Online]. Available: https://en.wikipedia.org/wiki/SketchUp. [Accessed October 2019].

[13] "Image Target," Vuforia Developer Library, [Online]. Available: https://library.vuforia.com. [Accessed January 2020].

[14] A. Mehtaa, N. P. Morris, B. Swinnerton and M. Homer, "The Influence of Values on E-learning Adoption," *Computers & Education*, pp. 1-16, 2019.

[15] S. Blanco-Pons, B. Carrión-Ruiz and J. Luis Lerma, "REVIEW OF AUGMENTED REALITY AND VIRTUAL REALITY TECHNIQUES IN ROCK ART," in *Proceedings of the 8th International Congress on Archaeology, Computer Graphics, Cultural Heritage and Innovation, 'ARQUEOLÓGICA 2.0'*, Valencia, 2016.

[16] "Educational Publications Department," [Online]. Available: http://www.edupub.gov.lk/. [Accessed 23 January 2020].

[17] J. Secretan, D. F. Wild and W. Guest, "Blueprint for an AR / xAPI Framework," in *Learning Analytics in Augmented Reality*, Oxford, 2019.

[18] November 2018. [Online]. Available: https://www.apple.com/uk/education/docs/ar-in-edu-lesson-ideas.pdf. [Accessed January 2020].

[19] S. Liang, "Research Proposal on Reviewing Augmented Reality Applications for Supporting Ageing Population," in *6th International Conference on Applied Human Factors and Ergonomics (AHFE 2015) and the Affiliated Conferences, AHFE 2015*, Sheffield, 2015.

[20] M. Jayaweera, I. Wijesooriya, D. Wijewardana, T. De Silva and C. Gamage, "Demo Abstract: Enhanced Real-Time Machine Inspection with Mobile Augmented Reality for Maintenance and Repair," University of Moratuwa, Moratuwa, 2017.

[21] G. Velivitiya, A. Hewathudella, N. Ekanayaka and B. Amarasinghe, "AUGMENTED REALITY SMART SHOPPING," Sri Lanka Institute of Information Technology, Malabe, 2019.

6. GLOSSARY

Augmented Reality	A technology that can superimpose a computer-generated image over a user's perspective of the real world, thus creating a composite view.
E-learning	Learning via electronic media or the internet

7. APPENDICES

AUGMENTED REALITY SCIENCE APP FOR O/L STUDENTS

We are a final year project group at Sri Lanka Institute of Information Technology (IT17107624 – De Silva K.V.P.W, IT17106252 – U.S Hettihewa, IT17157988 – Liyanage P.M, IT17098588 – N.M.W.K.P.C Naranpanawa). The purpose of this questionnaire is to gather requirements for our final year research project. Please spare few minutes from your busy schedules and be kind enough to respond to this survey. Further, we will assure that all correspondence, including completed survey forms will be kept confidential and secure.

1. What is your expected grade for science at the O/L examination?
    i. A
    ii. B
    iii. C
    iv. S
    v. F
2. Are you facing any difficulties in studying science?
    i. Yes
    ii. No
3. How familiar are you in using mobile phones?
    i. Very familiar
    ii. Somewhat familiar
    iii. Not familiar
4. Do you think that a mobile app with 3D technology will support you to study science more effectively?
    i. Yes
    ii. No
    iii. Neutral
5. Which way will be more convenient for you to study science?
    i. Reading notes
    ii. Using a mobile app with 3D technology
6. Number the following according to the order you think that 3D technology will be benefited most study (1- most benefited, 4 – least benefited)?
    i. Acids ☐
    ii. Bases ☐
    iii. Salts ☐
    iv. Hydrocarbons ☐

7. Number the following according to the order which is hard for you to study (1- most, 4 - least)?

i.	Digestive System	
ii.	Respiratory system	
iii.	Urinary System	
iv.	Blood Circulatory System	
v.	Reproductive System	

8. Which of the below topics on plant processes, you feel difficult in your studies? Number according to your preference. (1-most difficult, 3-least difficult)

i.	Photosynthesis	
ii.	Plant respiration	
iii.	Reproduction	

9. Number the following according to the order which is hard for you to study (1- most, 4 - least)?

i.	Plant cell structure	
ii.	Plant tissue organization	

10. Which of the following experiments do you feel difficult from your science syllabus? (1-most, 5-least)

i.	Starch production during photosynthesis	
ii.	Need of light energy for photosynthesis	
iii.	Need of CO2 for photosynthesis	
iv.	Need of chlorophyll for photosynthesis	
v.	O2 production during photosynthesis	

11. Number the following cycles according to the order which is complicated for you to understand? (1 – most, 4- least)

i.	Water Cycle	
ii.	Hydrogen cycle	
iii.	Nitrogen cycle	
iv.	Carbon cycle	

12. According to you, what kind of benefits you can gain by using a mobile app with 3D technologies to study your O/L science syllabus?

Appendix 1: Questionnaire