3D Model Based Interactive Application for Elementary Education

By

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A thesis submitted to the Department of Computer Science and Engineering in partial fulfillment of the requirements for the degree of
Master of Science in Computer Science and Engineering

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Declaration

It is hereby declared that

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2. The thesis does not contain material previously published or written by a third party, except where this is appropriately cited through full and accurate referencing.
3. The thesis does not contain material which has been accepted, or submitted, for any other degree or diploma at a university or other institution.
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Approval

The thesis/project titled "3D Model Based Interactive Application for Elementary Education" submitted by

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of Summer, 2019 has been accepted as satisfactory in partial fulfillment of the requirement for the degree of Master of Science in Computer Science and Engineering on 19th of August,2019.

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Abstract

This thesis demonstrates a 3d model based interactive application which has been initially deployed for android platform and functions on the basis of augmented reality technology targeting the sector of Bangla language based elementary education. The development of this model includes an extreme level of engineering particularly focusing on polygon and vertex count while developing 3d assets in virtual environment. As this model is based on augmented reality technology, real-world triggering has a huge impact on it and the preparation of these triggers were a crucial part of this scientific endeavor. To validate the performance of this model we have tested it in five different environments based on three core matrix and figured out that this kinds of models are a great fit for students aged from 4 to 5 years old along with a staggering returning rate of 56 times on an average within 3 days. Our study also shows that the learning rate of male students are relatively faster than female students by 3.08% when they are using our proposed model as a medium of learning.

Keywords: Augmented Reality for Education, Solid Surface 3D Modeling, Alphabetic Interaction, Mobile Application, Bengali Language Learning, Elementary Learning Application.

Dedication

To my brother Anindya Ghosh,

Around whom I always feel energized and compassionate about my works.

Acknowledgement

First of all I would like to express my utmost gratitude to the Almighty for giving me the strength and determination to complete this research successfully.

I would also like to appreciate all those kind souls who made this research possible with their consistent support, inspiration, criticism and good wishes.

I am literally in short of words to thank my honorable supervisor Dr. Jia Uddin, Associate Professor, Department of Computer Science and Engineering, BRAC University- for his relentless support to the entire process of this project. Without his continuous supervision and constant mentorship, a thesis of this magnitude would never be completed.

I can never thank my parents and younger brother enough for their dedication, inspiration and belief in my capabilities. Without their presence, nothing would come to light indeed.

Finally, I want to say a special thanks to BRAC University for enabling me to conduct this research and providing me the right support and tools to do so.

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List of Acronyms

3D	Three Dimensional
2D	Two Dimensional
AR	Augmented Reality
VR	Virtual Reality
UI	User Interface

Chapter 1

Introduction

Education is a fundamental right for every human being and language has been regarded as the most rudimentary medium to spread education for thousands of years. Human enters into the process of education right from childhood. In this particular state of human life, mother tongue is the best way of acquisition. Particularly focusing on Bangladesh where Bangla is regarded as the first language, a child starts his/her learning through the Bengali alphabet. Bangla is a vast language having a large heritage and history of thousand years. This language is decorated with 50 letters combining 11 vowels and 39 consonants. In the very first year of a kid's school life, these 50 letters are considered to be his/her first learning. And in school even on today's date a very traditional approach is followed to teach kids which generally include a writing board, chalk/marker, a book, writing paper and pencil.

Right now we are living in an era of scientific evolution and we have access to technologies like- augmented reality (AR), virtual reality (VR) and 3D through computer science. We can bring benefits for our elementary education sector by the help of these cutting edge technologies as the developed countries are doing. If we take a closer look at English language, many high-tech mobile applications have deployed in last decade and they are bringing significant changes in the process of a kid's acquisition. But focusing on Bangla language based elementary learning, we have a very limited options to pick. Many group of enthusiasts have started working on this sector right now but there are no significant breakthroughs yet. For instance we can pick three applications in a row- Bangla Kids Learning App [1] published by Urva Apps, হাতেখড়ি (Bangla Alphabet) [5] published by shurjoMukhi Limited and Kids Learn Bangla Alphabet [6] published by TopofStack Software Ltd. All these three applications are deployed in android platform targeting the sector of

elementary education. But they all are basically 2D image based application where tapping the next button just changes the existing image on the screen. This approach has not that much difference with the traditional system. Here the only addition is- it is experienced on a smart phone. Important to note that there is no studies yet which suggests the effectiveness of this kind of application.

To overcome this challenge, we propose an android based augmented reality application which is very interactive in nature. Here the printed triggers are providing the support of regular books and the main attraction stays inside the application where the user places the triggers to get input through device camera and acquires the access to explore 3D alphabet in the fashion of augmented reality technology. This application is designed in a very user friendly and simple way such that the target group (kids) does not face any problem to interact with it. And most importantly, we have tested the effectiveness of our proposed model in five different environments with different age groups and genders. So we can strongly suggest the effectiveness of this model based on concrete evidence.

1.1 Objectives

At this part of the thesis we would like to mention our core objectives as bullet points which will reveal the significance of our work-

- To develop the 3D models of all 50 Bangla alphabet (including vowel and consonants) and the process of this development should cover an intensive level of engineering as they need to be created manually keeping the core concepts of 3D modeling in mind, that are – vertex count, polygon count and edge count.
- To reveal the detailed count of vertex, polygon and edge that are required to create the 3D models of all Bangla alphabet. And also to create printed triggers that are track-

able by the deployed application and have the ability to show 3D Bangla alphabet on top of it.

- To deploy an augmented reality based android application anchored on developed 3D models which should be in functional state and have to perform great in real-world context.
- To move at least in five different real-world environments with the developed application to justify the effectiveness. On those real world environments, the impact of our model should be measured on different age groups by doing age-based clustering. Our objective also involves the measurement of engagement of users with our work. Lastly to document the impact of our contribution on different gender groups. To be mentioned, the objective of real-world assessment included a total of 98 student whose necessary information and our findings are mentioned in this thesis in details.

1.2 Thesis Outline

The rest of the thesis is well organized to demystify the entire process of implementing our work and portray the findings. Chapter 02 outlines the previous works in the field of elementary education, 3D technology and AR technology. Chapter 03 elaborately describes the proposed model. Chapter 04 demonstrates the experimental results that we have found based on our developed works. Lastly, Chapter 05 concludes the paper.

Chapter 2

Background Study

Every aspect of education is now continuously being modernized by the magical touch of advanced computing technologies. Elementary education is not an exception. People now a days have access to a computer or at least a smart phone which is also a powerful computer indeed. As the overall count of smart phone user is much higher than regular computers particularly in Bangladesh, targeting this particular segment to propose a new model of elementary education based on Bangla language is more logical. It should be mentioned that numerous researches have done on this segment based on emerging technologies. For instance, previous researches on 3D as a medium of strong multimedia tool have focused on many important aspects. Research on classification of 3D models has already done for 3D animation environments [2]. Specific 3D tool based research for film and television [3, 12], rapid 3D human modeling and animation based on sketch and motion database [4], real water simulation for 3D animation [7] - researches on all those areas have done. Even researches on- emotion based facial animation [8, 35], real-time speech driven facial animation using neural network [9], 3D measurement technologies for computer animation [10], 3D cartoon character animation engine [11] have come up with new findings. The area of interactive 3D animation system [13] and experimental teaching of 3D animation [14] have also explored.

In continuation of the aforesaid discussion, our contribution on the augmented reality application is equally unique having the potential of an excellent research work. The sector of multimedia is a very dynamic field which is becoming enriched by the continuous evolution of technologies like- Augmented Reality (AR). Though it seems like AR is a very fresh and new technology, the beginning can be traced back to the year 1968. At that period Ivan Sutherland developed the very first head-mounted display system. Later on this emerging technology included applications in virtual fixtures for the Air Force and enhanced visual

navigation tests for NASA. However until the year of 1990, the term AR was not matured and Boeing researcher Tom Caudell brought it into action. In the early of 2000s, AR and internet finally joined forces but there was no significant breakthrough until 2009. When the smartphone revolution started to boost from 2009, the interest in AR began to explode [29].

Like many other sectors, AR has made a huge impact on education. In today's world of engineering education- AR based lab system exists which enables teachers and students to work remotely via internet/intranet in current classroom labs, including virtual elements which is capable to interact with real ones [30]. Impact of AR is clearly visible in the sector of medical education as well where training in real-life context is not always possible due to safety, costs and many other factors. In those cases, AR can potentially offer a highly realistic suited learning experience supportive to complex medical learning and transfer [31]. Apart from engineering and medical education, AR is also putting its bold footprint in skill based trainings [32].At present AR is not only conquering the different domains of higher education where the target group is adults [26] but also knocking the door of elementary education. Researchers have begun to study AR for teaching colors and shapes to kids [20]. AR as a technology of elementary education- most of the previous studies targeted languages like English [24], Japanese [25], Kanji [27]. Another notable thing is most of the previous works are tightly coupled with internet connectivity. Majority of them requires internet connection during runtime [28] which sometimes come out as a big issue particularly for those places where internet connection is not available or worst case scenarios like natural disasters. Previous researches on AR as a medium of learning also did not pull out the importance of Bengali language. They had serious lack of necessary details in the modeling process of Bangla alphabet [33], and mainly focused on supplementary elements [34]. Bangla alphabet were largely represented in the form of 2D images.

To overcome those limitations our proposed model of an Android based AR app makes a significant number of contributions. Firstly, we are focusing on Bengali language so that the young learners who are the native speaker of this language are getting the opportunity to have a smart learning aid at their fingertips. This application can also be a great help for those learners who are not native speaker of Bengali. Secondly, our developed work does not require internet connection during operation so that this application can run effectively in those places where high speed internet connection is not available. Thirdly, we are adding a new dimension in the way of teaching kids in comparison with the traditional teaching approach where they can experience the Bangla alphabet in 3D. When a kid can perceive a letter at its fullest extent, acquisition is simply a joyful consequence and undoubtedly it is an effortless approach of learning. To be mentioned, our proposed model does not use VR technology and this is because- VR based applications require gadgets like google card board or VR box. And it is troublesome for those users who use spectacles. Our final notable contribution is we have done real-world experiments that suggest the effectiveness of our proposed model which makes our effort significantly different from others.

Next chapter of this thesis will elaborately discuss about the system implementation and detailed workflow of our proposed model.

Chapter 3

System Implementation and Workflow

Figure 3.1 represents a block diagram which indicates different stages that were involved in the implementation of our proposed learning application for elementary learners. As we can see, there are six major steps involved in this system implementation process. Every one of them are describe in details as sub-section of this chapter.

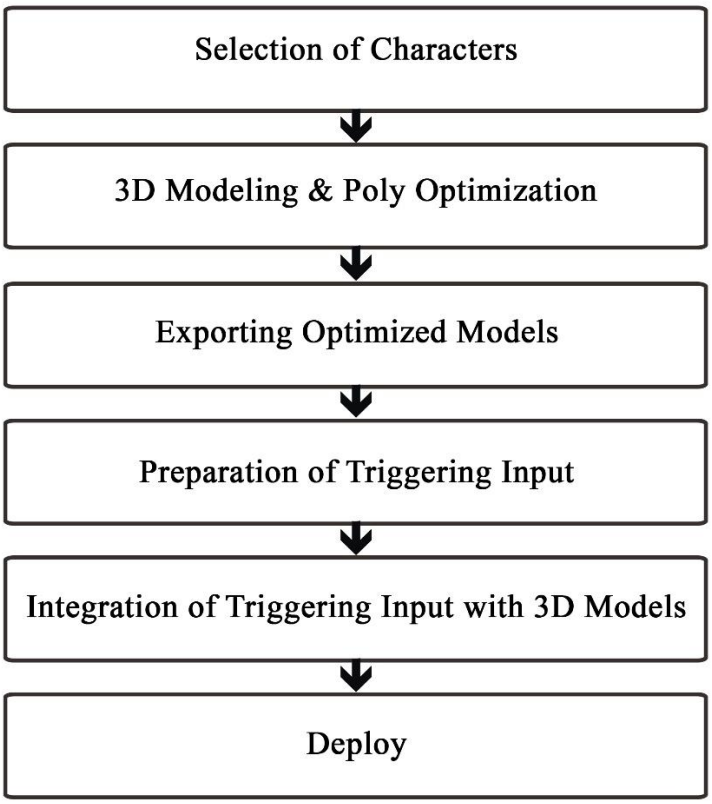

Figure 3.1: Different Stages of Implementing the Proposed Learning Model

3.1 Selection of Alphabet

As we know Bengali language has vowel and consonant just like any other languages. Our determination was to make a one stop solution. So at this stage we decided to include both vowels and consonants in our project. Thus we ended up with the inclusion of 50 letters in our project at this stage.

3.2 3D Modeling and Ploy Optimization

As our intention was to integrate 3D letters with our learning application, so we had to perform some modeling tasks. Here creating the 3d models of Bengali alphabet were the major concern. Inside the virtual environment we created the line art of every single letter. Later on we converted them to poly objects. At that point there was no depth on those letters. So we had to apply “Shell” modifier on them just to make them a proper three dimensional model as demonstrated in Figure 3.2. The process ends up with the conversion of those shapes into poly objects.

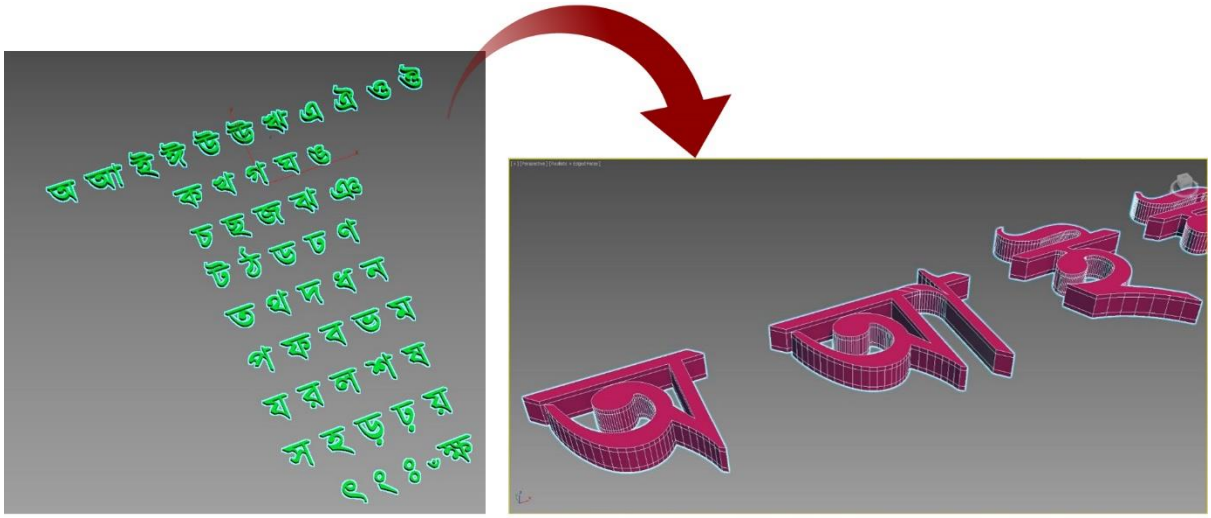

Figure 3.2: Bengali Letters Getting Their 3D Shape

Being poly objects, all the letters that we created for our learning application had three crucial parameters. These parameters are – edge, vertex and polygon. Table 3.1 shows the polygon count and vertex count for every single Bengali letter that we modeled for the implementation of our learning application. These two parameters are very easy to figure out inside the virtual 3D environment of almost any 3D development tool. But our Table has an additional column in it that shows the edge count of every single 3D letter. And this is a unique contribution of our thesis indeed as the edge count of 3D models (of Bangla alphabet) have not been revealed

by any enthusiasts or researchers so far even though this value has crucial impact on the development of any 3D model. So we would like to mention the process of how we figured out this edge count.

We applied Euler's Polyhedron formula at this stage. But before diving into that formula, it would be great to explore the core concepts of polyhedron a bit more. Polyhedron is basically a solid object and a handful of flat faces make the surface of it. Those flat faces are bordered or surrounded by straight lines. In a closer look each face turns out to be a polygon. Those polygons are closed shapes in 2D plane formed by points and connected by straight lines.

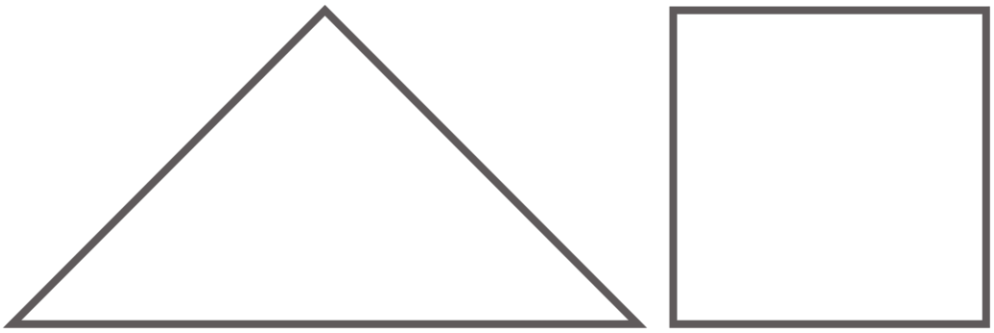

Figure 3.3: Illustration of Polygonal Shapes

Under any circumstances polygons can never have holes in them as illustrated in Figure 3.4. Here the left-hand shape has every reasons to be claimed as a polygon while the right hand shape is not, as a hole exists in it.

In a state where all the sides are of same length and their in between angles are also equal, we can refer a polygon as regular. The triangle and square stated in Figure 3.3 replicates regular polygons. A regular polygon many have shapes other than triangle or square, for instance- the shape of a pentagon or hexagon or any ideal form of n-gon are also valid.

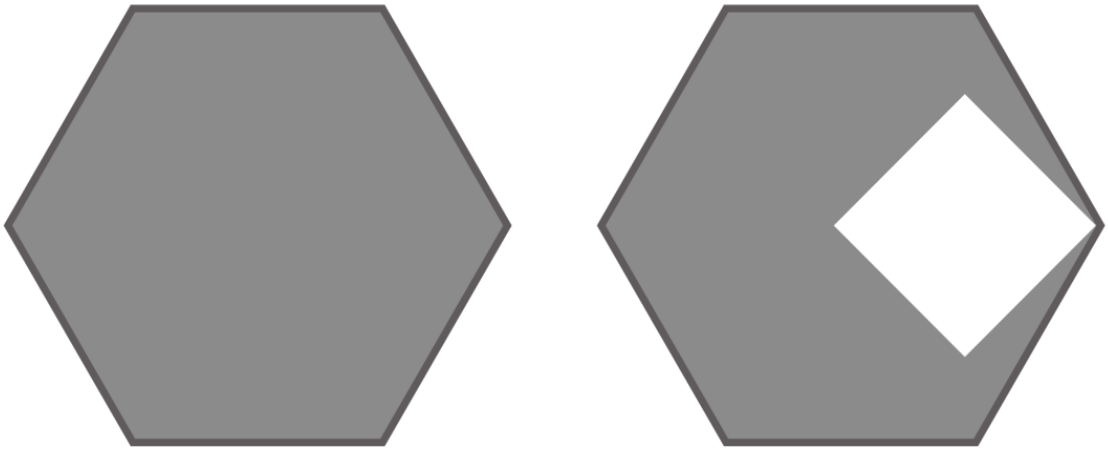

Figure 3.4: Illustration of Hole on Polygonal Surface

From those 2D shapes if we move one dimension up then we will end up finding a polyhedron. An ideal polyhedron is absolutely closed and its surface is formed by a number of polygonal faces. Important to mention that polyhedron is solid in nature. In the context of polyhedron- the sides of polygonal faces are identified as edges while vertices are the corners of a poly-face. Thus, when two faces meet along, any vertex lies on at least three different faces. Figure 3.5 illustrates this discussion by the help of a very well-known polyhedron.

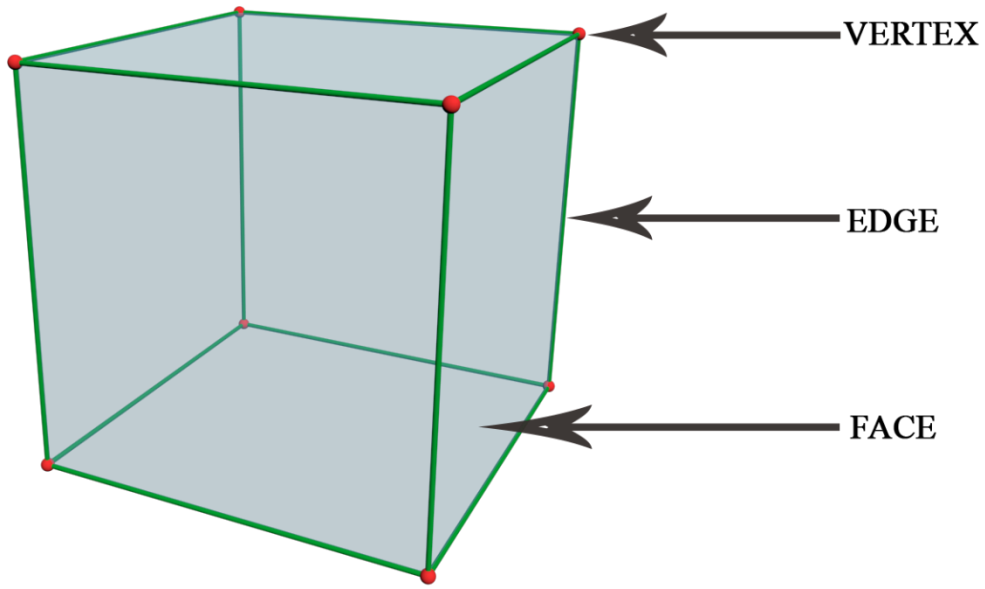

Figure 3.5: Pointing Vertex, Edge and Faceon a Cubic Polyhedron.

A polyhedron should always have to be in one piece. For instance, two or more individual parts linked by only an edge or a vertex cannot build it. This means the shape stated in Figure 3.6 is not a polyhedron even though two separate shapes are connected by edges.

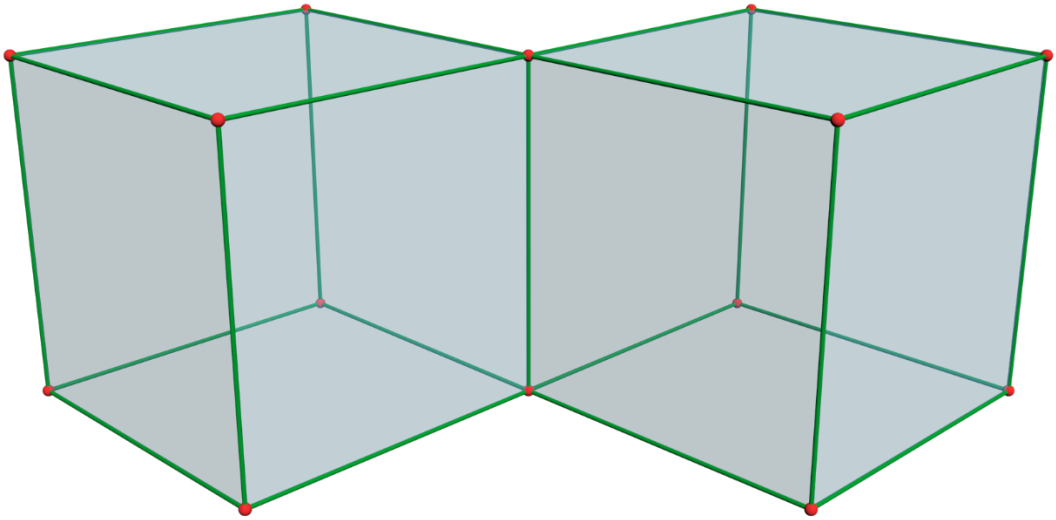

Figure 3.6: Illustration of Not Forming a Polyhedron Even After Edge Connection

For the exact same reason mentioned earlier, the shape in Figure 3.7 is also not a polyhedron even after having vertex connection.

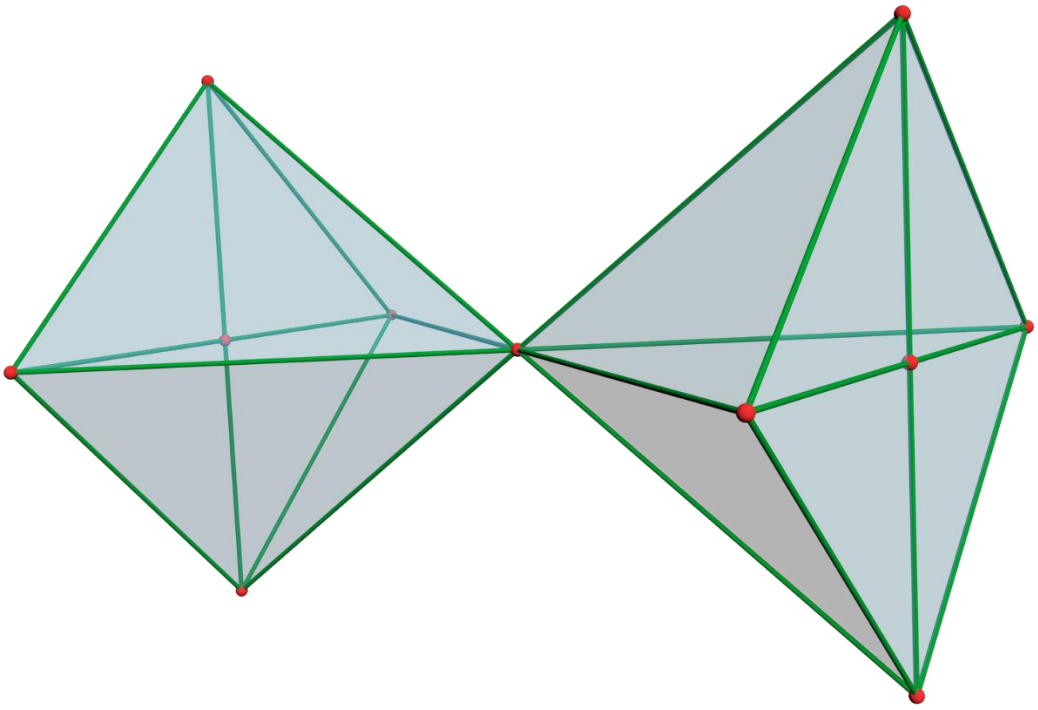

Figure 3.7: Illustration of Not Forming a Polyhedron Even After Vertex Connection

After all these discussion, now we are ready to integrated Euler's formula with our work. Let us consider the polyhedron stated in Figure 3.5 which is a cube. This cube has 8 vertices and variable V holds this value. On the other hand it has 12 edges and variable E holds this value. Lastly variable F holds the number of faces. For the case of cube it has 6 faces. Euler formula suggests that,

$$V - E + F = 2$$

If we articulate this, the number of vertices minus the number of edges plus the number of face is equal to two. Getting back to our example here we have-

$$V = 8\,;\; E = 12\,;\; F = 6$$

Following Euler's Formula,

$$V - E + F = 2$$
$$\Rightarrow 8 - 12 + 6 = 2$$
$$\Rightarrow 14 - 12 = 2$$
$$\therefore 2 = 2$$

And the result is totally as expected. Now if we see closely at the equation, we already have two values in our hand- Vertex and Face, and we need the value of Edge. So if we simple plot the values of V and F for every 3D alphabet we inevitable end up by getting the value of E that is the edge count. And that is exactly what we did to calculate the edge count for every alphabet. If a 3D modeler knows all these three values, it certainly would be a great help to get an idea to predict the formation of a particular 3D model.

We would like to mention that many groups of enthusiasts have done the 3D modeling of alphabet from many languages including Bangla. But none of them have ever published the entire polygon, vertex and edge count of the alphabet. Unlike them we have published the detailed count of each Bengali letter so that the future researchers in this particular sector can take this finding as a start.

Table 3.1: Polygon and Vertex Count during the Formation of Every Single 3D Letter

Serial No.	Name of 3D Model	Vertex Count (V)	Poly-face Count (F)	Edge Count (E = V + F - 2)
1	অ	544	274	816
2	আ	772	390	1160
3	ই	1080	542	1620
4	ঈ	1212	608	1818
5	উ	1168	586	1752
6	ঊ	1156	580	1734
7	ঋ	624	314	936
8	এ	800	402	1200
9	ঐ	1120	562	1680
10	ও	900	452	1350
11	ঔ	1140	572	1710
12	ক	556	280	834
13	খ	628	316	942
14	গ	632	318	948
15	ঘ	468	236	702
16	ঙ	888	446	1332
17	চ	400	202	600
18	ছ	768	386	1152
19	জ	1132	568	1698

20	ঝ	352	178	528
21	ঞ	1512	758	2268
22	ট	876	440	1314
23	ঠ	732	368	1098
24	ড	512	258	768
25	ঢ	452	228	678
26	ণ	676	340	1014
27	ত	580	294	872
28	থ	684	344	1026
29	দ	324	164	486
30	ধ	512	258	768
31	ন	288	146	432
32	প	664	334	996
33	ফ	656	330	984
34	ব	208	106	312
35	ভ	672	340	1010
36	ম	544	274	816
37	য	316	160	474
38	র	432	220	650
39	ল	744	374	1116
40	শ	712	358	1068
41	ষ	312	158	468

42	স	576	290	864
43	হ	708	356	1062
44	ড়	680	344	1022
45	ঢ়	592	300	890
46	য়	564	286	848
47	ৎ	656	330	984
48	ং	512	260	770
49	ঃ	840	424	1262
50	ঁ	428	218	644

3.3 Exporting Optimized 3D Models

In order to use the 3d models created in virtual environment to any game engine, it was important to export them in a perfect format and settings. Otherwise the topology and textures may get highly affected during the transformation of working environments. As a result we were looking for a file format which was able to maximize creative potential and optimize productivity with simple interoperability workflows between certain software tools and transfer custom data between applications which are commonly used in film production, game development, and advertising purposes.So, the best format in this case was ".fbx".The short form ".fbx" came from the word 'Filmbox". FBX allowed us to seamlessly exchange digital assets with the immediate next tool of our production pipelines.Adding FBX to our pipeline gained the flexibility to open, manipulate, and export custom data to meet the needs of our production.We selected each 3d model and exported the object in .fbx format. In this process, an important option "Embed Media" should always be checked in Autodesk 3ds max

during the exporting process which is shown in Figure 3.8. Otherwise the model will miss the material when imported in the game engine.

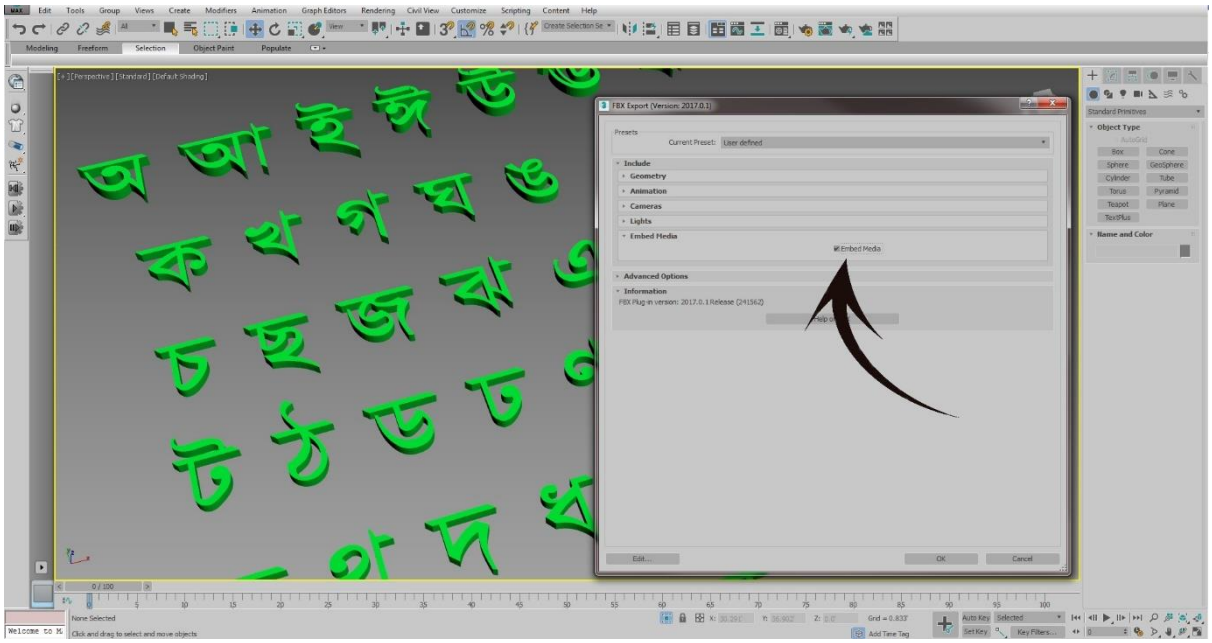

Figure 3.8: Exporting 3D Models by Enabling "Embed Media".

3.4 Preparation of Triggering Input

Figure 3.9: Sample of Triggers That Can Interact with Proposed Model

As we are proposing an augmented reality based mobile application, trigger plays a vital role here. Augmented reality based applications can support many types of triggers but

particularly for this model we focused on printed triggers. We planned the entire model in a way such that the triggers itself can be a learning aid. So, all the Bangla letters were printed on a checkered background as shown in Figure 3.9. But printing the triggers was not enough because they were not ready to interact. That's way we took the help of Vuforia which is a 3rd party tool for Unity. We feed soft imagery version of all triggers in Vuforia and created a database which was possible to download and integrate with Unity as stated in Figure 3.10.

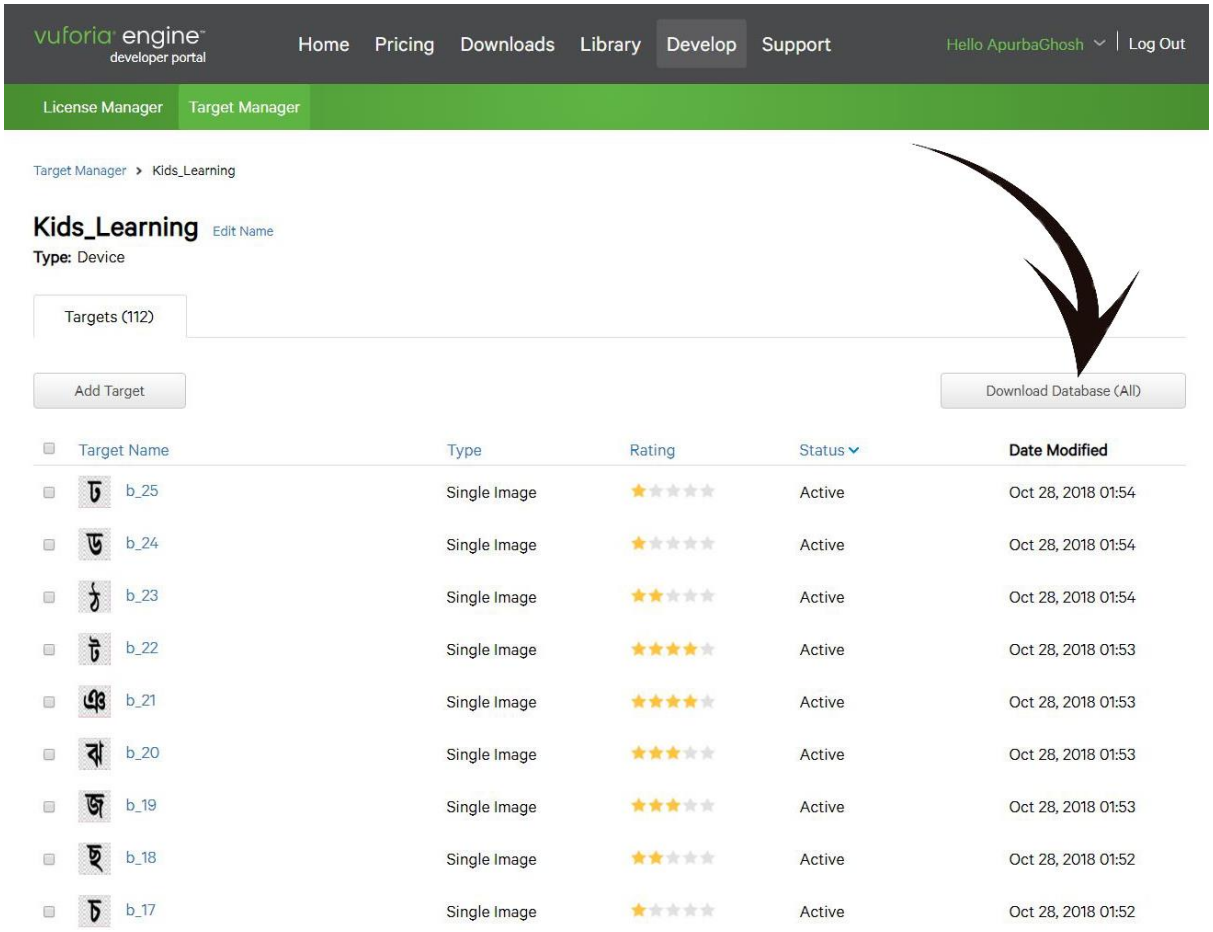

Figure 3.10: Triggering Symbols inside Vuforia which are ready to download in the Form of a Database

To be mentioned, Vuforia generated triggering database as a Unity package file which contains all 50 Bangla letters including vowels and consonants. This package file basically works as a placeholder for 3D models which results the graphical output on the basis of triggering inputs.

3.5 Integration of Triggering Input with 3D Models

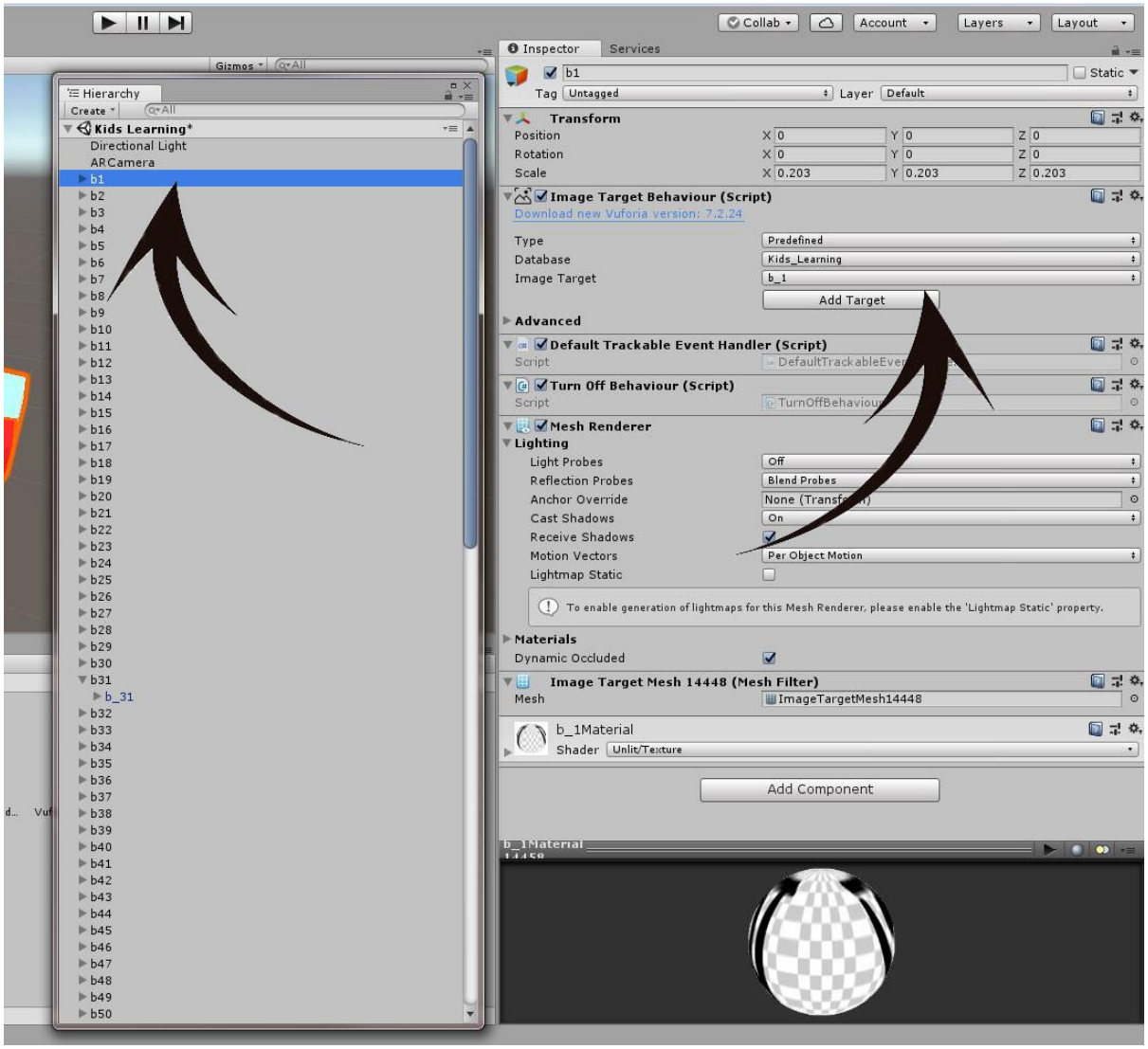

Figure 3.11: Image Targets Are Being Selected for Associated 3D Models

Up to this stage, we have two major components of our proposed model ready –3D models and triggering database. Now it is the time to integrate these two. So what we did here is basically created a scene in Unity and enabled AR camera. Then we imported all the 3D Bangla letters which act as the main asset of our proposed model. These key components will be displayed after the deployment of the application. Later on we opened the triggering database which was made by the help of Vuforia. The database is named as “Kids Learning” and we can see it in opening state at Figure 3.11. This figure also shows that image targets are

being selected individually for every single 3D output and this is the main operation to integrate triggers and 3D models.

3.6 Deploy

Following the process that has stated so far in this thesis, our application was ready with all functionalities. But the fact is we still needed to play and run this inside game engine. So, it was not ready for audience.

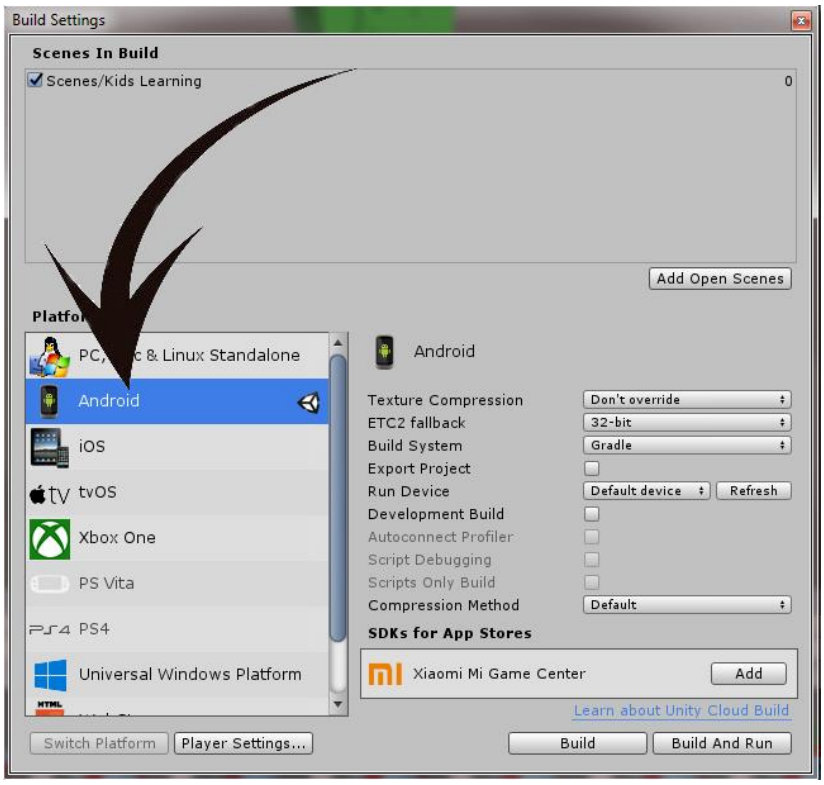

Figure 3.12: Build Settings Window where Android is Being Selected

In order to build an .apk file which could run successfully on android based devices, we need to work on "Build Settings" as shown in Figure 3.12.In the "Build Settings" option, we wanted to have "Android" platform enabled. So we had to install android sdk prior to the deploy process. Here in "Build Settings" there are many important settings. We can change the name of the app, company name, versions, and preferred devices, logo of the application, cutscenes and all other necessaries. Inside the build settings, we had to arrange our scenes according to order.To be noted without building the scenes in serial, the application won't be

deployed properly as useable .apk file. In the case of working with the file in other workstations, we found it useful to have the project settings folder always with the exported package. In order to use the same work files in other computer, we needed to open a new project and import the custom package in that new project. The “Project settings” folder was replaced by the previous saved project settings folder. Thus all tiny details were reloaded. Otherwise, it’s very common to have errors, which are almost impossible to solve without creating that part from scratch.

3.7 Workflow

Figure 3.13 demonstrates the system architecture of our android based augmented reality application.

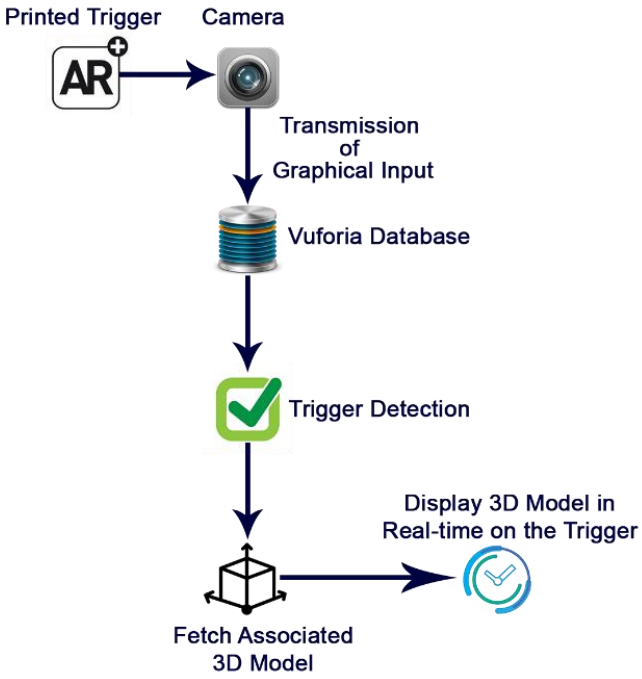

Figure 3.13: System Architecture of the application

In the multi segmented model of this application, AR triggers will be printed in paper at first. To be mentioned the triggers can be painted on different types of surfaces as well but the necessary thing is, pattern should be same as they are stored in the database. Otherwise, the match will not be established. The device camera will be enabled by the application and it

will collect graphical inputs from the printed trigger. Later on, this will be transmitted to Vuforia database. Once the graphical inputs reach the database and find a proper match, the 3D model associated with the trigger will be fetched. At the finishing stage, the fetched 3D model will be displayed in real-time on top of the AR trigger.For the AR application we choose Android platform and the reason is Android provides a wider usability and more mobility so that not only the teachers at school but also parents at home can use this application for the development of their kids. Bengali language has vowel and consonant. And our work is a one-stop solution for learning both of them. For both vowel and consonant, our system allows children to interact with three-dimensional virtual alphabets as shown in Figure 3.14using a very simple and user-friendly approach; simply by accepting triggering inputs from the devices' camera, ideally an android operated smart phone.

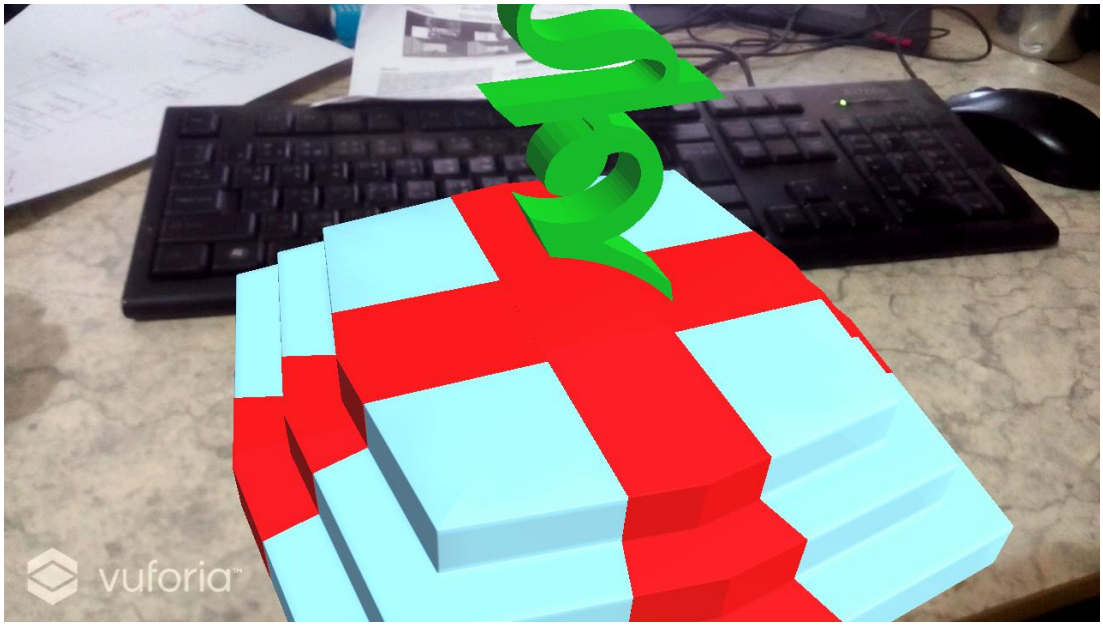

Figure 3.14: Interaction with virtual alphabet

As this AR application shares the same environment for vowels and consonants, the user need not to go through any hassle like: changing the interface or shifting from application. The entire package is so nicely designed that the orientation of triggering input does not matter at all. For instance- the very first letter Shor-E-Aww (অ) can be at an angle of 90

degree or 270 degree with the user's device and in every cases, the model effectively detects the trigger and presents the three dimensional letter associated with it as depicted in Figure 3.15.

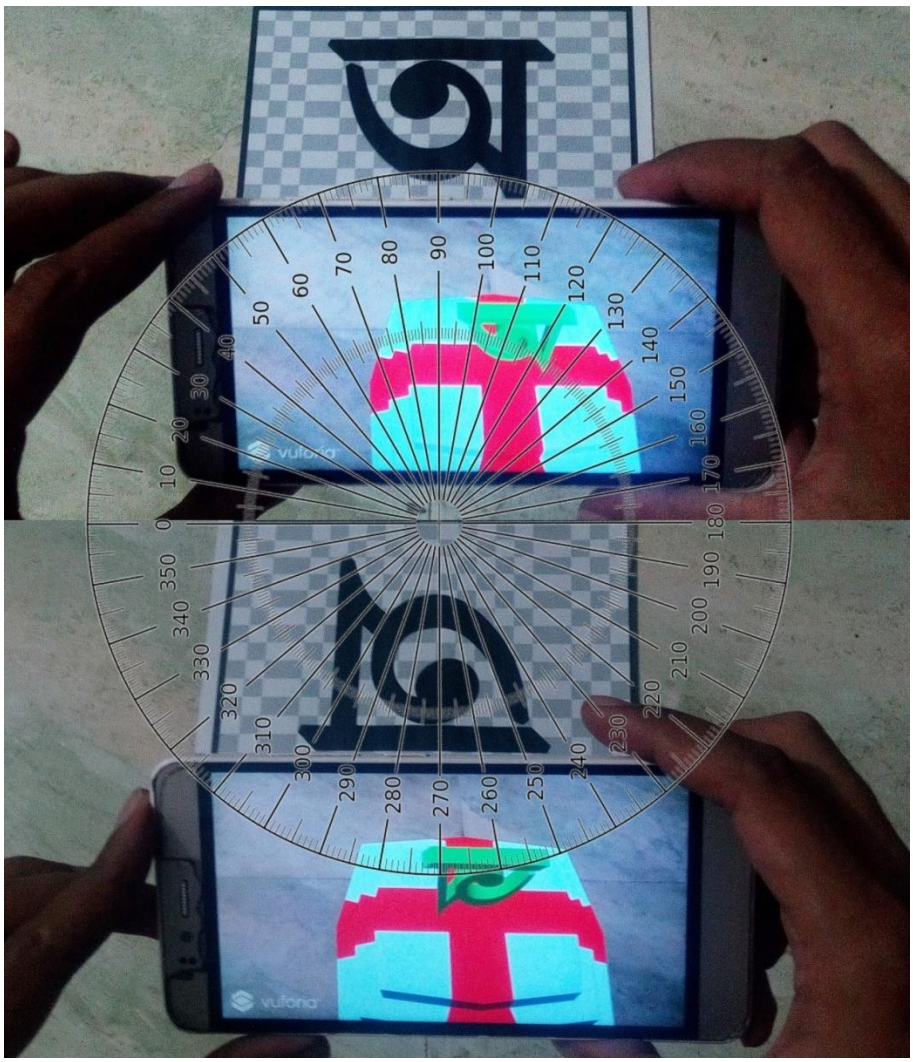

Figure 3.15: Successful Trigger Input from Various Angles

Chapter 4

Experimental Results

After the development of our learning application, it was important to test the effectiveness. To justify the effectiveness of our proposed system, we pushed ourselves to move a bit further. We went to five schools to get different environments. Findings on different environments are mentioned here in this chapter. Figure 4.1 depicts some photographs of those environments.

Figure 4.1: Group of students who took part in the system demonstration

4.1 Environment 1: Vorer Pakhi Model School and Kindergarten

Table 4.1 demonstrates the list of students who participated in the experiment of environment 1, where we went to Vorer Pakhi Model School and Kindergarten to test our proposed learning application. This table includes rudimentary but crucial factors about them which had real impact on our experiment.

Table 4.1: Students Who Participated in the Experiment of Environment 1

Serial No	Name	Date of Birth (D/M/Y)	Age	Gender
1	Mehesan	15/12/2015	3 Years 5 Months	Male
2	Moumita	18/08/2015	3 Years 8 Months	Female
3	Kh. Nishan	4/3/2015	4 Years 3 Months	Male
4	Saif	22/10/2014	4 Years 7 Months	Male
5	Md. Redoyan Ahmed	21/05/2014	5 Years	Male
6	AtiaDewan	25/08/2014	4 Years 8 Months	Female
7	AdianDewan	27/08/2014	4 Years 8 Months	Male
8	Md. ShakilZowarder	23/06/2014	4 Years 11 Months	Male
9	Naiem	06/01/2015	4 Years 5 Months	Male
10	Atif	13/02/2014	5 Years 3 Months	Male
11	MostakinDewan	15/12/2013	5 Years 5 Months	Male
12	Toya Moni	20/11/2014	4 Years 6 Months	Female
13	Nishan	11/03/2014	5 Years 3 Months	Male

14	Soayeb	25/6/2015	3 Years 11 Months	Male
15	Soaib Hossain	17/11/2014	4 Years 6 Months	Male
16	Mazidul Islam(Mouhi)	07/05/2015	3 Years 11 Months	Male
17	ToufiqYeasirAyan	10/6/2014	5 Years	Male
18	Mira	30/08/2013	5 Years 8 Months	Female
19	Iffat Jahan Shathi	28/08/2015	3 Years 8 Months	Female
20	Mehedi Hasan Nirob	07/05/2015	4 Years 1 Month	Male
21	Imrul Hasan	20/10/2013	5 Years 7 Months	Male
22	Tamim Islam	14/01/2014	5 Years 4 Months	Male
23	Md. Tanzim Islam	01/02/2015	4 Years 4 Months	Male
24	Md. Rifat	07/03/2014	5 Years 3 Months	Male
25	Zannatul	10/12/2012	6 Years 6 Months	Female
26	Nusrat	26/09/2012	6 Years 7 Months	Female
27	Tahsin Ahmed Alvi	21/05/2014	5 Years	Male
28	Md. Syam	01/05/2013	6 Years 1 Month	Male
29	Md. Biazid Bostami	10/05/2013	6 Years 1 Month	Male

As we can see in this table there are 29 students aged from 3 years 5 months to 6 years 7 months old. We were interested to see how our system works on different age groups. On that context we did a clustering of these students as stated in Table 4.2.

Table 4.2: Age Based Clustering

Age	Cluster Name
>3 to <4	Cluster A
>4 to <5	Cluster B
>5 to <6	Cluster C
>6	Cluster D

After this classification we provided our developed learning application and triggers to all clusters. Our intention was to see how much time it takes on an average to learn 5 letters (Bengali vowel) for each cluster. At this stage we found a peculiar result, something that we never expected to happen. The differences among average time required for every cluster was significantly different from. For cluster A where the students were 3 to 4 years old, it took an average of 37 minutes to learn 5 letters. Cluster B required 23 minutes. The time drastically decreased for cluster C and D. Accordingly, it took 5.6 and 4 minutes on an average to learn 5 letters as per our requirement.

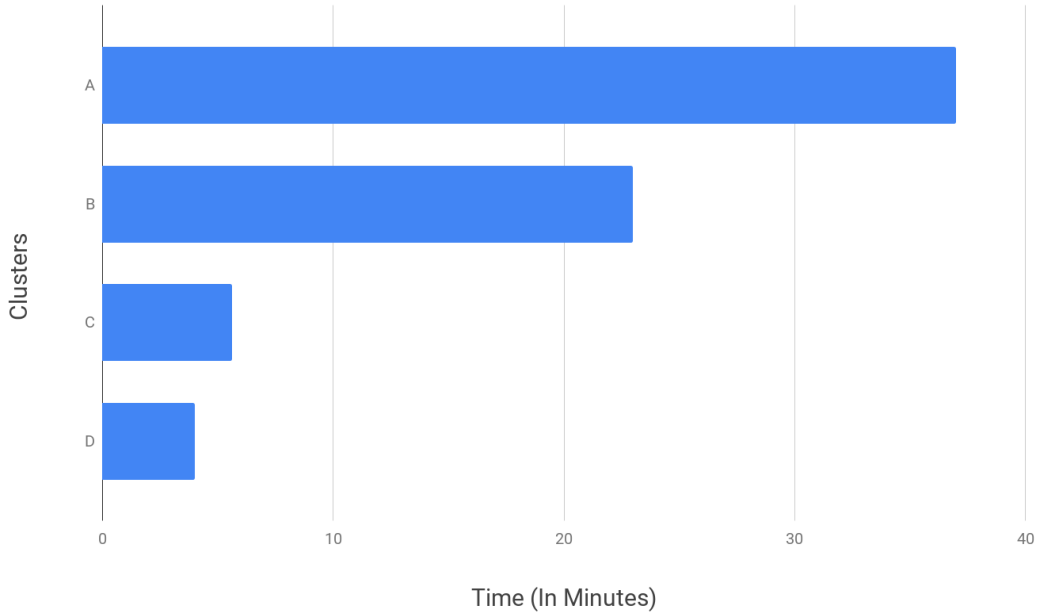

Figure 4.2: Time (In Minutes) vs. Clusters

When the average time difference between the bordering clusters was 33 minutes as stated in Figure 4.2, we really felt a thirst to find out the reasons. Then we started to talk with every single group. What we found was an obvious. Cluster A and B required more time because they were absolutely new to the Bengali letters. They hardly have seen those letters in their

life. Where as, cluster C and D were already familiar with the letters. Our learning application on a smartphone was an exciting addition. Besides they had a good grip which helped them to align the triggers with the system. Thereby we can say that age is a critical factor to get the best out of this application. For really tender kids, our proposed model may work but not bring a fast result. It is really suitable for the kids aged from 4 to 5 years old. From the developer's point of view- whenever we build an application, we highly prioritize how engaging the application really is. For our proposed learning application we were interested to see this as well. This time we needed to take help of the parents. We installed the application on their smart phones and requested them to count- how many times their kids ask them to open the application so that he/she can interact. We also requested them to keep track of this for three days.

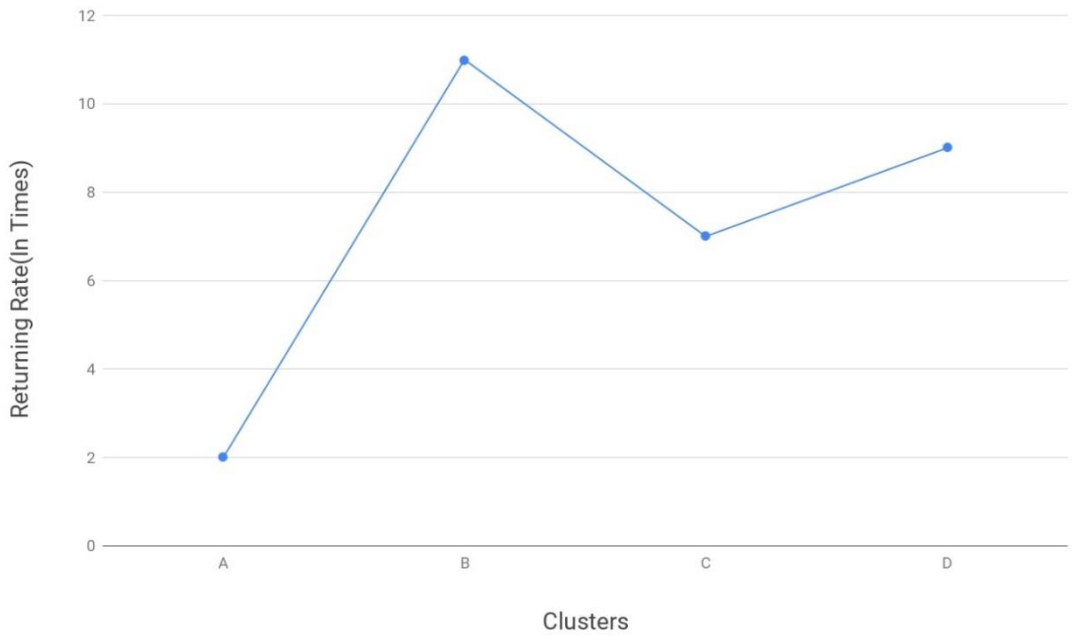

Figure 4.3: Returning Rate (In Times) vs. Clusters

After the specified time, we got back to the parents and collected data from them on the aforesaid factor. We plotted this date on our age based clusters after doing average. The returning rate for each clusters were significantly different from each other.

As we can see in Figure 4.3, cluster A returned to our application 2 times on an average which is not that much convincing. But the returning rate increases for cluster B, where they got back to our application 11 times. Moving forward to cluster C, the returning rate again decreases and reaches at a level of 7 times. Though it is less than cluster B, it certainly is not as less as cluster A. Lastly for cluster D; we examined an increase in the returning rate. On an average they got back to our application for 9 times. This rate was not enough to beat cluster B but the result was not disappointing either. After getting the above results, we were interested to find out the reasons behind the variation of returning rate for every clusters. Cluster A, where the kids are under 4 years old had returned to the application only 2 times. The reason behind it is- their tiny little hands were not much efficient to align the camera with triggers. Thus they found it a bit complicated to use. Where are cluster B showed the maximum returning rate. They were relatively elder than cluster A and were sharp enough to grab the concept of how to use the application. Besides their parents encouraged and helped them to interact. In cluster C, the returning rate is comparatively lower than cluster B. It's because they had lack of the assistance from their parents. Since the kids had a preliminary idea on Bengali alphabet, parents did not felt the necessity to assist their kids to interact with the application. For our last cluster D, the returning rate again increases. It's simple because they were able to reinvent their already learnt topic. They found fun to pass times by interacting with this application without any additional assistance from their parents. Our experiment with the returning rate also suggests that cluster B is the great fit for this application. So we were keen to observe this group a bit further. This time we considered only cluster B and classified them by gender and picked two males and two females. As student information has already mentioned in this thesis, we here only stating their names with serial no on the table- Naiem (male; serial no: 9); Nirob (male; serial no: 20); Atia (female; serial no: 6); Toya (female; serial no: 12). Our intention was to see- does gender

really makes a difference? So we again brought our system in front of them and told them to interact with the first 3 consonants of Bengali alphabet. Without letting them, know we were tracking the time of their learning. As we can see in Table 4.3, our male participants Naiem and Nirob took 13 minutes and 13.08 minutes accordingly to learn the assigned lesson with the help of our developed model. On the other hand Atia and Toya who are our female participants took 13.05 minutes and 12.07 minutes accordingly to learn the same lesson in exact same way.

Table 4.3: Gender Based Difference in Learning Time

Name	Gender	Time Required to Learn	Total Time for Individual Group	Time Difference Between 2 Groups
Naiem	Male	13.00 min.	26.08 min.	56 sec.
Nirob	Male	13.08 min.		
Atia	Female	13.05 min.	25.12 min.	
Toya	Female	12.07 min.		

Thus the male group required a time of 26.08 minutes in total and the female group required a time of 25.12 minutes in combined. Hence the experiment suggests that the learning rate of female students is 56 seconds ahead of male students when they are using our developed application as a medium of learning. However it is wise to mention that this aforesaid analysis should not be taken as a concrete constant. Depending on some important factors like- environment and upbringing, the result may change.

4.2 Environment 2: Shishu Kanon Kindergarten

Table 4.4 demonstrates the list of students who participated in this experiment of environment 2, where we went to Shishu Kanon Kindergarten to test our proposed learning

application. This table includes the exact same factors that we considered during the experiment with environment 1.

Table 4.4: Students Who Participated in the Experiment of Environment 2

Serial No	Name	Date of Birth (D/M/Y)	Age	Gender
1	Dolon Roy	23/08/2015	3 Years 9 Months	Female
2	Shakir Ahmed	14/3/2015	4 Years 3 Months	Male
3	KaziJahid	27/10/2014	4 Years 7 Months	Male
4	RafimHossen	20/05/2014	5 Years 1 Months	Male
5	Enamur Rahman	25/09/2014	4 Years 8 Months	Male
6	IqramulBayeed	27/05/2014	5 Years	Male
7	Sumaiya	23/06/2014	5 Years	Female
8	ShubhrajibBasu	06/01/2015	4 Years 5 Months	Male
9	MdJahid Hasan	13/02/2014	5 Years 4 Months	Male
10	Tanvir Hasan	15/10/2013	5 Years 8 Months	Male
11	Istiaque Hasan	12/11/2014	4 Years 7 Months	Male
12	KazolBanik	11/03/2014	5 Years 3 Months	Female
13	Nahid Ahmed	15/7/2015	4 Years 1 Month	Male
14	Nadia Akhter Sayma	17/10/2014	4 Years 8 Months	Female
15	Durlov Roy	15/05/2015	4 Years 1 Month	Male

16	Mohaimanur Rahman	09/6/2014	5 Years	Male
17	Md. Tanvir Al Arubi	30/08/2014	4 Years 9 Months	Male
18	Nilima Rahman	28/07/2014	4 Years 10 Months	Female
19	Abdullah Afnan	07/12/2015	4 Years 6 Months	Male

As we can see in Table 4.4 there are 19 students from different age groups. We followed the exact same pattern mentioned in Table 4.2 to do the age based clustering so that we can move forward to the experiments. We provided the learning application and triggers to all clusters. Our intention was to see how much time it takes on an average to learn 5 letters (Bengali vowel) for each cluster. The result that we found in this stage is stated in Figure 4.4.

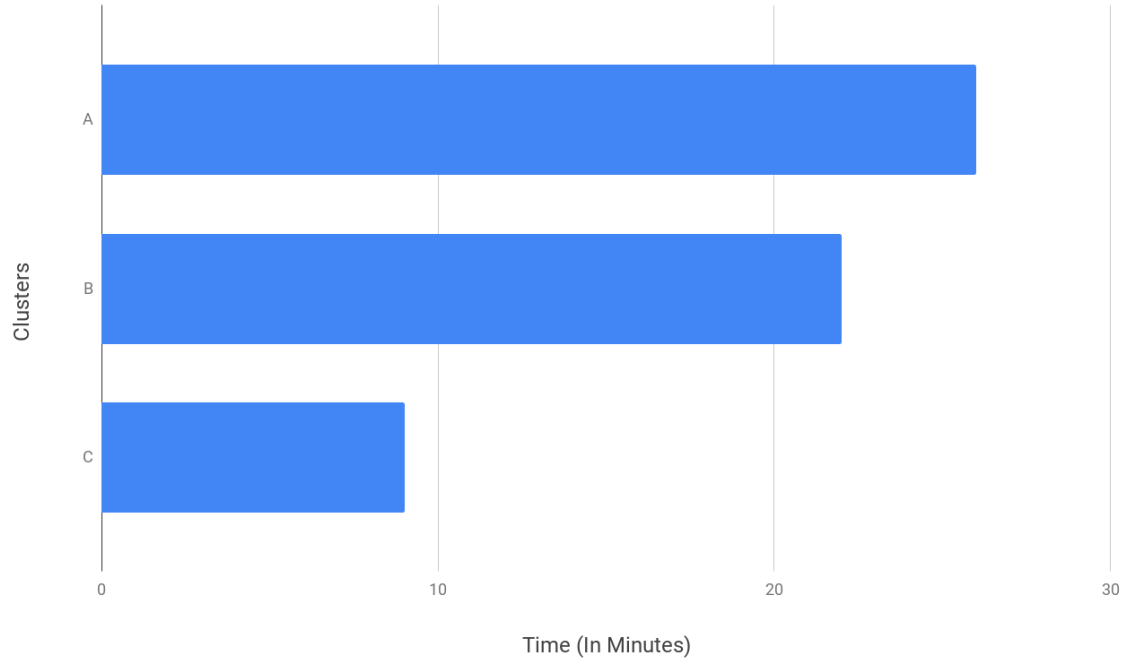

Figure 4.4: Time (In Minutes) vs. Clusters

For cluster A where the student was 3 to 4 years old, took 26 minutes to learn 5 letters. Cluster B required 22 minutes on an average. Like our experiment in environment 1, time decreased for cluster C and took an average of 9 minutes. To be mentioned, for environment 2 cluster D was inactive as there were no student that fits on that particular age group. Here

the average time difference between the bordering clusters was 17 minutes. Cluster C required less time because of the exact same reason that we found in environment 1. Cluster C already had a good prior idea of what to be learnt whereas cluster A and Cluster B were fresher. And obviously cluster C had a good grip in comparison with the remaining two clusters. So we can say age plays a vital role to get the best outcome from our proposed application.

In the next stage we did experiment on engagement of users with our application. We installed the application on the smart phone of our participants' parents and requested them to keep track for three days on- how many times their kids asks them to open the application. After the given time we collected the data and plotted it on age based clusters after doing average as depicted in Figure 4.5.

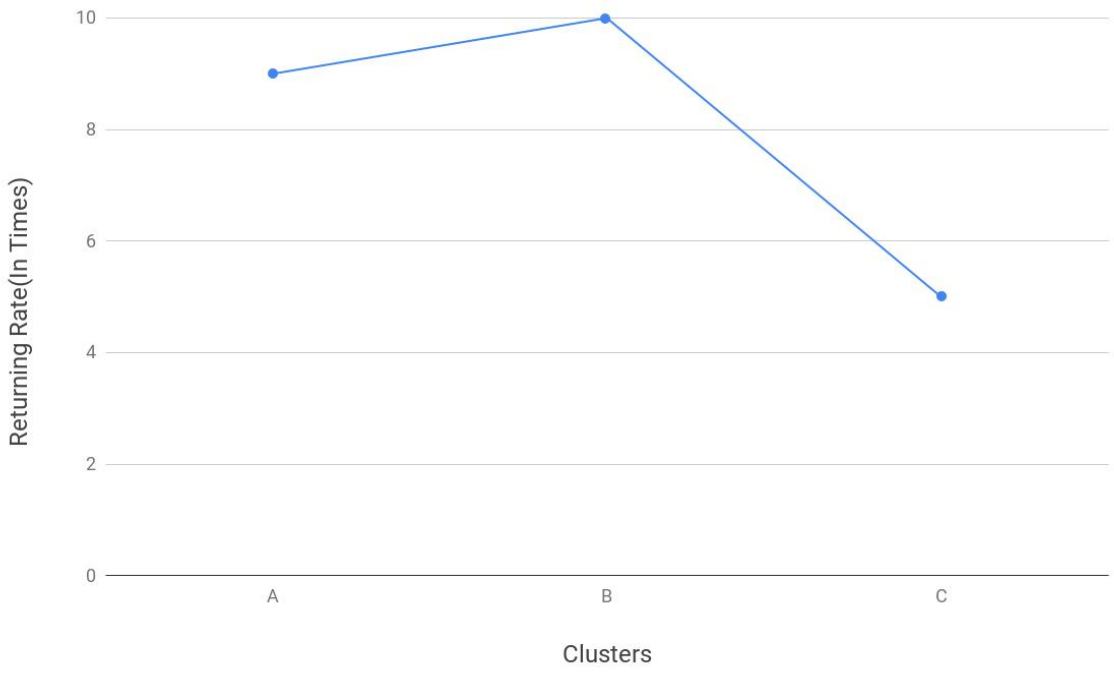

Figure 4.5: Returning Rate (In Times) vs. Clusters

As we can see here, there is a not huge difference between cluster A and cluster B on their returning rates. Here cluster A returned 9 times and cluster B returned 10 times. This scenario is different from the result of environment 1. The reason behind this difference is- the

participant in cluster A on environment 2 was almost at the edge of touching cluster B by age.On the other hand, environment 2 has lack of sufficient number of participants in cluster A. As we can see on Table 4.4, there is only one participant in cluster A which is not a good number to establish a strong impression. However, the returning rate for cluster C remains similar for both environments showing a downward result for the exact same reason mentioned in environment 1. So for environment 2, our experiments so far suggest that the users between the ages of 4 to 5 years old are the appropriate users for our developed application.

According to our experimental sequence, we picked two male and two female from this age group to see the impact of gender on the process of acquisition with the help of our developed application. We here mentioning their names only as their other information have already mentioned in this thesis. They are- KaziJahid (male; serial no: 03); Sumaiya (female; serial no: 07); Nahid Ahmed (male; serial no: 13) and Nilima Rahman (female; serial no: 18). We again let them interact with our system and told them to learn first 3 consonants of Bengali alphabet. We were tracking their acquisition time without letting them know. Our finding of this stage is represented in Table 4.5.

Table 4.5: Gender Based Difference in Learning Time

Name	Gender	Time Required to Learn	Total Time for Individual Group	Time Difference Between 2 Groups
Jahid	Male	14.06 min.	26.14 min.	3.41 min.
Nahid	Male	12.08 min.		
Sumaiya	Female	13.25 min.	29.55 min.	
Nilima	Female	16.30 min.		

Here in Table 4.5, our male participants Jahid and Nahid took 14.06 minutes and 12.08 minutes accordingly to learn the assigned lesson with the help of our developed model. On the other hand Sumaiya and Nilima who are our female participants took 13.25 minutes and 16.30 minutes accordingly to learn the same lesson in exact same way. Thus the male group required a time of 26.14 minutes in total and the female group required a time of 29.55 minutes in combined. Hence the experiment suggests that the learning rate of male students are 3.14minutes ahead of female students when they are using our developed application as a medium of learning. This scenario is unlike to environment 1 because female students required less time to learn in that environment. Hence it suggests our previous saying; depending on some important factors like- environment and upbringing, the result may change.

4.3 Environment 3: Moin Nagar Govt. Primary School

Table 4.6 demonstrates the list of students who participated in the experiment of environment 3, where we went to Moin Nagar Govt. Primary School to test the efficiency of our proposed learning application. This table includes the exact same factors that we considered during the experiments with previous environments.

Table 4.6: Students Who Participated in the Experiment of Environment 3

Serial No	Name	Date of Birth (D/M/Y)	Age	Gender
1	NazmushShakib	30/01/2015	4 Years 4 Months	Male
2	Koli Akhter	19/03/2015	4 Years 3 Months	Female
3	IktidarulAlam	29/07/2014	4 Years 10 Months	Male
4	Antara Akhter	20/05/2015	4 Years 1 Month	Female

5	Abdullah Al Maruf	25/09/2014	4 Years 8 Months	Male
6	Khaled Hasan	27/05/2013	6 Years	Male
7	Rakib Khan	28/02/2014	5 Years 3 Months	Male
8	Lorna Bala	01/01/2015	4 Years 5 Months	Female
9	K. M. Imran Hossain	01/04/2014	5 Years 2 Months	Male
10	TanjimAkter	15/10/2013	5 Years 8 Months	Female
11	SusmoyRanjanSarker	12/06/2014	4 Years 6 Months	Male
12	AkhlimaAfroze	17/04/2014	5 Years 2 Months	Female
13	AnikSaha	15/07/2015	3 Years 11 Months	Male
14	Emran Hosen	17/06/2013	6 Years	Male
15	AnisulHaoqueShohan	15/05/2015	4 Years 1 Month	Male
16	Akash	10/06/2013	5 Years 8 Months	Male
17	EaktishadKamrulAdor	05/07/2014	4 Years 11 Months	Male

As we can see in Table 4.6 there are 17 students from different age groups. We followed the exact same pattern mentioned in Table 4.2 to do the age based clustering as we did for environment 1 and environment 2. We provided the learning application and triggers to all clusters to see how much time it requires on an average to learn 5 letters (Bengali vowel) for each cluster.

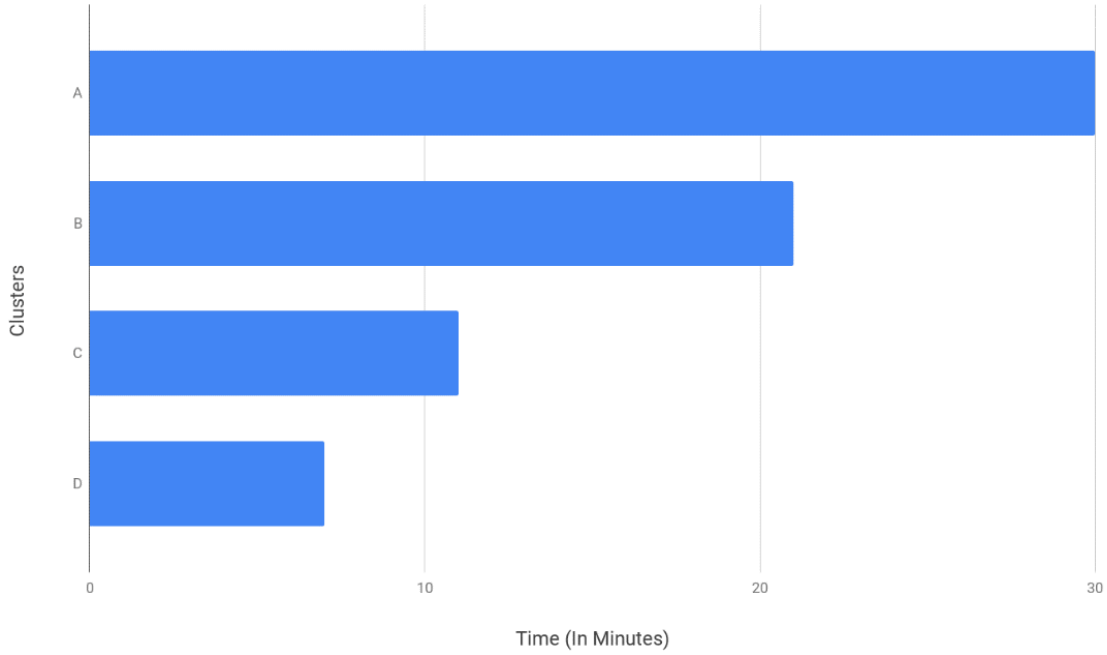

Figure 4.6: Time (In Minutes) vs. Clusters

The result that we found in this stage is stated in Figure 4.6. For cluster A where the student was 3 to 4 years old, took 30 minutes to learn 5 letters. Cluster B required 21 minutes on an average. Just like our previous experiments, time decreased for cluster C and took an average of 11 minutes. Cluster D required the fewest amount of time, an average of 7 minutes. Here the average time difference between the bordering clusters was 23 minutes. Cluster C and D required less amount time because of the exact same reason that we found in our previous experiments. Both of these clusters already had a good prior idea of what to be learnt whereas cluster A and Cluster B were newbies. Important to mention that we should not put higher importance on the findings from cluster A as there is only one participant in this environment. Findings from other clusters are more reliable. And on the basis of that we can say- age plays a vital role to get the best outcome from our proposed application; which we already suggested in our experiments with other environments as well.

Our next phase of experiment is engagement testing. Likewise we installed the application on the smart phone of our participants' parents and requested them to keep track for three days

on- how many times their kids asks them to open the application. After the given time, we reached them and collected the data. Later on we plotted the acquired data on age based clusters after doing average as depicted in Figure 4.7. As we can see here, there is a huge difference between the previous experiments with other environments and this environment. Here cluster A returned 12 times which is way higher than previous times. Cluster B returned 10 times. Returning rate for cluster C is slightly higher at 11 times. Cluster D shows the minimum returning rate of 3 times. There are some reasons behind the dramatic change of this experiment in environment 3. This is a government controlled primary school and academic pressure on upper classes is huge. So cluster D did not able to interact with our system as many times as we expected. On the other hand there was only one participant in cluster A, who was highly fascinated by the idea of our proposed model. His eagerness clearly reflects on the finding. If the number of participants in this cluster was a bit higher than a change on this finding was very possible to occur.

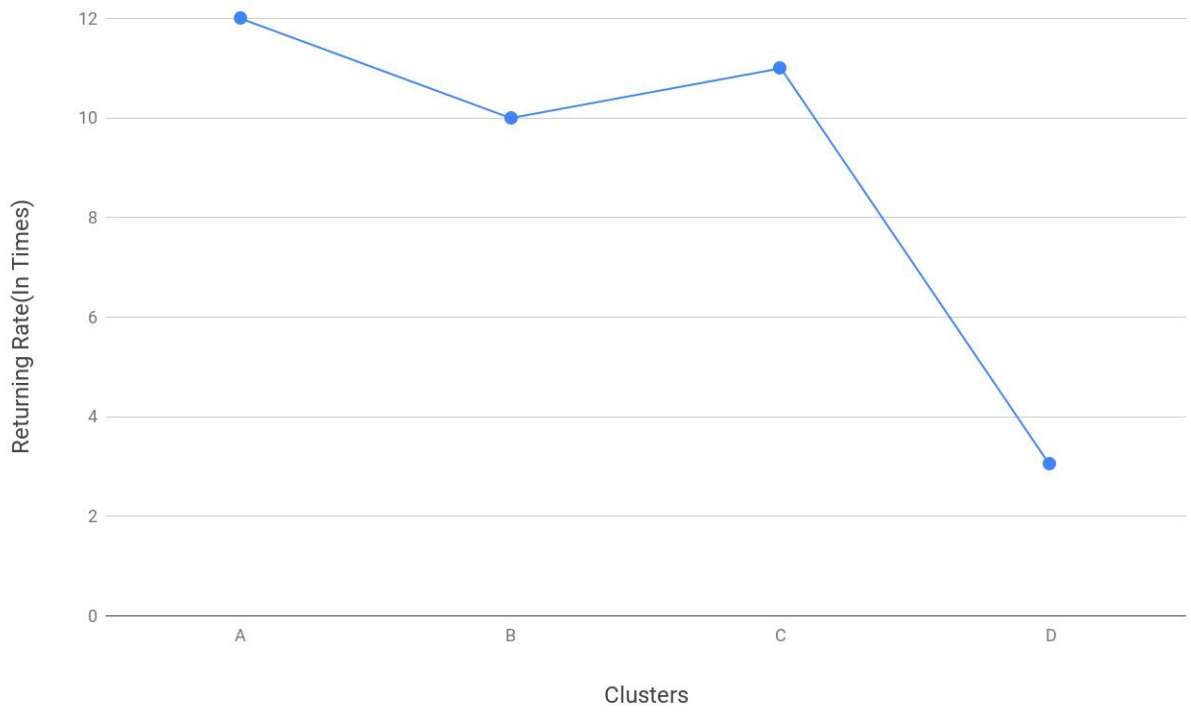

Figure 4.7: Returning Rate (In Times) vs. Clusters

So for environment 3 where the engagement is higher for three clusters- A, B and C; we picked up 2 males and 2 females from those clusters to see the impact of gender on acquisition process. We assigned the same task as we did for environment 1 and environment 2. Our findings are depicted in Table 4.7.

Table 4.7: Gender Based Difference in Learning Time

Name	Gender	Time Required to Learn	Total Time for Individual Group	Time Difference Between 2 Groups
Anik	Male	11.00 min.	24.02 min.	8.3 min.
Akash	Male	13.02 min.		
Lorna	Female	17.25 min.	32.32 min.	
Koli	Female	15.07 min.		

Here our male participants Anik and Akash took 11.00 minutes and 13.02 minutes accordingly to learn the assigned lesson with the help of our developed model. On the other hand Lorna and Koli who are our female participants took 17.25 minutes and 15.07 minutes accordingly to learn the same lesson in exact same way. Thus the male group required a time of 24.02 minutes in total and the female group required a time of 32.32 minutes in total. Thus the experiment suggests that the learning rate of female students are 8.3minutesslower than the male students. For last 3 environments- in 2 cases we have found that male students perform better than female students and in 1 case female students perform better than male students while they are using our developed application as a medium of learning.

4.4 Environment 4: Nur Jahan Pre Cadet School

Table 4.8 demonstrates the list of students who participated in the experiment of environment 4, where we went to Nur Jahan Pre Cadet School to test the efficiency of our proposed learning application. This table includes the exact same factors that we considered during the experiments with previous three environments.

Table 4.8: Students Who Participated in the Experiment of Environment 4

Serial No	Name	Date of Birth (D/M/Y)	Age	Gender
1	AsmaulHosna	15/09/2014	4 Years 9 Months	Female
2	Nazmul Islam	03/05/2015	4 Years 1 Months	Male
3	Sadia Tasnim	13/11/2014	4 Years 7 Months	Female
4	MasumbillahZihad	20/05/2015	4 Years 1 Months	Male
5	MahbubAlamRidoy	25/09/2014	4 Years 8 Months	Male
6	Meskat Hasan	29/12/2013	5 Years 5 Months	Male
7	Mehedi Hasan	28/02/2015	4 Years 3 Months	Male
8	PubaliBishwas	01/02/2014	5 Years 4 Months	Female
9	Rakib Hasan	05/07/2014	4 Years 11 Months	Male
10	Md. Mozammel	06/09/2015	4 Years	Male
11	Al Amin Abid	12/06/2013	5 Years 6 Months	Male
12	Fajle Rabbi	08/07/2014	4 Years 10 Months	Male
13	AurnaDhor	15/12/2014	4 Years 6 Months	Female
14	Ali Asif	17/06/2013	6 Years	Male
15	KaziShara	20/07/2014	4 Years 11 Months	Female
16	SounavMitra	09/06/2015	4 Years 0 Months	Female
17	Aditi Bala	15/07/2014	4 Years 11 Months	Female

As we can see in Table 4.8 there are 17 students from different age groups. We followed the exact same pattern mentioned in Table 4.2 to do the age based clustering as we did for environment 1, environment 2 and environment 3. We provided the learning application and triggers to all clusters to see how much time it requires on an average to learn 5 letters (Bengali vowel) for each cluster.

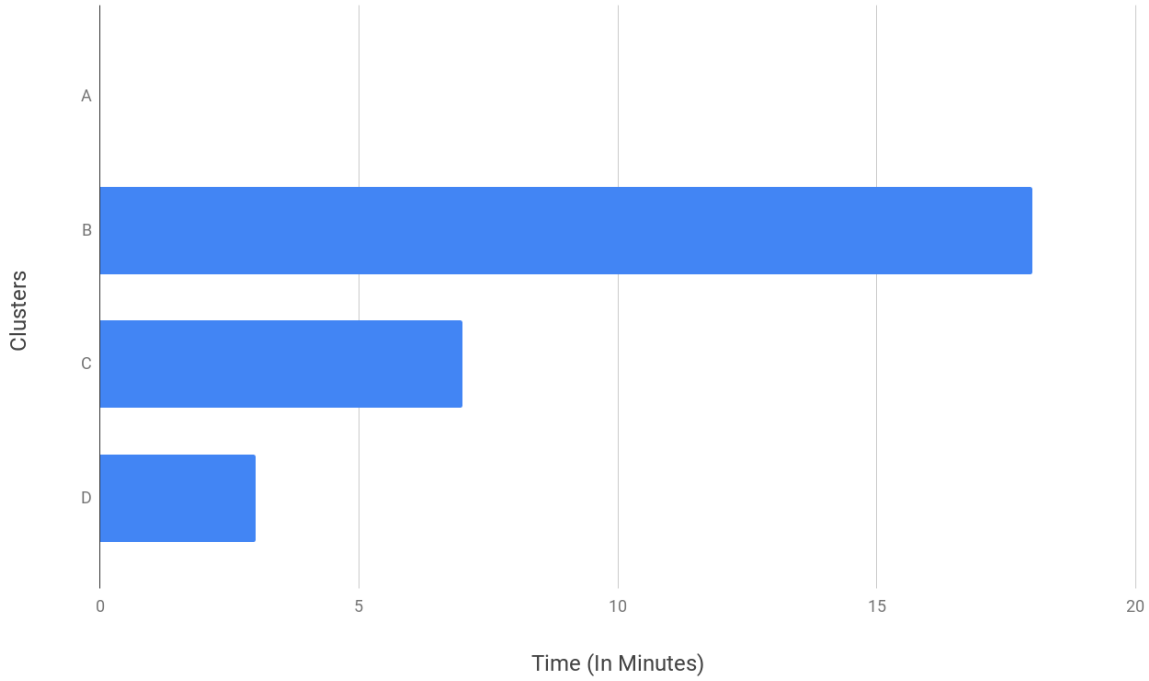

Figure 4.8: Time (In Minutes) vs. Clusters

The result that we found in this stage is stated in Figure 4.8. In this environment we had no member for cluster A as there was no student who's age was 3 to 4 years old. Cluster B required 18 minutes on an average. Just like our previous experiments, time decreased for cluster C and took an average of 7 minutes. Cluster D required the fewest amount of time, an average of 2 minutes. Here the average time difference between the bordering clusters was 16 minutes which is significantly lower than the previous environment. The reason behind this change is obvious. In this context cluster B acts as the bordering cluster and the age difference is not as much as cluster A to cluster D. Cluster C and D required less amount time

because of the exact same reason that we found in our previous experiments. Important to mention that in this environment we had a good number of participants in cluster B. So the findings on this particular cluster from environment 4 can be taken seriously.

For engagement testing experiment, we installed the application on the smart phone of our participants' parents as usual. We requested them to keep track for three days on- how many times their kids asks them to open the application. After the given time, we reached them and collected the data. Than we plotted the acquired data on age based clusters after doing average as depicted in Figure 4.9.

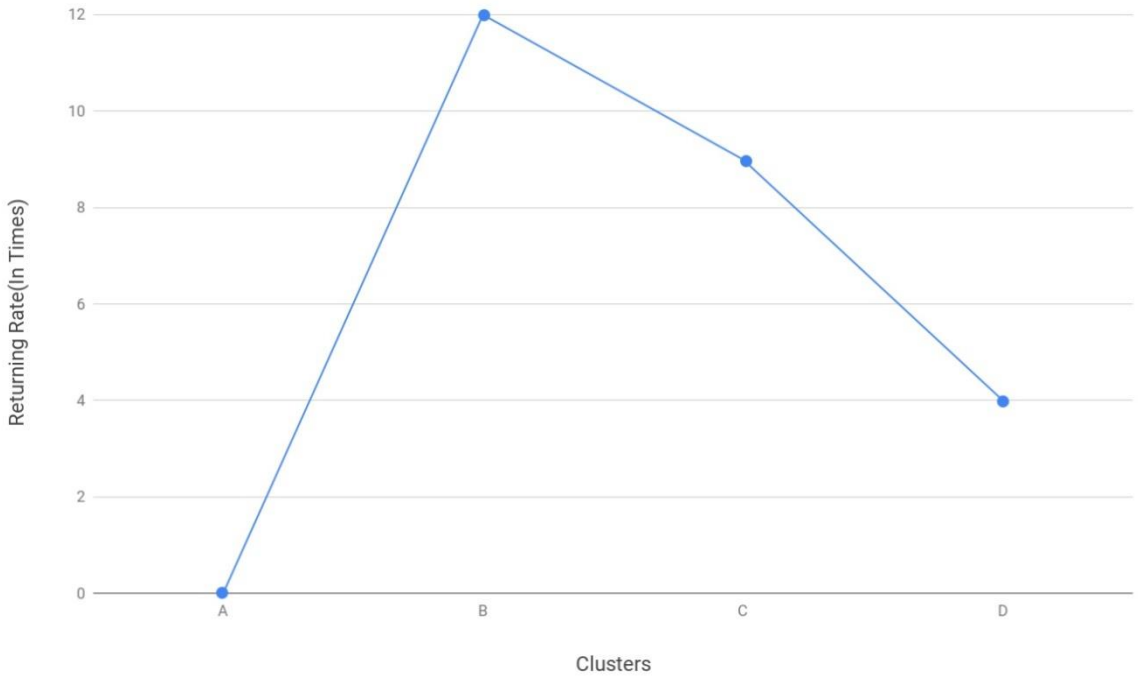

Figure 4.9: Returning Rate (In Times) vs. Clusters

As we can see here, the returning rate for our most legitimate cluster that is cluster B is higher than anyone at a rate of 12 times. There is no output from cluster A as there is no participant. Returning rate for cluster C decreased and reached at a level of 9 times. Cluster D shows the minimum returning rate of 4 times as like the previous environments. Hence we can say that cluster B is the best suit for our developed model in environment 4.

In the next stage of our experiment we picked 2 male and 2 female as usual to see the impact of gender on acquisition process. We assigned the same task as we did for environment 1, environment 2 and environment 3. Our findings are depicted in Table 4.9.

Table 4.9: Gender Based Difference in Learning Time

Name	Gender	Time Required to Learn	Total Time for Individual Group	Time Difference Between 2 Groups
Nazmul	Male	14.04 min.	27.46 min.	5.37 min.
Ridoy	Male	13.42 min.		
Aurna	Female	12.00 min.	22.09 min.	
Aditi	Female	10.09 min.		

Here our male participants Nazmul and Ridoy took 14.04 minutes and 13.42 minutes accordingly to learn the assigned lesson with the help of our developed model. On the other hand Aurna and Aditi who are our female participants took 12.00 minutes and 10.09 minutes accordingly to learn the same lesson in exact same way. Thus the male group required a time of 27.46 minutes in total and the female group required a time of 22.09 minutes in total. Thus the experiment suggests that the learning rate of female students are 5.37 minutes faster than the male students. From environment 1 to environment 4, till now we have found two cases where male students took the lead and in two other cases female students took the lead.

4.5 Environment 5: Little Angels Learning Home

Table 4.10 demonstrates the list of students who participated in the experiment of environment 5, where we went to Little Angels Learning Home to test the efficiency of our proposed learning application. This table includes the exact same factors that we considered during the experiments with previous four environments.

Table 4.10: Students Who Participated in the Experiment of Environment 4

Serial No	Name	Date of Birth (D/M/Y)	Age	Gender
1	Md. GolamMorshed	23/08/2014	4 Years 10 Months	Male
2	Riana Rashid Elma	14/06/2015	4 Years	Female
3	Rahul Kamal	27/09/2013	5 Years 8 Months	Male
4	Nasib Mohammad Arif	20/05/2014	5 Years 1 Months	Male
5	RifatTasnima	20/09/2014	4 Years 9 Months	Female
6	Abu TalebKhandakar	27/05/2014	5 Years	Male
7	Khadiza Begum	18/02/2015	4 Years 4 Months	Female
8	Arman Hossan	09/02/2014	5 Years 4 Months	Male
9	Md. Tanvir Ahmed Abir	05/07/2014	4 Years 11 Months	Male
10	Sakib Chowdhury	06/09/2015	4 Years	Male
11	AfshanaAfrose	12/06/2013	6 Years	Female
12	Md. AzizulHoque	27/02/2014	5 Years 3 Months	Male
13	S. M. Hasan Al Reza	15/12/2013	5 Years 6 Months	Male
14	SharifulAlamHimon	12/10/2014	4 Years 8 Months	Male
15	Fatema Rahman	01/07/2014	4 Years 11 Months	Female
16	Fahad Ahmed	15/09/2014	4 Years 9 Months	Male

As we can see in Table 4.10 there are 16 students from different age groups. We followed the exact same pattern mentioned in Table 4.2 to do the age based clustering as we did for

previous four environments. We provided the learning application and triggers to all clusters to see how much time it requires on an average to learn 5 letters (Bengali vowel) for each cluster.

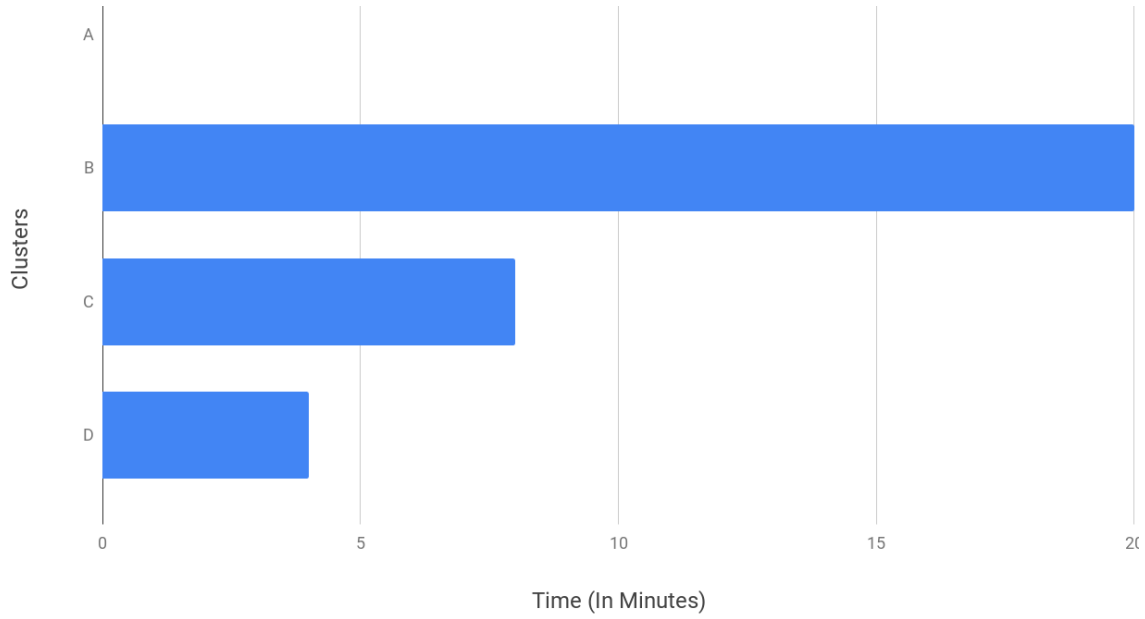

Figure 4.10: Time (In Minutes) vs. Clusters

The result that we found in this stage is stated in Figure 4.10. In this environment we had no member for cluster A just like environment 4as there was no student who's age was on that particular segment. Cluster B required 20 minutes on an average. Likewise time decreased for cluster C and took an average of 8 minutes. As usual Cluster D required the lowest amount of time, an average of 4 minutes. Here the average time difference between the bordering clusters was 16 minutes which is significantly lower than the previous environments and exact same as the result of environment 4. The reason behind this change is obvious. Here B and D acts as the bordering cluster and the age difference is not as much as cluster A to cluster D. Cluster C and D required less amount time because of the exact same reason that we found in our previous experiments. Just like environment four here we had a good number of participants in cluster B. So the findings on this particular cluster from environment 5 can be considered valuable.

For engagement testing experiment, we followed the same procedure. We installed the application on the smart phone of our participants' parents. We requested them to keep track for three days on- how many times their kids asks them to open the application. After the given time, we reached them and collected the data. Later on we plotted the acquired data on age based clusters after doing average as depicted in Figure 4.11.

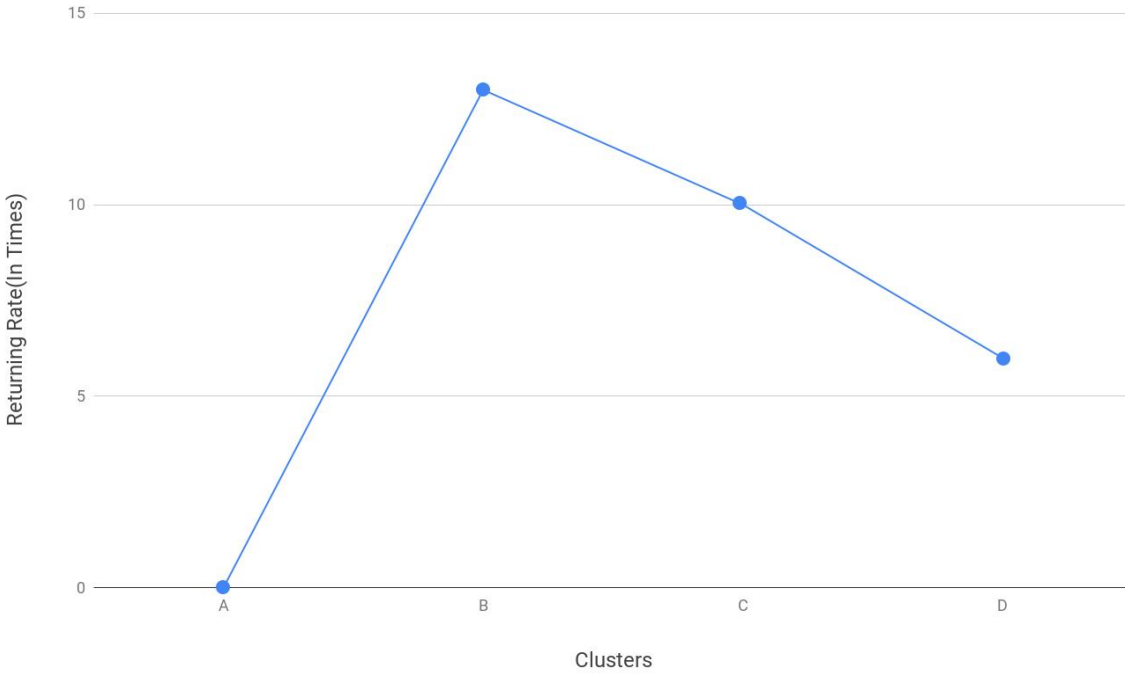

Figure 4.11: Returning Rate (In Times) vs. Clusters

In our findings, the returning rate for cluster B is higher than anyone at a rate of 13 times. There is no output from cluster A as there is no participants just like environment 4. Returning rate for cluster C decreased and reached at a level of 10 times which is one time greater than the previous environment. Cluster D shows the minimum returning rate of 6 times as like the previous environments. At this stage of our experiment we strongly can say that cluster B is the right segment for our developed application. The high returning rate of this cluster in almost every environment suggests this fact. In the next stage of our experiment we picked 2 male and 2 female as usual from the most returning cluster that is

cluster B to see the impact of gender on acquisition process. We assigned the same task as we did for our previous four environments. Our findings are depicted in Table 4.11.

Table 4.11: Gender Based Difference in Learning Time

Name	Gender	Time Required to Learn	Total Time for Individual Group	Time Difference Between 2 Groups
Sakib	Male	12.03 min.	23.3 min.	21 sec.
Himon	Male	11.27 min.		
Elma	Female	12.07 min.	23.09 min.	
Tasnima	Female	11.02 min.		

Here our male participants Sakib and Himon took 12.03 minutes and 11.27 minutes accordingly to learn the assigned lesson with the help of our developed model. On the other hand Elma and Tasnima who are our female participants took 12.07 minutes and 11.02 minutes accordingly to learn the same lesson in exact same way. Thus the male group required a time of 23.30 minutes in total and the female group required a time of 23.09 minutes in total. Thus the experiment suggests that the learning rate of female students is 21secondsfaster than the male students. Throughout our journey of five environments- 3 cases showed the higher performance of female students and 2 cases showed higher performance of male students.

4.6 Accumulated Outcomes from Five Environments

This section reflects the accumulated outcomes that we have found after doing experiments on five different environments. Firstly, we are going to mention the findings on – how much time is required to learn 5 Bengali letters for each cluster. To be mentioned the age based clustering is mentioned in Table 4.2. Following table that is Table 4.12 represents the findings from all five environments. As we can see here- cluster A, B, C and D required 93

minutes, 104 minutes, 40.6 minutes and 17 minutes accordingly. From our onsite observation we can say that cluster C and D are not the right segment for our application even though they required minimum time. They were already well known about what to learn. On the other hand cluster A required time more than usual. But cluster B showed a reasonable engagement time to learn the assigned tasks. Therefor we can say- the students aged from 4 to 5 years old are the right group of users for our proposed model.

Table 4.12: Cluster Based Learning Time for Each Environment in Average

Clusters	Environments	Time (in min.)	Total Time
	Environment 1	37	
	Environment 2	26	
Cluster A	Environment 3	30	93 min.
	Environment 4	0	
	Environment 5	0	
	Environment 1	23	
	Environment 2	22	
Cluster B	Environment 3	21	104 min.
	Environment 4	18	
	Environment 5	20	
	Environment 1	5.6	
	Environment 2	9	
Cluster C	Environment 3	11	40.6 min.
	Environment 4	7	
	Environment 5	8	
	Environment 1	4	
	Environment 2	0	
Cluster D	Environment 3	7	17 min.
	Environment 4	2	
	Environment 5	4	

Now we are going to state the findings on returning rate for each clusters to our proposed model. Accumulated data from each environment is stated on Table 4.13 in this context.

Table 4.13: Cluster Based Returning Rate for Each Environment in Average

Clusters	Environments	Returning Rate (in times)	Total Returning Rate
	Environment 1	2	
	Environment 2	9	
Cluster A	Environment 3	12	23
	Environment 4	0	
	Environment 5	0	
	Environment 1	11	
	Environment 2	10	
Cluster B	Environment 3	10	56
	Environment 4	12	
	Environment 5	13	
	Environment 1	7	
	Environment 2	5	
Cluster C	Environment 3	11	42
	Environment 4	9	
	Environment 5	10	
	Environment 1	9	
	Environment 2	0	
Cluster D	Environment 3	3	22
	Environment 4	4	
	Environment 5	6	

Table 4.13 clearly shows the higher returning rater for cluster B. This basically means the students aged from 4 to 5 years old have used our proposed model more frequent than any other groups. This finding one more time justifies that this particular age group is the perfect suit for our proposed model of learning application. Lastly we are going to state the gender based performance on our proposed model. Table 4.14 states the accumulated date from different environments on this context. On a given scenario as mentioned in 4.1 to 4.5; male students was able to learn the assigned task within a combined time of 127.00 minutes. On

the other hand female students required 132.17 minutes to attain the same goal. Thus based on our experiments we can say that male students perform better than female students with our proposed model.

Table 4.14: Gender Based Performance

Gender	Environment	Total Time for Individual Group (In minutes)	Accumulated Time (In minutes)	Time Difference and Lead
Male	Environment 1	26.08	127.00	5.17 (3.08%) Lead: Male
	Environment 2	26.14		
	Environment 3	24.02		
	Environment 4	27.46		
	Environment 5	23.30		
Female	Environment 1	25.12	132.17	
	Environment 2	29.55		
	Environment 3	32.32		
	Environment 4	22.09		
	Environment 5	23.09		

4.7 Review from Parents

We also prepared a questionnaire consisting of four questions and visited 10 families in our neighborhood where there is a kid. After demonstrating our system to the kids as well as their parents, we provided the questionnaire to the parents and received feedback from them. All those questions along with their feedbacks represented by the help of four distinct pie charts (4.12 - 4.15) are stated below.

1. The Proposed AR model is _____ to use.
   O Super Easy O Easy O Hard O Very Hard

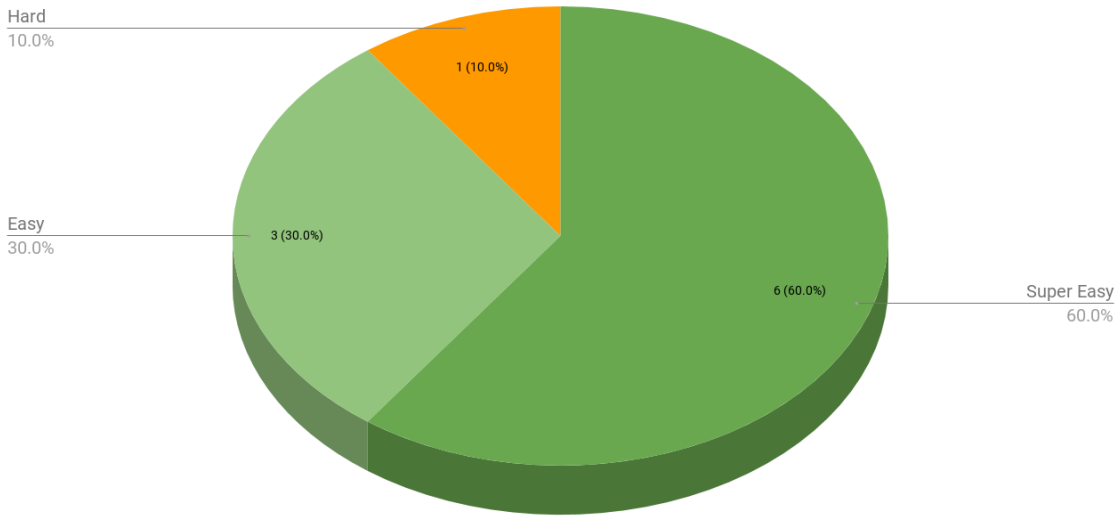

Figure 4.12: Pie chart based on the feedback of aforesaid topic

2. The performance of the proposed AR model is _____.

   O Very Satisfactory

   O Satisfactory

   O Dissatisfactory

   O Utterly Disappointing

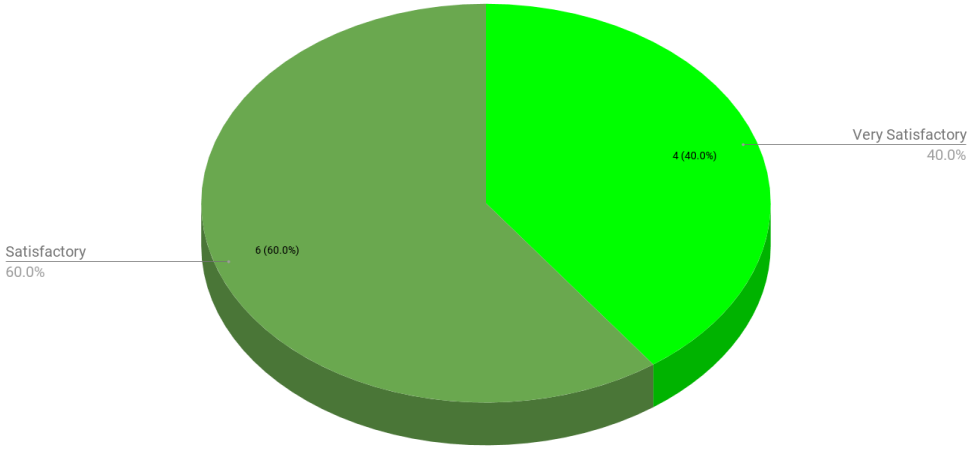

Figure 4.13: Pie chart based on the feedback of aforesaid topic

3. Kids can easily use this application –

   O Strongly Agree O Agree O Disagree O Strongly Disagree

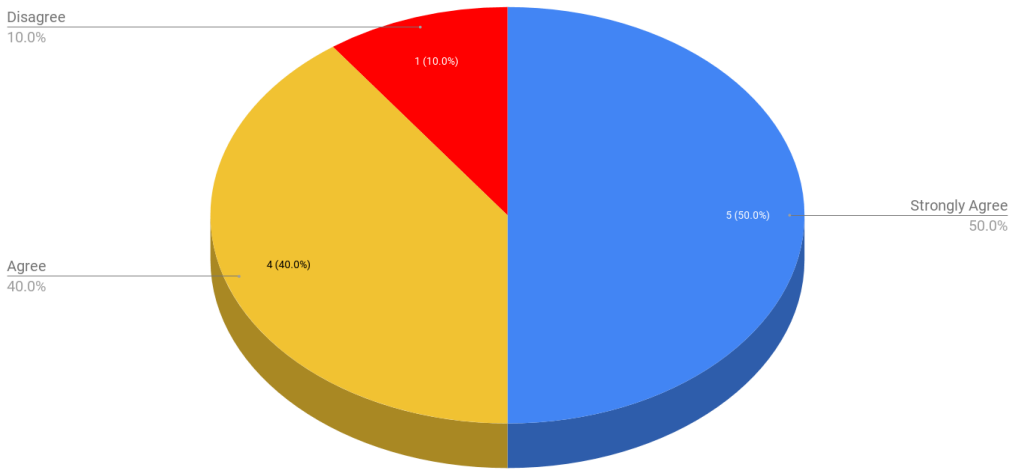

Figure 4.14: Pie chart based on the feedback of aforesaid topic

4. Being a parent, I have no problem if my kid use this application –

   O Strongly Agree O Agree O Disagree O Strongly Disagree

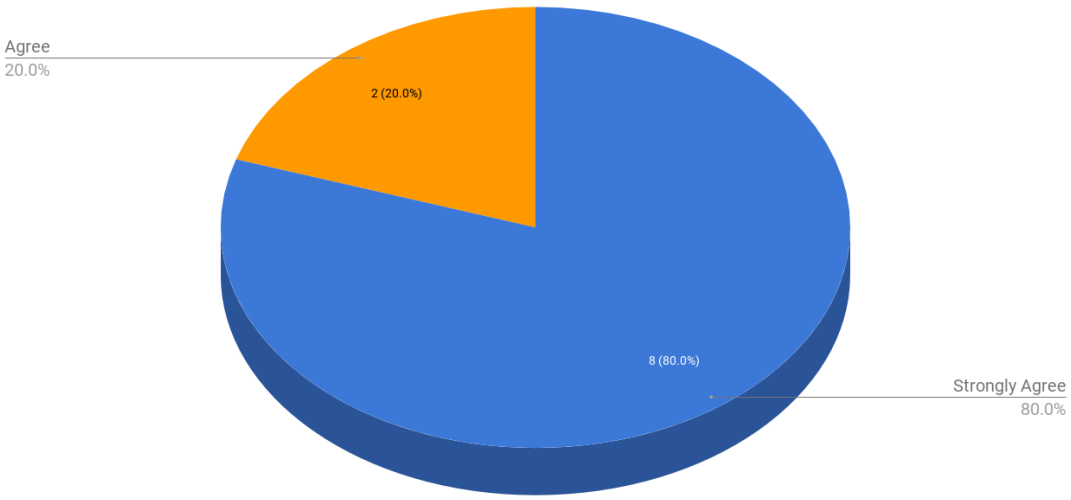

Figure 4.15: Pie chart based on the feedback of aforesaid topic

To teach kids with this app, we also applied a metaphoric group contest method where the kids were formed in few individual groups. Every group was supervised by a teacher who helped them learn via our augmented reality based mobile application instead of traditional books. After a grooming session, all teams came together. All of them had printed AR triggers with them along with the application on an android operated smartphone. In the first round, one group just showed the printed triggers to its opponent where the opponent were asked to speak out what letter it was. In the second round, one group simply pronounced out loud and opponent group was asked to find out the exact letter from the printed triggers. In order to make this study more meaningful, we also did a comparative study where we formed two groups. Each group had five members aged from four and half to six years old. One group was given the augmented reality application where as other group was given traditional books. The objective was, each of them had to learn about the proper shape of three Bengali letters.

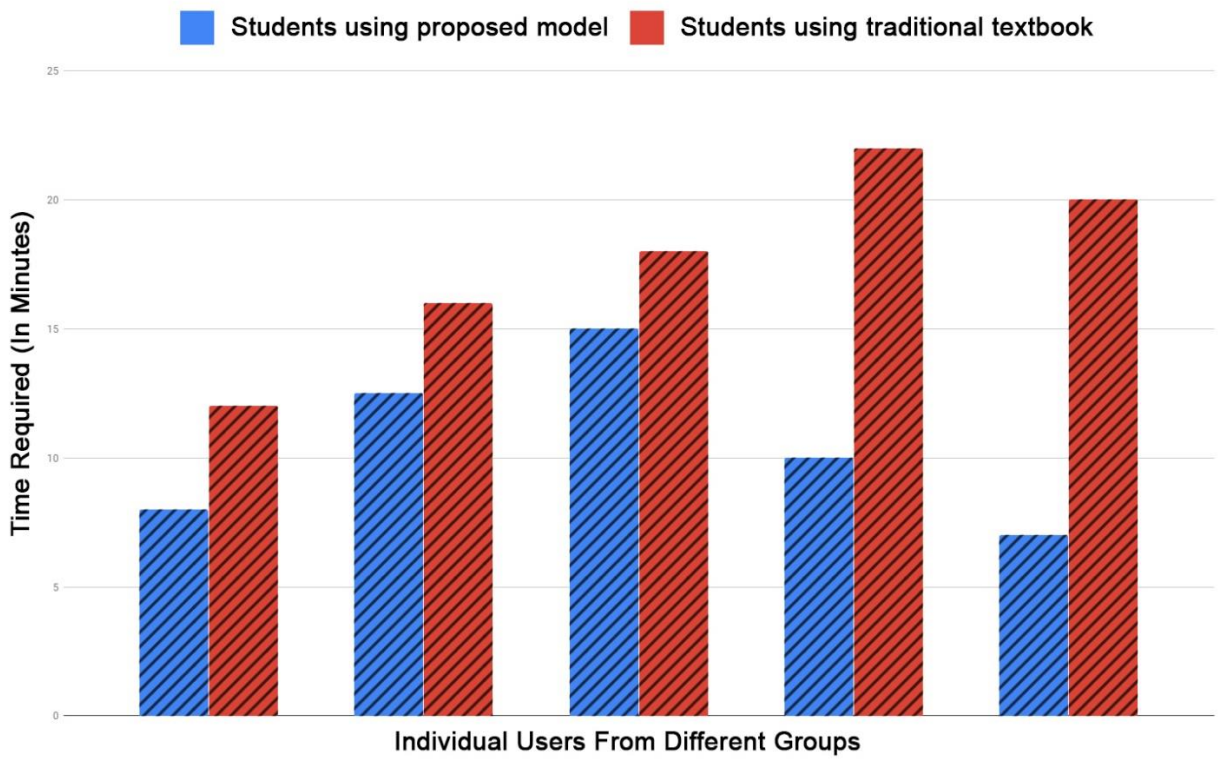

Figure 4.16: Comparative Study Between Proposed Model and Traditional Textbook.

Needless to mention, we assigned the same three letters for all to learn so that the output can be measured in a linear way. Our findings from this comparative study is represented in Figure 4.16 where group A, who used traditional textbooks are depicted by red color. And group B, who used our proposed model are depicted by blue color. Team A required an average time of 17.6 minutes to learn three letters. In this case the minimum time required to learn was 12 minutes and maximum was 22 minutes as stated in Figure 4.16.On the other hand for team B where the android based augmented reality application was provided, came up with an astonishing result. In this case the average time required to learn three letters was 10.5 minutes in an average. Here the minimum time required to learn was 7 minutes and maximum was 15 minutes as stated in Figure 4.16. In all our pilot studies, kids expressed their positive feeling about AR experience and it is expected that the proper utilization of this application will open a new door of possibilities to make learning easier, effective and enjoyable for kids.

Chapter 5

Conclusion

This thesis describes the detailed implementation process and demonstration of an android based augmented reality learning application. Our proposed model has the ability to teach Bangla letters to elementary kids by the help of cutting edge technologies like- 3D modeling and augmented reality. This documentation strongly points out our area of contribution that is Bangla language based elementary education. The reason of contributing on this particular sector is also described here in details. Right at this moment there are applications available on our focused platform and targeting the same purpose. But this thesis chalks out the core differences between our proposed model and prior contributions. We are not only implementing a model but also measuring its performance in different environments. At the same time we are unleashing the detailed polygon, vertex and edge count of every single 3D Bangla letter which has never published before. Thus future researches in this sector will get an anchor to move further. On the basis of our experiments with multiple environments, we found that the age group of 4-5 years old are the great suit for this model. Our experiments also suggests that male students performs better than female students while they use our proposed model as a medium of learning. Acquisition rate of male students is 3.08% faster than female students. Lots of challenges arose while implementing the model and every aspects of these challenges are mentioned in this thesis. The application is an excellent combination of 3d technology and game development process and appropriate utilization of the application can bring significant changes in the sector of elementary education holding the hand of advanced computing technologies.

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