

AR based Interactive Educational Tool for Life Sciences

by

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DECLARATION

This project report is submitted to the Computer Science and Engineering, University of Liberal Arts Bangladesh in partial fulfillment of the requirements for the degree of Bachelor of Science. So, I hereby, declare that this project report is based on the surveys found by me. Materials of work found by other researchers are mentioned by reference. This project report, neither in whole, nor in part, has been previously submitted for any degree.

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CERTIFICATE OF APPROVAL

The project report entitled “AR based Interactive Educational Tool for Life Sciences” is submitted to the **Computer Science and Engineering**, University of Liberal Arts Bangladesh, Dhaka in partial fulfillment of the requirements for the degree of Bachelor of Science.

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ABSTRACT

In many educational institutions, various methods have been applied to improve learning outcome. However, there is another latest technology for education, known as Augmented Reality (AR), which is not much in use currently. The augmented reality technology allows 3D models and visuals to be viewed in real world. This proposed project introduces an AR based educational interactive tool that would facilitate better learning of the subject matter, Life Sciences also known as Biology. The particular subject matter has been chosen because of the practical works involved and detailed understanding required. A study showed that students learn better using additional visuals. Therefore, this educational application would provide extra benefit to the students of Life Sciences. The application would allow students and instructors to view 3D models along with labels from the input 2D images extracted from textbooks. Additional animations and audio effects will be available for some 2D images such as throbbing effect on heart model. The users can also rotate, zoom in and zoom out the 3D model as per convenience. The system simply requires a smartphone to be operated by the users.

LIST OF TABLES

1.1	Summary of 16 studies of applying AR on individuals with disabilities	4
1.2	Project Finance	6
3.1	Functional Requirements	15
3.2	Nonfunctional Requirements	16
3.3	Use Case Description	17
5.1	First Test Case	28
5.2	Second Test Case	29
5.3	Third Test Case	29
6.1	Sustainability Plan of the System	31

LIST OF FIGURES

1.1	An AR volcano eruption	2
1.2	Comparison of mean values for pre-usage and post-usage questionnaires	3
1.3	Waterfall Model	5
2.1	(a) Anatomy 4D target image, (b) Anatomy 4D mobile application screenshot	7
2.2	Screen captures of views through BiochemAR	8
2.3	Left: Router Marker. Right: Smartphone Scanning Marker	8
2.4	Snapshots of hybridized orbitals in a CH ₄ molecule using markerless AR app	9
2.5	Tourism Application Image Target Recognition	9
2.6	(a) Traditional Communication (b) AR Communication. Furniture products from left to right: SANDBACKEN sofa, MICKE desk, and KVISTBRO basket	10
3.1	Business Process Model	13
3.2	Use Case Diagram	19
3.3	Data Flow Diagram	20
3.4	Flowchart of the application	21
4.1	Halfway Front-End Design	22
4.2	Complete Design showing (a) English labels on the 3D model, and (b) Bangla Labels on the 3D model	23
4.3	Screenshots of the User Interface Design	24
4.4	Main Interface Design without Labels and Extra Features on Smartphone Screen	25
5.1	Screenshot of work done in Unity 3D	27
5.2	Target Image added to Vuforia Engine	27
5.3	Screen View of Application with Left: English Labels, Right: Bangla Labels	28
5.4	Images showing Left: scaling down to get zoomed out view and Right: scaling up to get zoomed in view, of the 3D model	29
5.5	Application in Use	29

LIST OF ABBREVIATIONS

Abbreviation	Definition
AR	Augmented Reality
3D	Three Dimensional
4D	Four Dimensional
KcsA	Prokaryotic (Chemistry term)
REQ	Requirement
TC	Test Case
UC	Use Case
DFD	Data Flow Diagram

TABLE OF CONTENT

CHAPTER TITLE	PAGE
ACKNOWLEDGEMENT	iii
ABSTRACT	iv
LIST OF TABLES	v
LIST OF FIGURES	vi
LIST OF ABBREVIATIONS	vii
1 INTRODUCTION	1
1.1 Introduction	1
1.2 Motivation	3
1.3 Objectives	4
1.4 Expected Outcomes	5
1.5 Project Management and Finance	5
1.6 Report Layout	6
2 BACKGROUND	7
2.1 Related Works	7
2.2 Comparative Analysis	11
2.3 Scope of the Problem	12
2.4 Challenges	12
3 REQUIREMENT SPECIFICATION	13
3.1 Business Process Modeling	13
3.2 Application Stakeholders	14
3.3 Requirement Collection and Analysis	15
3.3.1 Enumerated Functional Requirements	15
3.3.2 Enumerated Nonfunctional Requirements	16
3.4 Use Case Modeling and Description	17

3.5	Data Flow Diagram	20
3.6	System Flowchart	20
3.7	Design Requirement	21
4	DESIGN SPECIFICATION	22
4.1	Design	22
4.2	Interaction Design and User Experience (UX)	24
4.3	Implementation Requirements	26
5	IMPLEMENTATION AND TESTING	27
5.1	Implementation of Standalone Front-End System	27
5.2	Test Cases	30
6	IMPACT ON SOCIETY, ENVIRONMENT AND SUSTAINABILITY	32
6.1	Impact on Society	32
6.2	Impact on Environment	32
6.3	Ethical Aspects	33
6.4	Sustainability Plan	33
7	CONCLUSION AND FUTURE SCOPE	34
7.1	Discussion and Conclusion	34
7.2	Scope for Further Development	34
	REFERENCES	35

CHAPTER 1: INTRODUCTION

1.1 Introduction

The education sector since the past few years has evolved greatly. The changes became much more prominent after the arrival of Covid-19 pandemic. For example, the increased usage of technological devices for online learning during the pandemic [1]. Education now does not only mean sitting in confined traditional classrooms of bricks and mortar and listening live to the teachers, but a lot more different set ups due to online education system [1]. However, there are some other aspects yet to be introduced for better teaching and learning outcome, particularly in Bangladesh. In recent years, augmented reality (AR) has been included in educational institutions of some countries. A few of these institutions are University of North Carolina, Massachusetts Institute of Technology and Columbia University in USA, and Institute of Optoelectronic Information Technology and Color Engineering in China [2]. Augmented reality (AR) is basically a technology which adds computer-generated virtual information to the real world. The information that might be used are 3D models, images, text and audio [2].

The most well-known usage of AR technology can be seen in a game application launched in 2016 known as Pokémon Go. The game requires the user to fetch and capture virtual figures through a Poké ball and train them in Gyms to be battling against other players' figures [3]. The game's success is due to complex technology being presented in simplified form and focus on user experience [3]. Another usage of the AR can be found in a persistent technology which is AR Cloud. The AR Cloud in simple words refers to the digital copy of real world [2]. According to Charlie Fink, the arrival of AR Cloud will allow the entire world become a shared space screen for realizing the cooperation amongst multiple users [2]. These two renowned examples are quite great for familiarizing with the AR technology.



Figure 1.1 An AR volcano eruption [3]

Augmented Reality (AR) has been implemented in various fields, but as this application demands, our focus will be on the field of education. A demonstration of AR in the field of education can be seen Figure 1.1. There are a few educational applications that uses AR technology to produce 3D models and animations based on 2D images. Quiver and Aurasma are two of which can be used [3]. Nevertheless, these applications lack labels on the 3D objects and animations that might be required for understanding. This paper introduces a project on an AR based interactive educational application in the education sector for the subject matter, Life Sciences or Biology. The diagrams available from the textbooks would be viewed in 3D on smartphones, and the labels around them would be available both in English and Bangla. There are some other extra features integrated, to make the system much more interactive for the students.

1.2 Motivation

The motivation of this application is to assist students in understanding life sciences better since it is a practical subject and requires having clear concept for future endeavors. Using AR for educating students, can increase their motivation and thus lead them towards academic achievements through better understanding. Research was conducted at University of Cape Town where the learning motivation of undergraduate health science students was measured both before and after using an AR application [4]. The research included several questions to examine how AR application affected the four motivation aspects- Attention, Relevance, Confidence and Satisfaction [4]. As per final results, using the AR application for learning, increased the students' attention, confidence and satisfaction by 31%, 11%, and 13%, but 3% decrease was found in relevance factor which is insignificant [4]. The overall increase of motivation was 14% [4]. Therefore, developing an AR based tool would motivate students of Life Sciences and thus promote better understanding. The increase in values can be understood from Figure 1.2 [4].

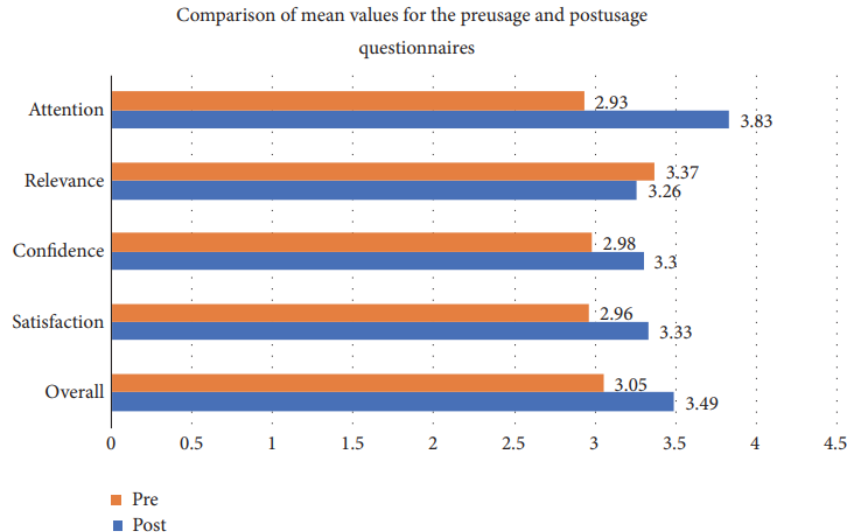


Figure 1.2 Comparison of mean values for pre-usage and post-usage questionnaires [4]

Additionally, reaching out to help students with cognitive impairments is another good reason to come up with this AR based tool. According to a research, AR based study material has been contributing in better understanding of people with cognitive impairment and also helped them in gaining vocational skills [5]. In a study, a systematic review of 16 relevant studies is represented which included the effects of AR based materials on individuals with disabilities [5]. The list is divided into six categories including cognitive disorders and intellectual disabilities. The summary of the studies is presented in a tabulated form in Table 1.1 [5]. Both the categories, Intellectual Disabilities and Cognitive Disorders, in the table contains studies which has positive outcome. Based on this study, it can be said that it is relevant to come up with an AR application for assisting the students with cognitive or intellectual impairment as well.

Table 1.1 Summary of 16 studies of applying AR on individuals with disabilities [5]

Special Needs	Authors	Variable	Positive Outcome
Visual Impairments	Huang et al. (2019)	supported tool for user with reduced vision	Yes
	Zhao et al. (2018)	understanding low vision people visual perception	Yes
Autism	McMahon et al. (2015)	increase science vocabulary knowledge	Yes
	McMahon et al. (2015)	support decision making	Yes
	Lorenzo et al. (2019)	improve social skills	Yes
General Special Needs	Lorenzo (2019)	enhance competitive in the job market	Yes
	McMahon (2015)	improve the academic skills of students	Yes
Intellectual Disabilities	Cate et al. (2017)	improve navigation skills	Yes
	Cacciatore (2018)	enhanced mathematics skills	Yes
	Benda et al. (2015)	working aid tool	No
	Smith et al. (2017)	improve navigation skills	Yes
	McMahon et al. (2015)	increase knowledge	Yes
	Bridges et al. (2020)	increase daily and independence skills	Yes
	McMahon et al. (2013)	effective in identifying possible allergens	Yes
Cognitive Disorders	Chang et al. (2013)	improve perception and vocational job skills	Yes
Vocational Education	Bacca et al. (2018)	influence students motivation	Yes

1.3 Objectives

There are some main objectives for this AR based interactive educational tool and they are:

- To introduce an effective usage of AR technology for educational purposes.
- To execute labels appearing on the 3D models of the diagrams.
- To grow interest of students towards life sciences through this interactive application.
- To assist life sciences instructors for attaining better learning outcome.
- To analyze the impact of this AR based learning tool on students.

All the objectives are to some extent related and are to be fulfilled as the application is progressing. After the fulfillment of these objectives, it would be very much helpful for not just the students but the instructors instilling the application into their curriculum.

1.4 Expected Outcomes

Through this interactive educational application there are several probable outcomes that would be beneficial for the education sector. However, the two vital possible outcomes are, (a) a workable AR based application for Life Sciences or Biology and (b) successful viewing of labels around the 3D models in both English and Bangla. It is very important to complete the basic requirements for this application to work accordingly. Some basic requirements may include, properly configuring the system to run on Android devices, adding of AR camera so that the user can hover over the images from textbook to get output, and ensuring accurate detection of images to display 3D models. The second outcome is a unique added feature which also needs to be fulfilled in order to establish better understanding of students from both the mediums.

1.5 Project Management and Finance

For project management the Waterfall Model has been selected to complete the application in a step-by-step procedure (Figure 1.3).

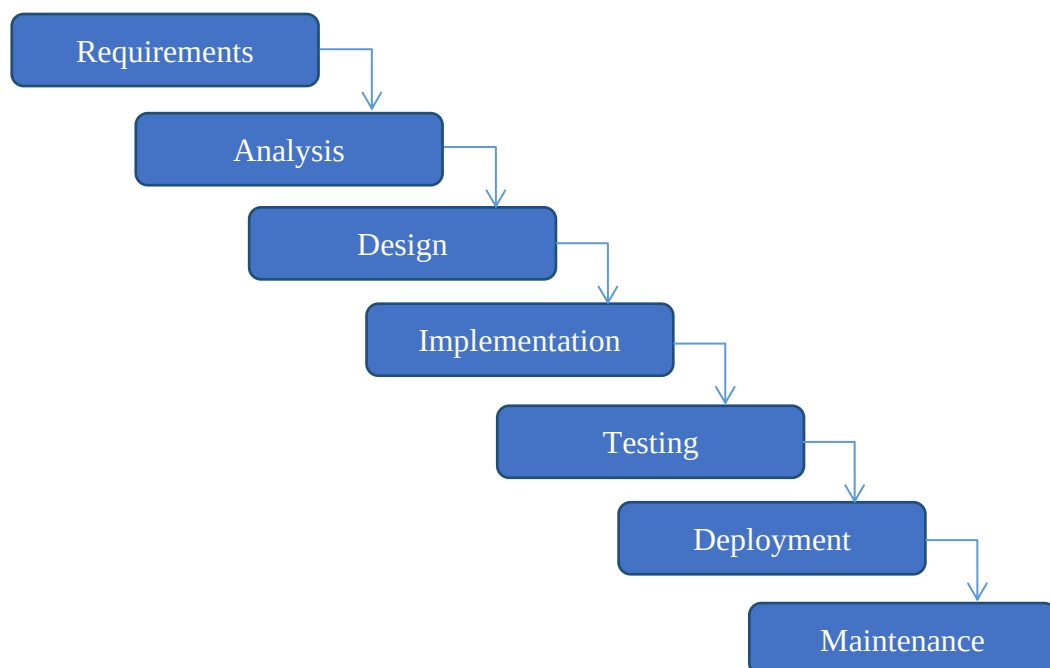


Figure 1.3 Waterfall Model

Table 1.2 Project Finance

Required Tools	Expense (BDT)
Laptop with minimum 8GB RAM	55,000 or above
Life Sciences/Biology Textbooks	800 each
3D Model Collection	9,497 (\$100 each)
Smartphone (Android)	10,000 or above
Total:	75,297

The application-based project requires a laptop or a computer with minimum 8GB RAM to be built. For the sample pictures based on which 3D models will be displayed, a few biology text books are also required. In this project 3D models for particular diagrams needs to be collected which are available in certain websites. The 3D models with good quality are quite expensive. Additionally, the application will be run on smartphones which are more or less available. The project expenses are summarized in Table 1.2. Besides the required tools holding monetary value, a free software known as Unity 3D needs to be installed. Unity 3D is mostly used for developing 3D based applications and has been utilized recently [19] [20].

1.6 Report Layout

The Chapter 1 of this paper includes the introduction of the proposed application. Chapter 2 consists the background of the chosen system which means the it has been compared with other existing works. Chapter 3 defines the requirements that this system holds. The Chapter 4 and 5 shows the design and implementation of this system that has been done so far. Then comes Chapter 6 which analyzes the impact this system has on society and environment. Lastly, the paper concludes with a discussion and future scope for development. The references are also included for the credibility of used citations.

CHAPTER 2: BACKGROUND

This chapter is going to provide detailed information about some of the recent works that are somehow related to the proposed AR based educational interactive tool. There are some gaps present in few of the works which this system aims to consider in future. A separate section has been constructed for the comparison of the related systems with the proposed system.

2.1 Related Works

Research has been conducted for identifying the effects of AR on the learning motivation of students. The motivation factor was calculated of health science students at University of Cape Town. The mobile application used for analysis of the motivation was Anatomy 4D. The free application, Anatomy 4D uses AR technology for interacting with the pictures of human body [4]. It uses target image to produce 3D model of the human body to be displayed on the mobile screen. The target image and the display screen of Anatomy 4D can be seen in Figure 2.1[4]. Similarly, there are other AR based applications which are developed particularly for the subject Anatomy to assist the learners [6][7].

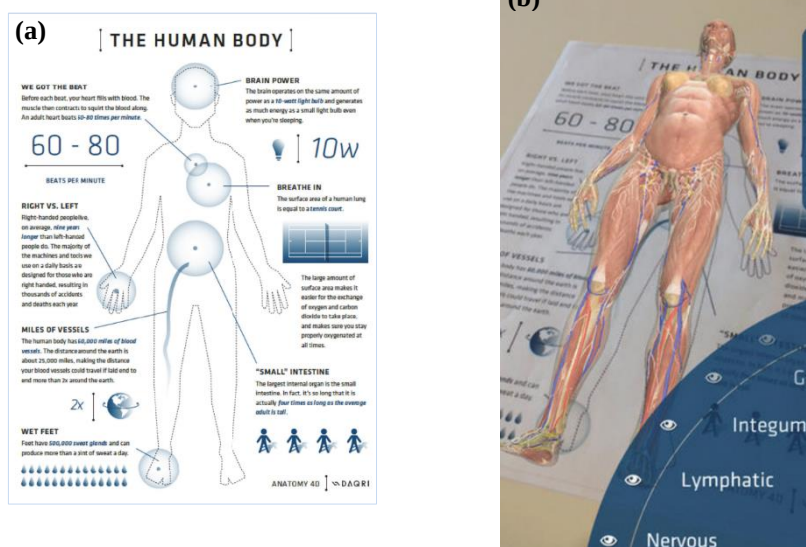


Figure 2.1 (a) Anatomy 4D target image, (b) Anatomy 4D mobile application screenshot [4]

An AR based educational application named BiochemAR has been constructed particularly for the subject matter, biochemistry. This application is developed to help biochemistry instructors to incorporate 3D visualizations of macromolecular structures in their study materials. The BiochemAR application comes with a learning module which uses the

structure of KcsA potassium channel for demonstrating the function of amino acid functional groups and protein secondary structure in enabling transport of ion, across a lipid bilayer channel. The visuals through BiochemAR can be seen in Figure 2.2 [8]. Similarly, in another paper, an AR based application has been proposed for development, particularly for learning Computer Network Device. The images of the display procedure of this application are shown in Figure 2.3 [9].

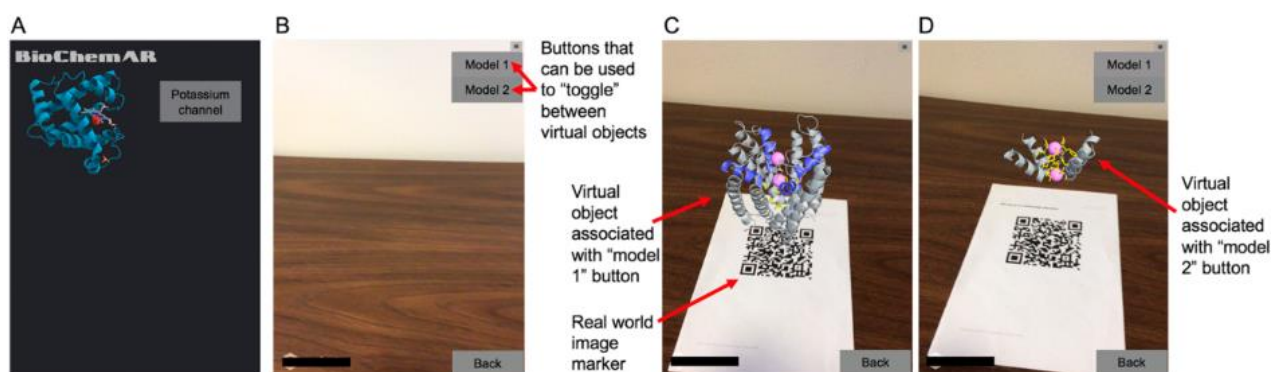


Figure 2.2 Screen captures of views through BiochemAR [8]



Figure 2.3 Left: Router Marker. Right: Smartphone Scanning Marker [9]

For the subject matter, Chemistry, a simple markerless AR based tool has been developed for students' aid. The application can be used in both Android and iOS devices. It has been constructed in such a way that students so not need printed marker in order to view the 3D molecular structures, thus making it cost-effective. The students just need to select a molecular structure from the menu and point their device cameras anywhere they want in order to see the target 3D model. The demonstration of this markerless AR based application can be seen in Figure 2.4 [10].

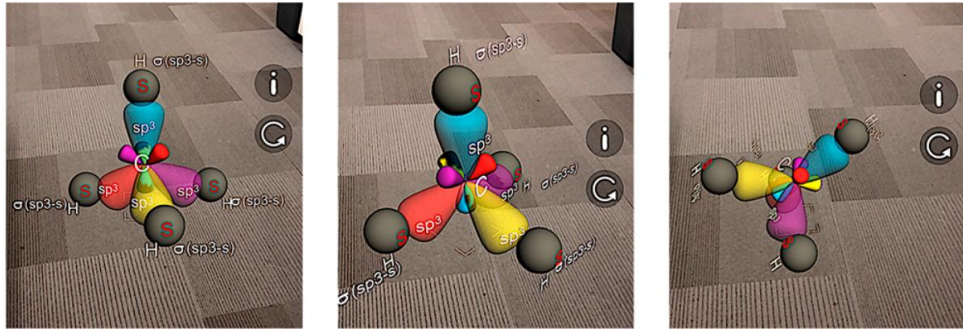


Figure 2.4 Snapshots of hybridized orbitals in a CH₄ molecule using markerless AR app [10]

Another application using the AR technology has been proposed but on the basis of tourism. The tourism application aims to provide interactivity to the clients through viewing extra information on distinguished items. This application would be able to display information like, road map, location, ratings and nearby places when a certain location is captured through mobile's camera. The proposed system will be implemented using Unity 3D [16] and Vuforia Engine. The implementation of the Tourism application on an android device can be seen in Figure 2.5 [11]. In an article, a list of case studies on the AR based applications for tourism has been analyzed and as per the analysis usage of AR provides convenience of marketing to the businesses and the destinations [12].

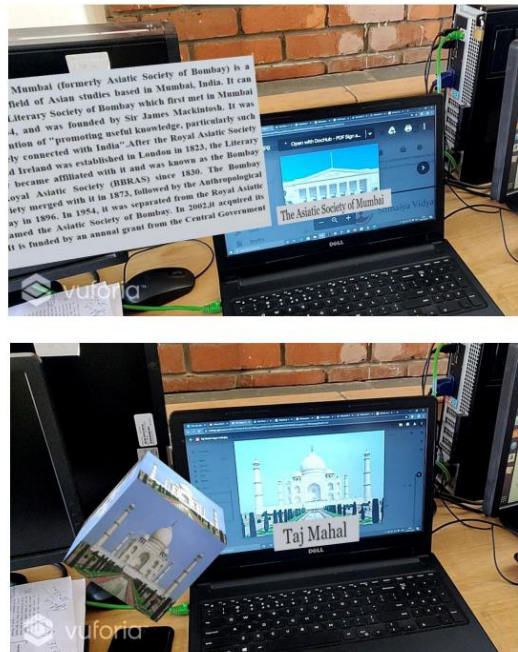


Figure 2.5 Tourism Application Image Target Recognition [11]

The effects of usage of AR technology in advertising was compared with the traditional approach in research. The research suggests that augmented reality advertisements are much more interactive and might help companies build an emotional bond with their respective customers. The application used for comparison of customer responses was IKEA Place application. Three IKEA furniture products were tested in both traditional and AR based setting as shown in Figure 2.6 [13]. The results showed that using AR based advertisements improves physiological responses of the customers and their willingness to pay.



Figure 2.6 (a) Traditional Communication (b) AR Communication. Furniture products from left to right: SANDBACKEN sofa, MICKE desk, and KVISTBRO basket [13]

In a study of Augmented Reality Tools for Sports Education and Training, a list of AR prototypes has been presented which can improve sport skills through additional information for helping the users to decide appropriately and regulating their behaviours. One of the recent prototypes discussed here is KickAR by Rogers et al. (2018). It is based on table football, where game balancing has been implemented through augmented reality. The system projects icons, and points out boosts and handicaps over the table, to influence the game and adjust it according to player skills. [14].

2.2 Comparative Analysis

The Anatomy 4D application used for a study, is the most similar work when comparing it with this AR based educational interactive application. It provides 3D models based on the target images, but its focus is specifically on human body. The proposed application in this project focuses on the other aspects included in Life Science. Moreover, the Anatomy 4D also lacks labels that are present in the proposed system's 3D models.

The BiochemAR application has a similar concept like this AR based interactive tool for Life Sciences. Both the applications are implemented for educational purposes and are to be operated through mobile devices. However, the BiochemAR application is designed for biochemistry and does not provide labels on the 3D models whereas this application is for life sciences or biology and contains labeling on the 3D models. Same goes for the markerless AR based application for chemistry.

The proposed system, Tourism Application, is brought forth to serve the tourists unlike this application for Life Sciences, but both are AR based applications and provides extra information on the 3D models it projects. Additionally, both the systems are implemented using similar tools, such as Unity 3D [17], which can be understood from the further discussion about this AR based interactive app for Life Sciences.

On the other hand, an AR based system KickAR by Rogers et al. (2018) found in a study, is designed for sports education, particularly table football. KickAR uses AR technology like this educational tool for life sciences but has a way different concept. KickAR system is not an application to be used on mobile devices unlike this educational application. However, both the systems provide additional information which makes it interactive for the users.

2.3 Scope of the Problem

There are great scopes for this project once it is completely executed as intended. Firstly, the application can be easily operated on smartphones which are quite available these days. Secondly, the labels on the 3D models can be switched to Bangla through just a simple touch. This also means that the application can be used by both the English medium and Bangla medium students. Therefore, it can reach maximum students. Moreover, not much training is required for the instructors and students to use this application since the options to operate it will be very much user-friendly.

2.4 Challenges

The application requires precise 3D models to be included which are difficult to get. Most 3D models with high quality design are quite expensive. It also requires good skills to add a touch of animation to each model for making it realistic such as throbbing effect on heart 3D model. Moreover, adding labels over the 3D images is challenging especially when two languages are to be incorporated like in this application Bangla labels along with English labels has been attempted.

CHAPTER 3: REQUIREMENT SPECIFICATION

3.1 Business Process Modeling

The business process of how this AR based interactive educational tool is going to work can be seen in Figure 3.1.

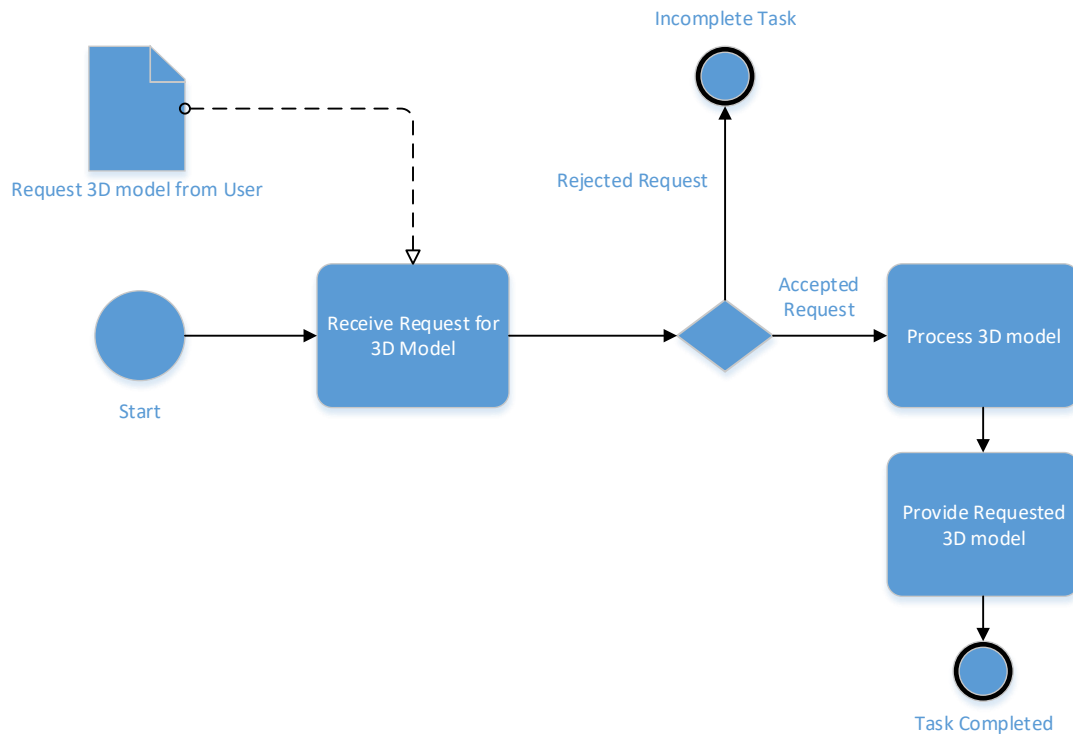


Figure 3.1 Business Process Model

The tasks being fulfilled by this AR based application is vital to fulfill the business criteria. In addition to that, proper marketing of the demonstrative model is needed. The demonstrative model can be taken to institutions for collecting suggestions from the instructors and administrators. Social media marketing is also another way to increase the usage of the system for profit. For deploying this type of application, approximately Tk. 1800000 is required. The amount may vary depending on how many textbooks of which academic levels are going to be used.

3.2 Application Stakeholders

There are some important stakeholders who are directly or indirectly impacted by this application-type system.

- I. Students- The students are the users of the system who will learn Life Sciences better using this tool.
- II. Instructors- The instructors of the subject matter are also the users who will benefit from the AR based tool when using it for teaching students.
- III. School Administrators- They might have interest in this system as it would let them increase the capability of the students under their school.
- IV. Developers- They are also to be interested regarding the design and implementation for the improvement of this system.
- V. 3D Modelers- The 3D Modelers are a part of this system as they are the ones to construct the models and provide it to the end users.

3.3 Requirement Collection and Analysis

3.3.1 Enumerated Functional Requirements

There are a group of functional requirements of the proposed system that are presented in Table 3.1 below. These are kept under three priority levels (1-> Low Priority, 2-> Moderate Priority, 3-> High Priority). The requirements are also marked with identifiers for convenience.

Table 3.1 Functional Requirements

Identifier	Priority	Requirement
REQ-1	2	The system will allow users to login through email address and password.
REQ-2	3	The system will allow users to capture images of diagrams from the textbook and submit it for the 3D model creation.
REQ-3	3	It will allow users to view the animated 3D models through hovering the smartphone over 2D images.
REQ-4	3	The system will allow users to rotate the 3D models.
REQ-5	3	The system will allow users to zoom in and out using pinch in and out gestures on the screen.
REQ-6	1	The system will let users focus on certain parts of human body 3D model through single touch.
REQ-7	3	The system will allow users to view labels in English over the 3D models.
REQ-8	2	The system will allow users to switch the language of the labels from English to Bangla for their understanding.

REQ-9	1	The system will allow users to go to the option of generating 3D models through certain keywords from the book in case the book lacks diagrams.
REQ-10	3	The system will allow 3D Modeler to provide 3D models and animations.

As per Table 3.1, the highly prioritized requirements (level-3 priority) are REQ-2, REQ-3, REQ-4, REQ-5, REQ-7 and REQ-10. The ones which have been completed amongst these are, REQ-3, REQ-4, REQ-5, REQ-7 and REQ-10. The other requirements are still in the making.

3.3.2 Enumerated Nonfunctional Requirements

The proposed system also requires to have some nonfunctional requirements which focuses on the efficiency when under use. These are also kept under three priority levels (1-> Low Priority, 2-> Moderate Priority, 3-> High Priority). The nonfunctional requirements are summarized in Table 3.2.

Table 3.2 Nonfunctional Requirements

Identifier	Priority	Requirement
REQ-11	3	The system should be compatible with smartphone operating systems.
REQ-12	3	The system should be easy to use and handle.
REQ-13	3	The system should have smooth transitions.

All the nonfunctional requirements enlisted in Table 3.2 hold equal priority and that is the highest most level (3-> High Priority). The reason for this is that, each one of them contributes in the application's overall performance which needs to be well enough when operated.

3.4 Use Case Modeling and Description

The use cases are there to indicate what are the actions the system will let its users to perform. The system has a list of use cases that has been individually described in Table 3.3. The connection amongst these use cases can be understood in the use case diagram in Figure 3.2.

Table 3.3 Use Case Description

Identifier	Use Case	Description
UC-1	Gaining Access	Allows students and instructors to gain access to all the features including the instruction option.
UC-2	Enter Email Address	Allows students and instructors to enter email address.
UC-3	Enter Password	Allows students and instructors to enter password for verification.
UC-4	View 3D Image	Allows students and instructors to view 3D images of the diagrams.
UC-5	View Labels	Allows students and instructors to view English labels on the 3D models.

UC-6	Choose Language	Allows students and instructors to choose language of labels from English and Bangla.
UC-7	Rotate	Allows students and instructors to rotate the 3D image.
UC-8	Zoom In/Out	Allows students and instructors to zoom in or out
UC-9	Focus Parts	Allows students and instructors to focus some parts on the human body 3D model.
UC-10	Generate 3D from Requested 2D	Allows 3D modeler to generate 3D images from 2D images requested by users.
UC-11	Generate 3D from Sample 2D	Allows 3D modeler to generate 3D images from sample 2D images.

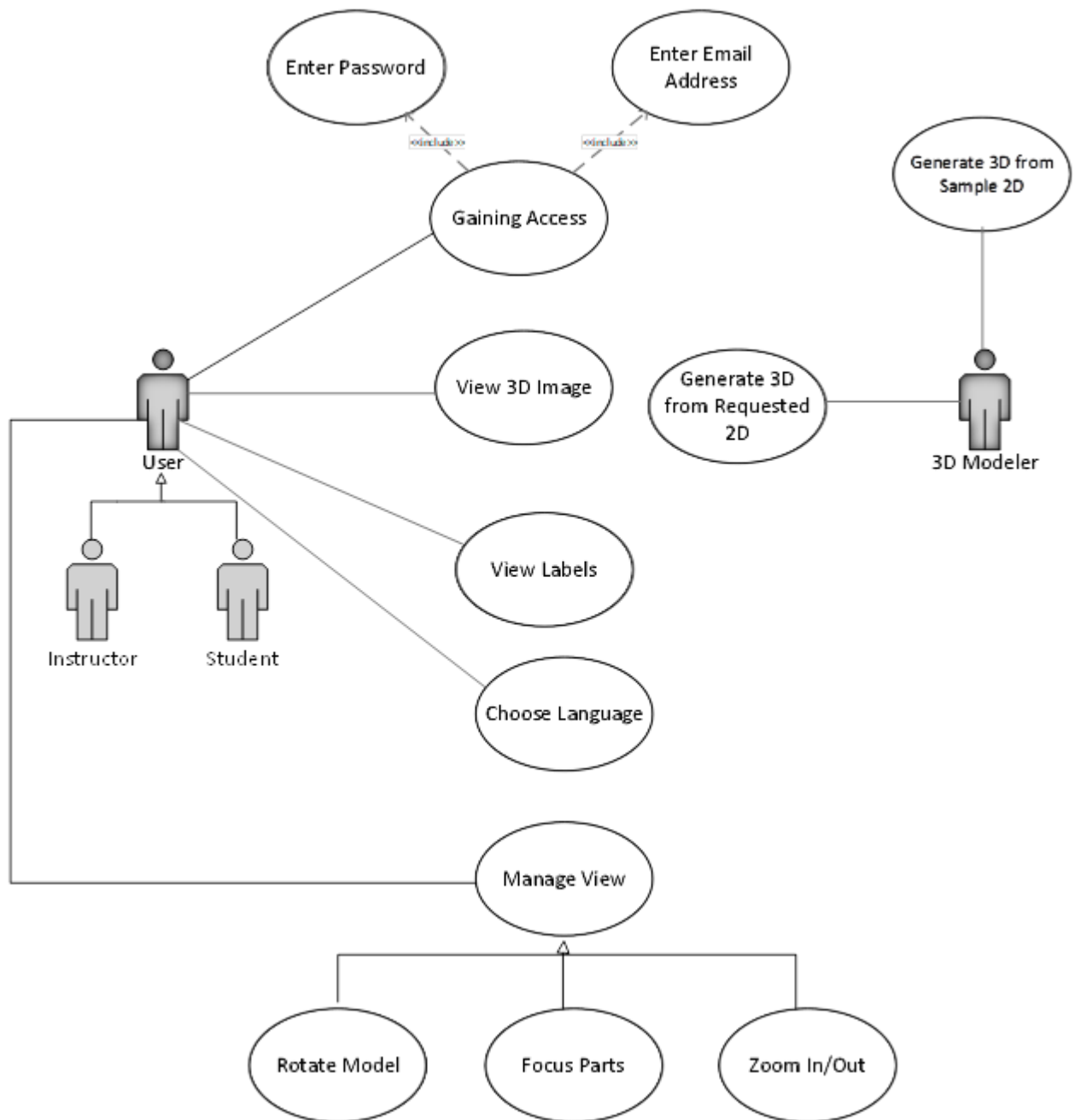


Figure 3.2 Use Case Diagram

The use case diagram in Figure 3.1 shows the relationships among the Actors and Use Cases. The Actors include, Instructor, Student and 3D Modeler. Some use cases are in inclusive relationship and some are kept in generalized form.

3.5 Data Flow Diagram

The data flow diagram (DFD) connects all the processes and gives a close look at how the system is going to work. Figure 3.3 contains DFD of the AR based interactive educational tool for life sciences.

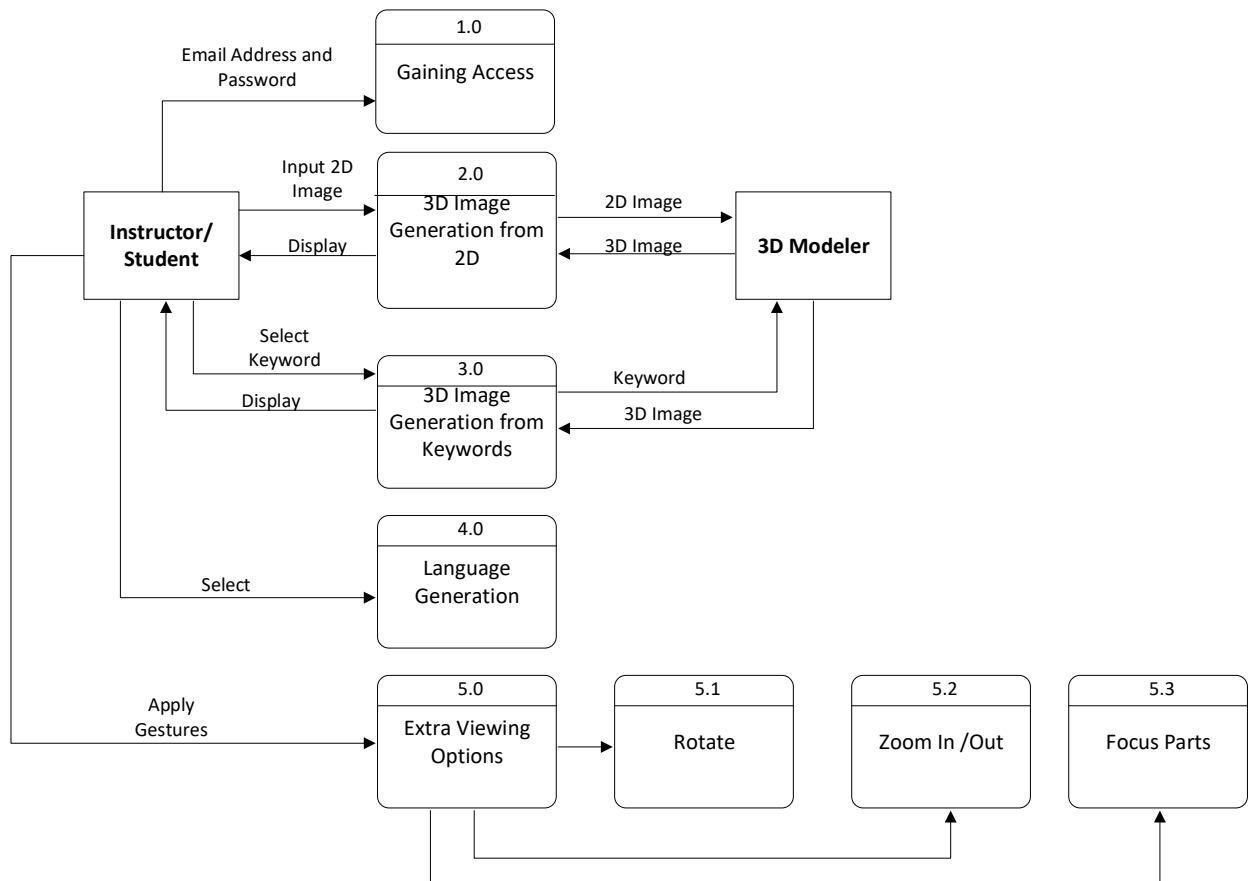


Figure 3.3 Data Flow Diagram

3.6 System Flowchart

The flow of the application can be understood from the flowchart in Figure 3.4. The user needs to enter his/her email address and password to gain access. Then the user needs to choose the option through which 3D image is going to be shown. The two options include viewing 3D image through 2D image from textbook and viewing the sample 3D image through entering keyword. The user can then have access to extra viewing options like rotation and zooming in/out. In case the user wants to view a new 3D model s/he will be taken to the initial options.

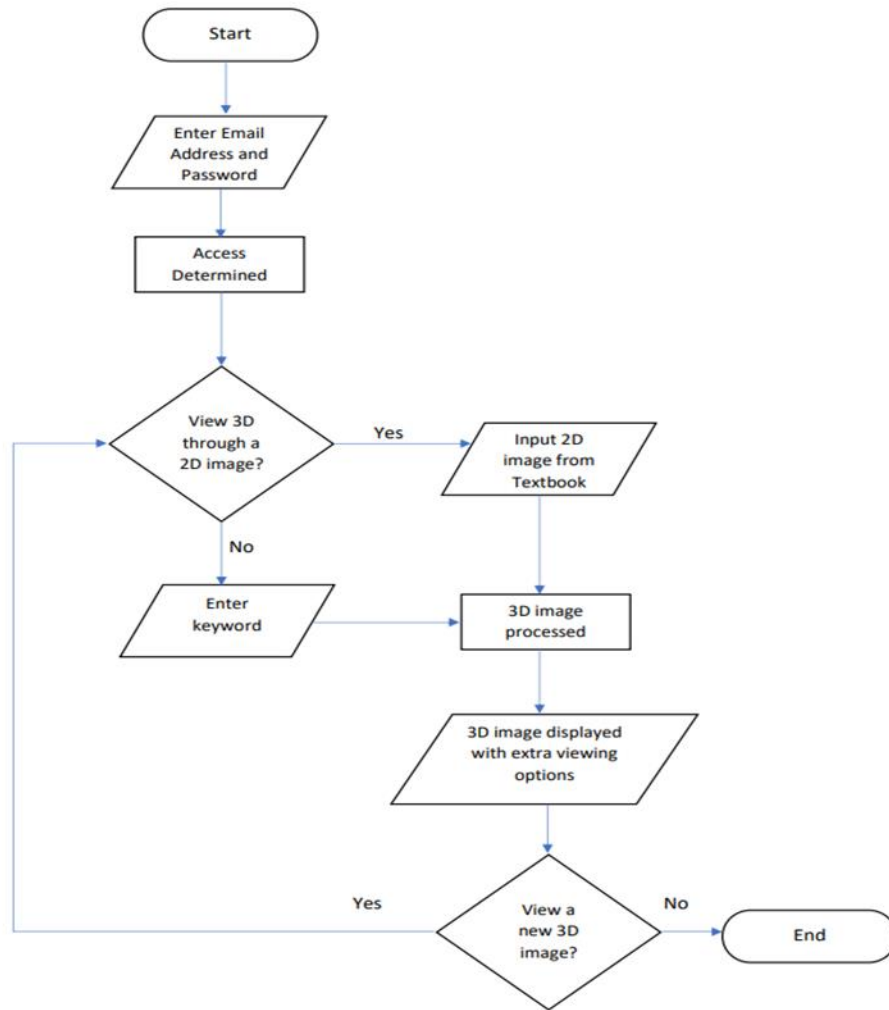


Figure 3.4 Flowchart of the application

3.7 Design Requirement

The entire AR based interactive educational tool is to be designed considering the convenience of its users. The system once constructed would let users to navigate into it, through some options which has simple terms for them to understand. The users will also have easy access to the extra workable features (rotation, zoom in/out) of 3D models through simple touch gestures on the smartphone screen. Overall, the system has been structured to make it as user-friendly as possible.

CHAPTER 4: DESIGN SPECIFICATION

4.1 Design

The entire main design of this application depends on the 3D models displayed with labels when camera is pointed at the respective target images/markers. This design has been implemented particularly for a heart 3D model. The pictures of how it looks on smartphone screen are shown in Figure 4.1 and Figure 4.2.



Figure 4.1 Halfway Front-End Design

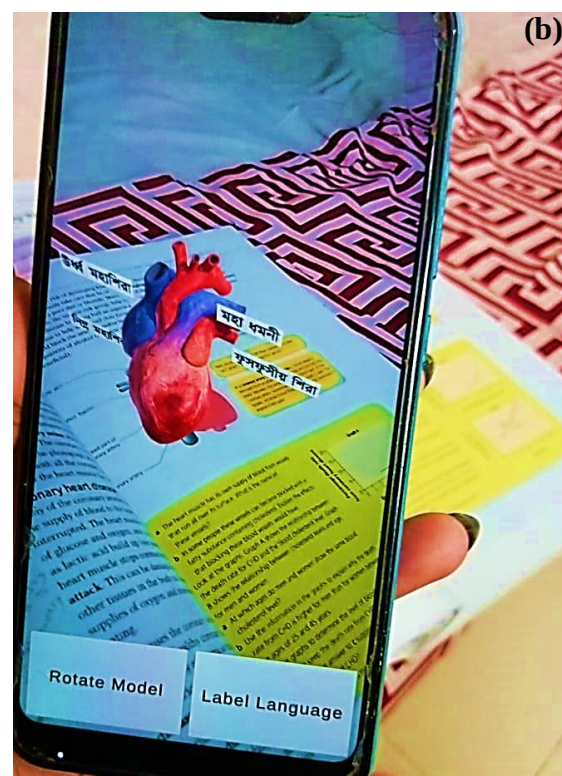
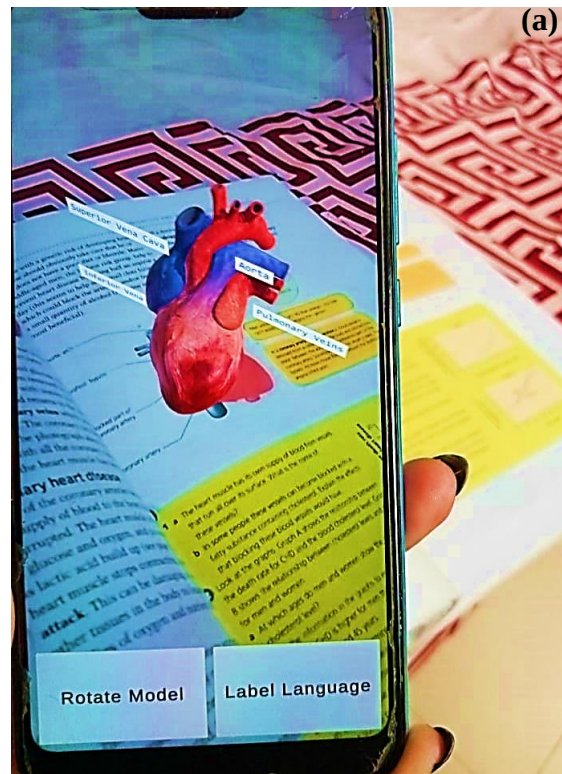


Figure 4.2 Complete Design showing (a) English labels on the 3D model, and (b) Bangla Labels on the 3D model

4.2 Interaction Design and User Experience (UX)

For the successful increased usage of this AR based application, the user interface should be designed in such a way which would be easy to operate and captivating for the users. The basic screen interfaces have been designed using Adobe XD and are shown in Figure 4.3. A name has been assigned to this application which is AR BioEd. The user needs to enter his/her email address and password, click on one of the options provided and then move ahead through the “Next” button. A help option is also provided in case the user encounters any difficulty.

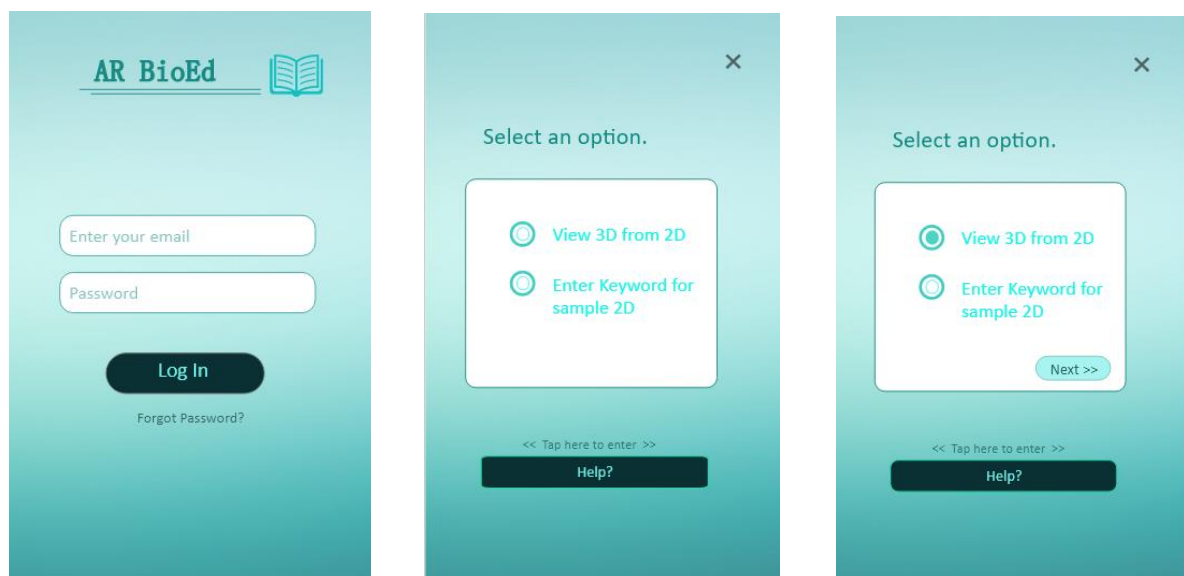


Figure 4.3 Screenshots of the User Interface Design

The initial main interface has been designed using halfway front-end implementation that is shown in Figure 4.4. In the user interface a 3D model of heart is displayed which would require the user to point the camera of smartphone on the textbook, containing the 2D image of heart. The image of heart is the marker needed to display the corresponding 3D model. The heart would also have throbbing effects to make it realistic. To go back to the previous options the user needs to tap on the button denoting “Tap here to go back”.



Figure 4.4 Main Interface Design without Labels and Extra Features on Smartphone Screen

The complete main interface has been designed using complete front-end implementation that are shown in Figure 4.5. The user can rotate the 3D heart model by simply clicking on the “Rotate Model” button and zoom in or out through applying pinch in pinch out touch gestures. The language available for the labels on the model are English and Bangla which can be switched anytime through single touch on the “Label Language” button.

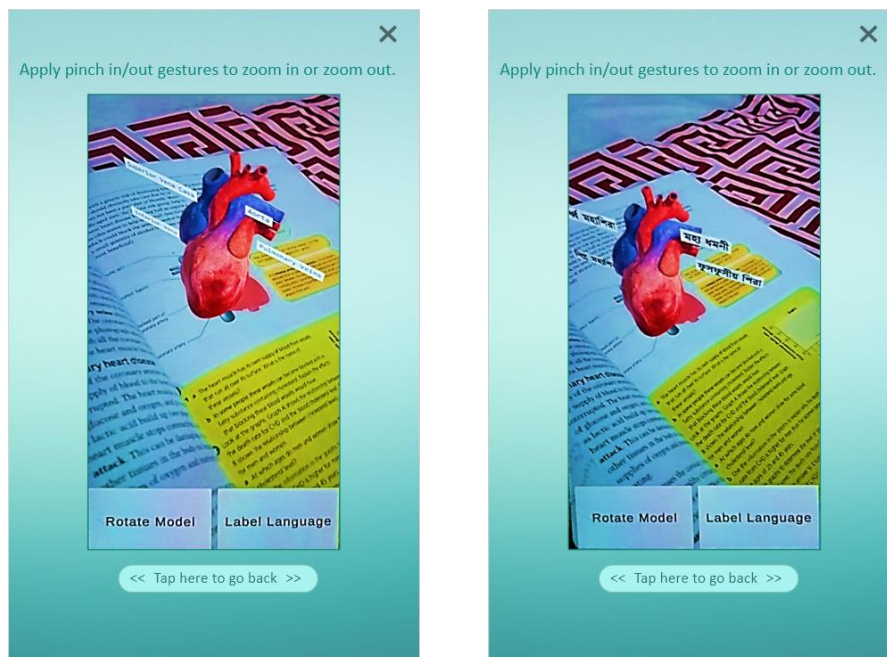


Figure 4.5 Complete Main Interface Design on Left: with English Labels and on Right: with Bangla Labels

The design of the interfaces gives us an overall idea of how the application might look once it is completely implemented. Further changes will be made in order to improve the system and adjust it with upcoming requirements.

4.3 Implementation Requirements

For implementing the AR based interactive educational tool, Unity 3D and Vuforia Engine are required. Unity 3D is a cross platform 3D engine and development environment which uses C# (C-sharp) programming language. This is going to act as the base of building the entire system. Vuforia Engine is a software development kit that would assist in augmenting the target images through detection. Additionally, the 3D models for specific images needs to be gathered through some external sources. Once the system is implemented, it should provide increased interactivity and smooth operations.

CHAPTER 5: IMPLEMENTATION AND TESTING

5.1 Implementation of Standalone Front-End System

This system has been implemented using a development engine known as Unity 3D. Unity 3D is highly used for creating AR based applications [18] [19]. The system also required some extra SDKs to be imported such as Vuforia Engine and Android Studio. Vuforia Engine helps detect the target images depending on which the particular animated 3D models can be shown. The target image, English labels and Bangla labels used were collected from some textbooks. The main work done while implementing this application can be understood through Figure 5.1 and Figure 5.2.

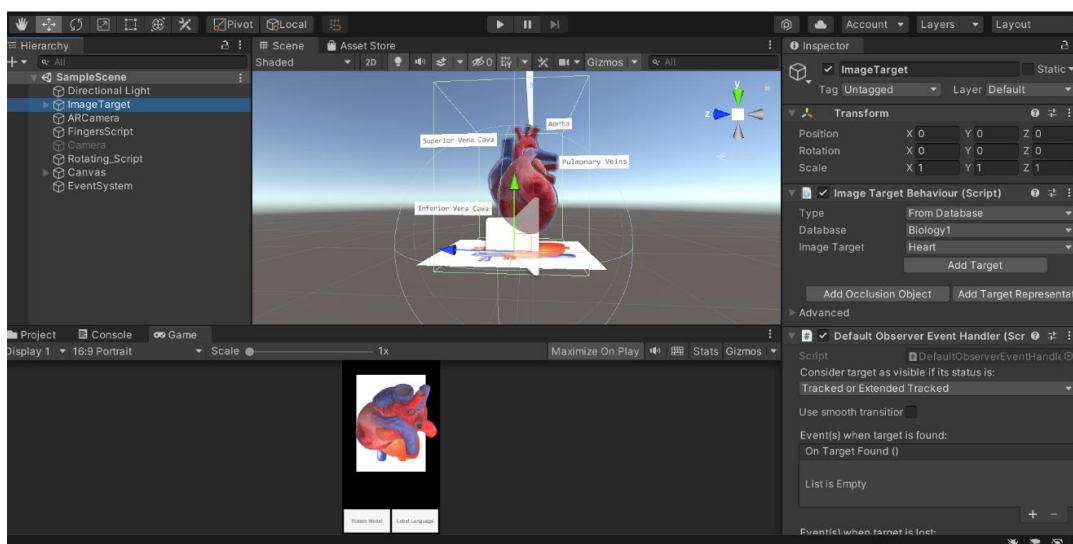


Figure 5.1 Screenshot of work done in Unity 3D

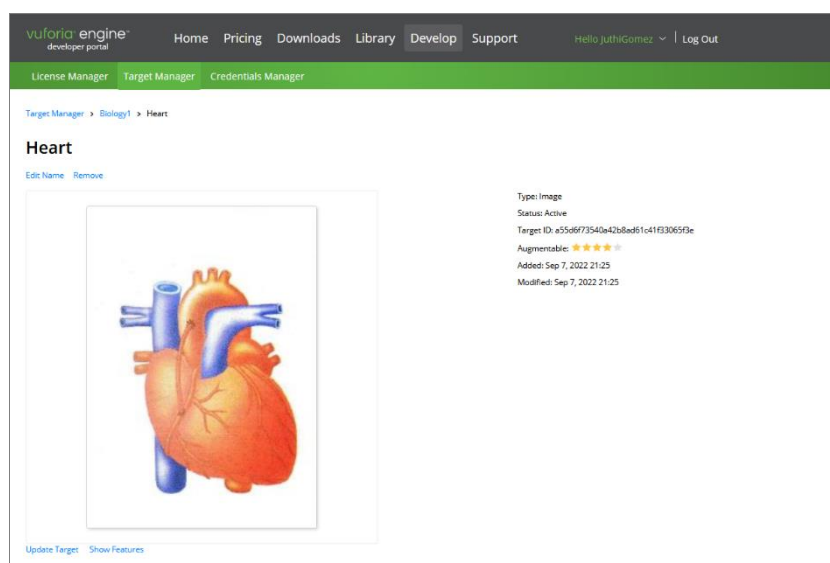


Figure 5.2 Target Image added to Vuforia Engine

The main work of viewing a 3D model has been done successfully. The English Labels are also added to the chosen model which can be switched to Bangla through a single click on the button named “Label Language” as shown in Figure 5.3. The model can be zoomed in and out just by applying pinch in and pinch out touch gestures using two fingers as shown in Figure 5.4. The model along with the labels can also be rotated 360° through a single click on the button named “Rotate Model” that can be seen in Figure 5.3. In addition, an audio of heart beat has been added to make it more realistic. The entire set up of the application can be understood through Figure 5.5. However, there is still a scope of improvement.

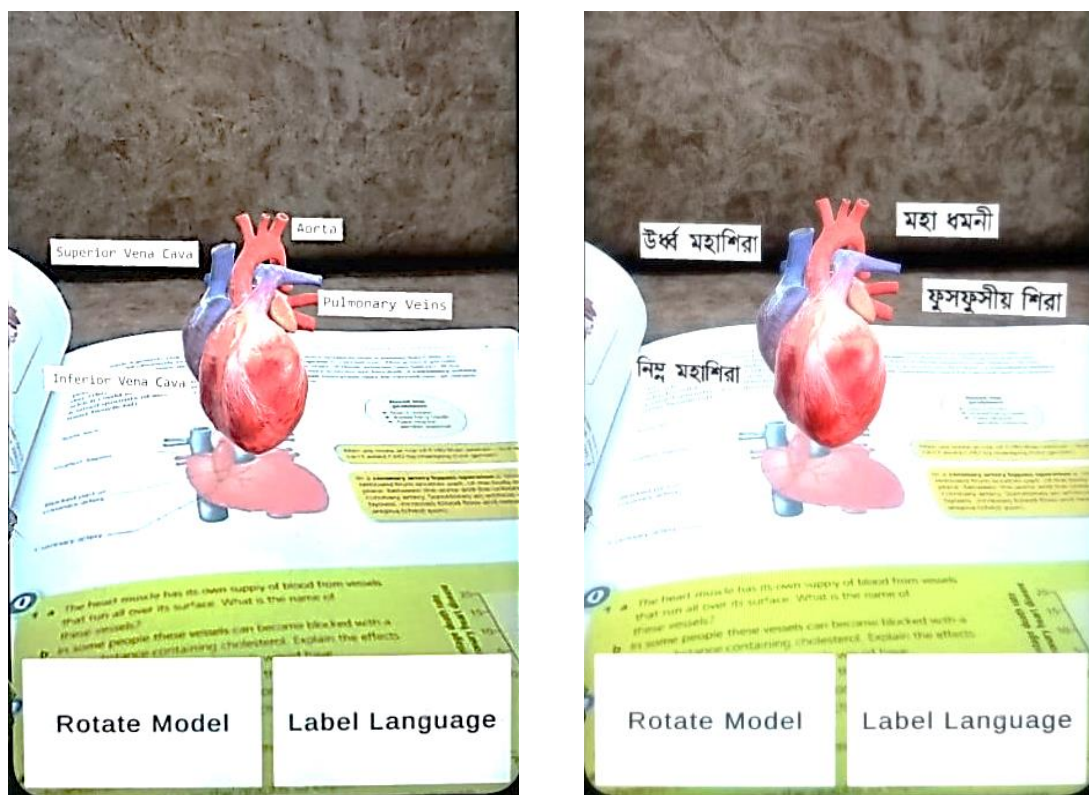


Figure 5.3 Screen View of Application with Left: English Labels, Right: Bangla Labels

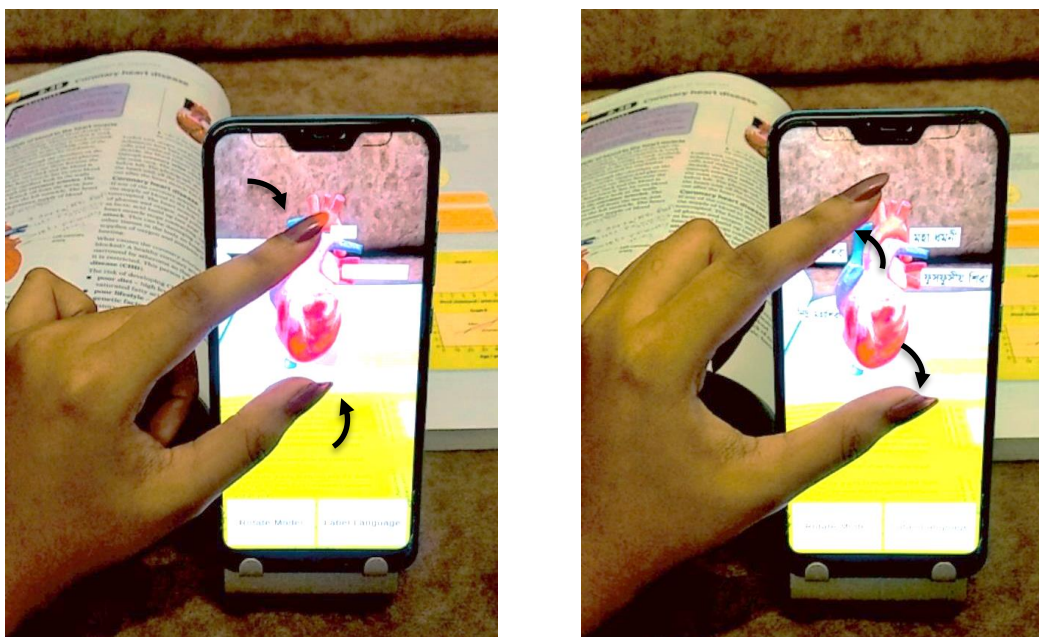


Figure 5.4 Images showing Left: scaling down to get zoomed out view and Right: scaling up to get zoomed in view, of the 3D model

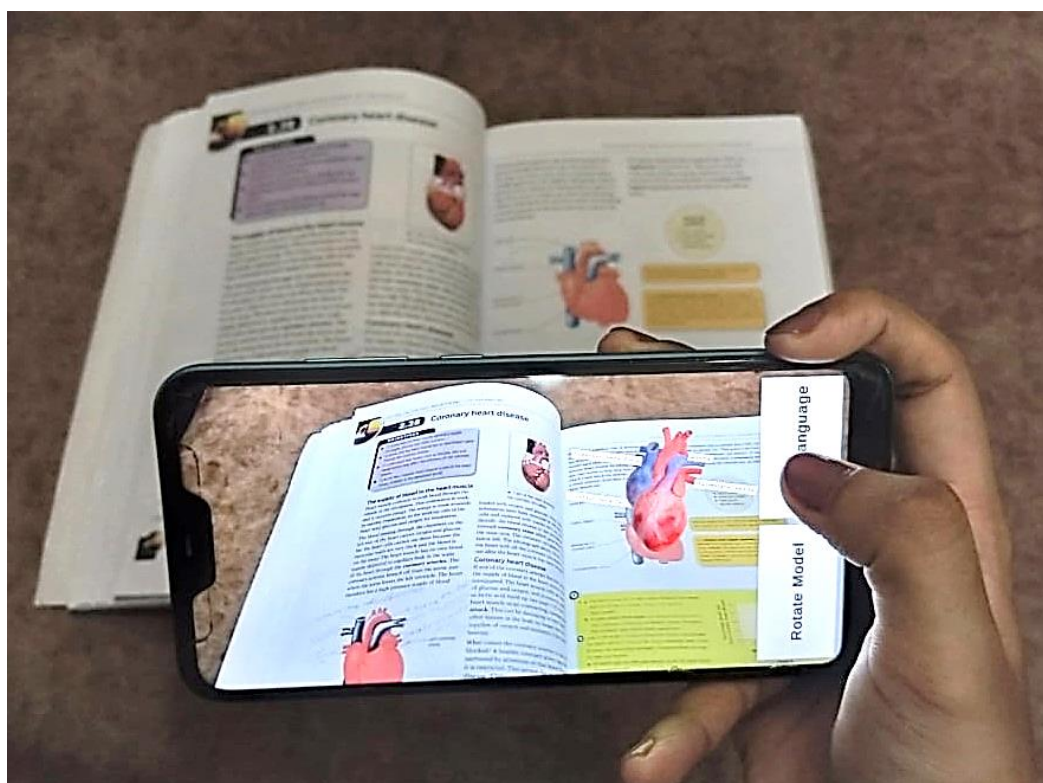


Figure 5.5 Application in Use

5.2 Test Cases

There is no particular type of testing that can be shown for this application, but the application was continuously being tested after each step which falls on a stage known as unit testing. In unit testing smallest parts of a system is tested like testing whether an input operation gives the expected outcome. For this educational tool, the three identifiable test cases that has been applied are shown in Table 5.1, Table 5.2 and Table 5.3. An extra feature which was tested includes the audio of heartbeat that worked properly.

Table 5.1 First Test Case

Test Case Identifier: TC-1			
Requirement Tested: REQ-4			
Pass/Fail Criteria: The test will pass if the 3D model can be rotated using a touch gesture. The test will fail if the 3D model does not rotate at all.			
Input Data: Touch Gesture			
Test Procedure	Expected Result	Problems Encountered	Resolving Procedure
Step 1: Apply a configured touch gesture.	- The system accepts the attempt and rotates the 3D model.	Configured slide left and right touch gesture with a single finger for rotation which did not work.	Added a button on UI for rotation and configured it for rotation on click.
Step 2: Apply other touch gestures.	- The 3D model does not rotate.		

Table 5.2 Second Test Case

Test Case Identifier: TC-2 Requirement Tested: REQ-5 Pass/Fail Criteria: The test will pass if the 3D model can be zoomed in and out using pinch in/pinch out gestures using two fingers on screen. The test will fail if the zoom in and out feature does not work. Input Data: Touch Gestures			
Test Procedure	Expected Result	Problems Encountered	Resolving Procedure
Step 1: Apply configured pinching in /out gesture. Step 2: Apply other touch gestures.	- The system allows to zoom in/out the 3D model. - The 3D model does not zoom in/out.	The configured option using a unity 3D package did not work properly.	A different unity 3D package was imported which let the 3D model zoom in and out using pinch in and out gestures.

Table 5.3 Third Test Case

Test Case Identifier: TC-3 Requirement Tested: REQ-7, REQ-8 Pass/Fail Criteria: The test will pass if the labels can be viewed in English at start and switched to Bangla through a single click. The test will fail if the labels do not appear properly. Input Data: Single click			
Test Procedure	Expected Result	Problems Encountered	Resolving Procedure
Step 1: Apply single click on a configured button. Step 2: Do not apply any gestures.	- The system allows to switch the language of labels from English to Bangla and vice versa. - The language of labels does not change.	No problems were encountered for this feature.	No resolving procedure was needed in this part since no problems were faced. The button for label language worked properly on the first attempt.

CHAPTER 6: IMPACT ON SOCIETY, ENVIRONMENT AND SUSTAINABILITY

6.1 Impact on Society

The AR based interactive tool for Life Sciences would help the students understand the concepts related to the subject matter, such as human body, even better. A study showed that visuals using augmented reality help students learn better [15]. To solve the problem of students losing interest by the traditional teaching methods, using AR as a new way to teach has been suggested based on the study [15]. Furthermore, understanding, internal organs of living beings closely is required for general practitioners and doctors to treat appropriately. Therefore, this application for life sciences, has the potential to work in favor of the society by educating future doctors or vets for ensuring good health.

6.2 Impact on Environment

When developing a system, it is highly important to consider the possible impact it is going to have on the environment. The impacts should mostly be positive. This AR based application is to be run on smartphones and this means no usage of extra papers. Therefore, there will be no negative impacts on the environment. The 3D models will be displayed based on the current textbooks which are used in classrooms. Additionally, usage of electricity will not be required in order to operate this system.

6.3 Ethical Aspects

This application's purpose is to reach as many students as possible for their own benefit. It is an education-based application and the users would gain access simply by entering an email address along with password. The users will not need to enter any other personal information thus avoiding exposure of personal data to unwanted sources. Moreover, the login system through email would be imposed to keep the captured 2D images safe from other unscrupulous sources.

6.4 Sustainability Plan

There are three basic criteria based on which the sustainability of applications is to be ensured. The proposed AR based interactive educational tool also has valid explanation to why and how it has the possibility to sustain in near future. The reasons for sustainability under the three criteria are precisely explained in Table 6.1.

Table 6.1 Sustainability Plan of the System

1. Community Sustainability	This educational application is going to benefit the educators and the students of Life Science directly. Therefore, their needs and convenience will be taken into consideration for the interface design. The application is also going to be a next step towards the SDG 4- Quality Education.
2. Financial Sustainability	There would not be much financial support needed in the continuation of this project except for maintenance and generation of 3D models. The finances will be raised for providing individual 3D models and animations particularly. The user has to only pay a certain amount for requesting a 3D generation from a 2D image they want to augment.
3. Organizational Sustainability	For long-term, the application has the potential to be utilized for other subjects as well thus increasing the size of the association. Moreover, financial support can be gained through external sources too such as some educational institutions willing to collaborate.

CHAPTER 7: CONCLUSION AND FUTURE SCOPE

7.1 Discussion and Conclusion

The AR based interactive educational tool has been designed for helping the learners and instructors of the subject matter Life Sciences. The requirements and functionalities of this proposed project can be clearly understood from the details provided in the previous sections. On successful execution of this project, lower secondary students will be able to feel much more interested in Life Sciences or Biology thus resulting in better performance in their future endeavors. As discussed earlier, visuals help students learn better which this system attempts to provide. Furthermore, it will make it convenient for the instructors as well to explain the fundamental concepts of the subject matter. Overall, the project will be beneficial and easily accessible due to it being at reach through commonly used smartphones.

7.2 Scope for Further Development

There are great scopes for this project once the basic is executed as intended. The current implementation has been done for the particular subject Life Sciences. The labels are also there on the 3D models that can be switched to Bangla through just a simple touch. This means that the application can be used by both the English medium and Bangla medium students. However, in future the application can be extended for other subject matters as well such as Mathematics and Physics. Therefore, it can reach maximum students and increase the usage of this application.

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