An Augmented Reality Application to teach Human Anatomy to Secondary School Students

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Abstract: Students start learning about Human Anatomy starting from standard VI (i.e. between ages 10 - 15 years) and gain a basic idea about all of the important organs and their functions. However, a quick survey reveals that students find it difficult to visualize how human organs look from inside and outside. They also lack an understanding of the basic functions of these organs. Further, as most of the instructional medium is based on a two-dimensional static paper-based medium, it lacks the look and feels of actual organs.

To tackle this problem Augmented Reality (AR) technology was utilized. AR is an interactive experience of a real-world environment that is enhanced by computer-generated perceptual information, sometimes across multiple sensory modalities. AR is an easy and feasible solution through which we can see and understand objects which cannot be seen in the real-world.

The proposed interactive AR application helps students learn about Human Anatomy in detail. The application gives the users the option to view 6 different organs of the human body along with their internal parts in real-time. Information about each organ and its classified parts is also provided by the application. The application helps the students to learn and visualize the human organs properly. This paper presents a qualitative analysis study of the application which can help the students as a learning aid.

Keywords: Human Anatomy ∘ Visualize ∘ Augmented Reality ∘ Interactive Experience

1. Introduction

The utilization of Augmented Reality (AR) in training is a significant subject of exploration. AR empowers the expansion of virtual items into genuine conditions to encourage constant association. The utilization of AR has gotten increasingly open as it no longer requires particular hardware and may effortlessly be utilized on cell phones. The vast majority presently own cell phones, and the utilization of these gadgets has expanded, in this manner empowering more prominent access to AR. The applications for portable AR in instruction are expanding quickly, and the possibility of versatile AR has expanded because of advances in portable innovation. AR portable applications are accessible for a few regions of instruction, and training related AR applications are currently more regularly found on cell phones.

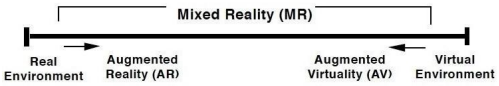
School is the primary stage where students learn science. Even now, with all the advances in instructive advances, the educating and learning forms in schools are as yet dependent on regular techniques. Although science course books are given in schools, beneficial learning materials are as yet required because some powerful ideas are hard to clarify in the conventional strategy for instructing. In this manner, a propelled learning material with innovation is required. Currently, teachers use the feature of videos and some applications which help the students understand the concepts. But, some concepts like Human Anatomy and Chemistry can still not be understood properly by the students due to the lack of visualization of the organs.

Augmented Reality is an innovation that can help in the viable learning process. The accompanying paper will talk about an AR Application which can assist the teachers and students with teaching and learning Human Anatomy all the more viably.

2. Literature Survey

2.1. Augmented Reality

AR combines real and virtual worlds, supplementing the real world with computer-generated virtual objects in real-time [1, 2]. According to one of the most commonly accepted definitions, AR is said to be a technology that has three key requirements: combining real and virtual objects in a real environment, aligning real and virtual objects with each other, and real-time interaction [3]. Fig. 1 shows Milgram's mixed reality continuum which is a taxonomy of how real and virtual elements may be combined. AR lies closer to the real environment end of the continuum as can be seen in Figure 1 [4].

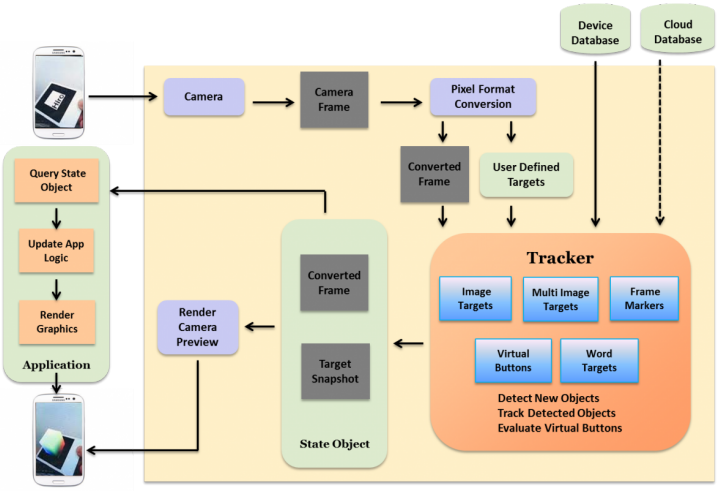


Milgram's mixed reality continuum
Fig. 1

In the case of mobile AR, technology involves the addition of digital elements to the real world through a smartphone camera. Examples of mobile AR applications include Pokemon GO, which is a location-based mobile AR game that enables users to catch various digital Pokemon creatures around their area.

2.2. SDK for Augmented Reality

Vuforia SDK is an AR software development kit for mobile devices launched by Qualcomm. It utilizes computer vision technology to recognize and capture planar images or 3D objects in real-time and permits developers to place virtual objects through the viewfinder of the camera and adjust the position of objects in the background of the camera. Vuforia SDK supports types of 2D and 3D objects including multiple target configurations, images with fewer symbols, and frame tags. There is an added function in the SDK. It takes advantage of virtual buttons to detect localized occlusion. Moreover, it can select and reconfigure the target image in real-time and create a target set according to the scheme [10, 11].



Workflow for Vuforia
Fig. 2

2.3. Augmented Reality in Education

Since its introduction, augmented reality (AR) has been shown to have good potential in making the learning process more active, effective, and meaningful. This is because its advanced technology enables users to interact with virtual and real-time applications and brings natural experiences to the user. Also, the merging of AR with education has recently attracted research attention because of its ability to allow students to be immersed in real experiences [5].

The educational value of AR is closely linked to how it is designed, implemented, and integrated into formal and informal learning environments. An important consideration is how AR technologies support and afford meaningful learning. Considering AR as a concept rather than a certain type of technology would be productive for educators [4]. The involvement of educators is important to facilitate the development of favorable AR applications for teaching, which increases the potential for AR to be incorporated in education [6]. AR applications have been developed in many areas of education.

2.4. AR in Healthcare Education

The effective development of healthcare competencies poses great educational challenges. A possible approach to provide learning opportunities is the use of augmented reality (AR) where virtual learning experiences can be embedded in a real physical context [7]. This study showed that AR was applied to a wide range of topics in healthcare education. Furthermore, acceptance for AR as a learning technology was reported among the learners and its potential for improving different types of competencies. AR provides opportunities for more authentic learning and appeals to multiple learning styles, providing students with a more personalized and explorative learning experience. It is believed AR will only become more ubiquitous in future medicine [8]. But despite all of this, the number of applications for healthcare to teach students is quite limited.

2.5. Speech Recognition in Augmented Reality

Automatic speech recognition has been brought into normal life recently by services like Apple's Siri or Google Now. People are more accustomed to speaking into their phone or computer, and they have come to expect accurate results from such encounters [12].

Application development that combines AR technology and speech recognition is expected to improve the productive vocabulary method as it reinforces the connection between visual scripts (orthography) and audio (phonology) in the reading words. A combination of speech recognition and AR can improve productive vocabulary methods through AR-based applications[14].

Today, implementing a speech recognition service is fairly straight forward through the use of software APIs such as Microsoft’s .NET speech recognition library. Such a library provides many data structures, such as Grammars, that allow developers to define words of interest, accuracies, and strings of words that should be recognized. The use of speech recognition software for an input module for this project was a clear requirement from the beginning [13].

2.6. System Usability Scale (SUS)

The System Usability Scale (SUS) was used to gauge the response of the test users after using the Human Anatomy application. Based on the SUS Scale changes were made to the application.

The SUS survey included requests for demographic information from users: their name, their company, their job role, the software being evaluated, the software version, date of the user’s evaluation, duration of the evaluation, and the user’s experience using the software. The survey then provided the following 10 standard

statements with 5 response options (5-point Likert scale with anchors for Strongly agree and Strongly disagree) [15]:

1. I think that I would like to use this system frequently.
2. I found the system unnecessarily complex.
3. I thought the system was easy to use.
4. I think that I would need the support of a technical person to be able to use this system.
5. I found the various functions in this system were well integrated.
6. I thought there was too much inconsistency in this system.
7. I would imagine that most people would learn to use this system very quickly.
8. I found the system very cumbersome to use.
9. I felt very confident using the system.
10. I needed to learn a lot of things before I could get going with this system.

There are several potential benefits of incorporating the System Usability Scale into the library website and system usability testing. The SUS has been in use for approximately 30 years and is a reliable, tested tool for evaluating a wide range of products and systems. The data it provides has a variety of uses. It can be used as a benchmark to measure how changes to a system or product are received by users. Or, it can be used to quantify user reaction to two alternatives, such as two different versions of the same web page or two different user interfaces, so that they can be compared for decision-making purposes. When used in conjunction with data gathered from other sources, such as usability testing, it can be a helpful supplemental tool for researchers who need to collect a source of big picture quantitative data that can be easily communicated to library administration and stakeholders [16].

3. Related Augmented Reality Applications

Today's technological advancement has led to various reforms in teaching and learning systems in the classroom. The tendency for children to use smartphones has motivated researchers to study the advantages of using smartphones in children. Nowadays, AR technology in the teaching and learning environment has attracted the interest of the community as it can attract children's attention in learning environments. There are several recent AR-applications in the educational field to see the effects and benefits to the students (Table 1). The use of AR applications is believed to be of interest to students to replace conventional and static learning environments with a more edutainment environment.

In today's life, technologies are very important and AR has become one of the most emerging technologies and started to gain attention among society. AR's ultimate goal is to provide better management and to access information wherever and whenever using a combination of interactive real-world and computer-generated world or virtual world in a coherent space. AR is a new technology that has the potential to be used in today's world of education and it has become more widespread and practical. Researchers have found that "AR-based education media could be a valuable and attractive additional material to education in the classroom and overcome some of the limitations of text-based methods, allowing students to absorb the material according to their preferred learning style". AR can also be used to improve traditional and static learning content in the classroom. This will appeal to children with additional media content such as audio, video, graphics, 3D objects, and more.

Some of the well-known AR applications and their features are listed below. ƛ Current Augmented Reality Applications (Table 1).

AR Application	Domains/Uses of AR	Features of Application
AR Solar System	1) Solar System visualized in AR 2) Different planets, Sun and Asteroid Belt can be visualized in detail	1) Information on every planet given in great detail 2) Marker-based application
360ed's Element AR	1) AR Technology for visualizing atomic elements 2) Periodic Table is shown in 3d according to various options like Ionization Energy, Atomic Number, Electronegativity, etc	1) FlashCards used as markers for every element 2) A quiz can be taken according to the information learned in the application.
Animal 4D+	1) Animals are visualized in AR 2) Each animal produce their respective sound	1) Information on every animal is provided 2) Flashcards of each animal are used as markers for augmenting animal
AR Tattoo	1) Artworks and Tattoos visualized using AR	1) User-made simple markers on their body to display AR Tattoo 2) Custom made tattoo made by the user can also be displayed
AR Human anatomy	1) Organs visualized in AR	1) Showcases only model of the organ 2) Single marker-based application
Asthi AR - Human Anatomy in Augmented Reality	1) The entire Human body along with organs can be visualized in AR	1) No information about the organ is given 2) Markerless application with no stability
AR Anatomy 4D+	1) Anatomy Atlas with AR elements	1) Multiple markers for the entire application 2) All organs of the human body can be augmented 3) Interactivity present but no information provided

Table 1

4. Methodology

The Causal Research-based approach was used before making the prototype to understand the needs of both the students and teachers. A basic set of questionnaires was prepared for both the teachers and students differently. The target participants were students studying in secondary classes (from classes VI to X). Teachers who participated in the research were the teachers who taught Biology to secondary classes.

Teachers and students were divided into different groups. Both the groups were given a defined set of questionnaires and were also asked to fill the System Usability Scale (SUS) questionnaire after using the application. A pre-usage and post-usage questionnaire were used as instruments for data collection. The questionnaires were in the form of a five-point Likert scale along with the System Usability Scale.

Questions related to the pre-usage questionnaire for the students were related to the difficulties they face during classes while studying the human body and how they generally overcome them. They were asked about the effectiveness of notes, textbooks, and the slides they use while studying. Also, they were asked about any specific organ which they felt that they were not able to understand during their lectures or were not able to visualize them properly.

Questions related to the pre-usage questionnaire for the teachers were related to the difficulties they faced while teaching about Human Anatomy to the students while in lectures. They were asked about which means of communication they use while teaching the students and what problems the students face while learning them. The teachers were also asked whether any particular organ they face difficulty to make the student visualize them better.

Questions related to the post-usage questionnaire were related to how the application is working and what difficulties they face while working with the application and whether the application is effective or not for the students. For this, the System Usability Scale (SUS) was used along with an open-ended Google Form to gauge the effectiveness and learn the reviews of the application.

4. Prototype

The prototype (Human Anatomy) AR Application was developed in Unity and using Vuforia SDK and was installed on a smartphone. Unity can be used to develop games, AR, and VR applications. After launching the application the user has to follow a set of instructions on how to operate the application. After the Instruction Phase, the user has to scan the provided marker to go further (Fig. 3).

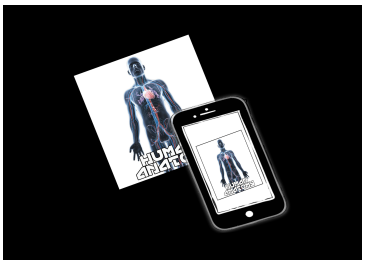


Fig. 3

After scanning the marker, 6 organ images placed equally on the circumference of the application image are displayed (Fig. 4).

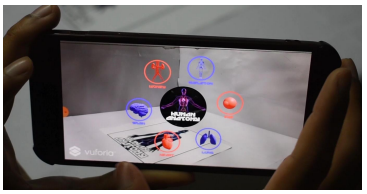


Fig. 4

Each image depicts the organ that will be shown. The organ showcased is a 3d-model which is shown in a real-world environment. The 6 organs which are shown via the application are the Brain, Lungs, Skeleton, Kidney, Eyes, and Heart. All the organs have a degree of realism with their animation and are constructed in such a manner that the students can easily understand the organ.

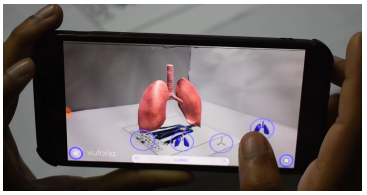


Fig. 5

An example will be the 3d model of the Lungs (Fig. 5). Each organ has been sub-divided into its various parts. By clicking on the organ part, only that part is shown and additional information about the part of the organ is also displayed (Fig.6).

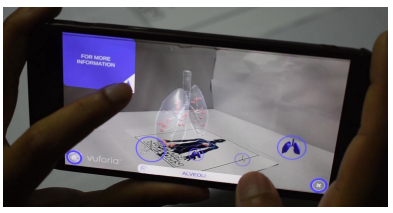


Fig. 6

If the student wishes to acquire more information about any specific part they can be redirected to the 'Wikipedia' page for that organ by clicking on the 'info-button' (Fig. 7).

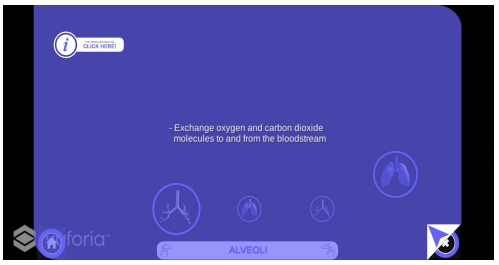


Fig. 7

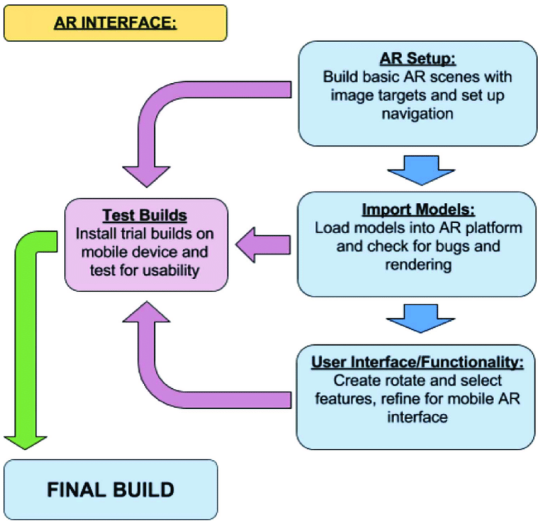


Fig. 8

Additional Features about the application is the zoom-in and zoom-out feature. A student can zoom-in or zoom-out on any organ by using two fingers to get a better look at the organ. Also, all the displayed organs rotate on an arbitrary axis by themselves which allows the user to see the organ from all angles. The user can stop the rotation momentarily when they want by holding on to the organ at any specific moment. Voice features are also available.

The Workflow of the application can be seen in (Fig. 8).

5. Results and Analysis

The overall Cronbach's alpha value obtained from the System Usability Score (SUS) is 0.856. An alpha score greater than or equal to 0.7 indicates an acceptable value, while an alpha value of 0.8 or higher indicates a good value. Therefore, the Cronbach alpha values obtained indicate that the results obtained were reliable.

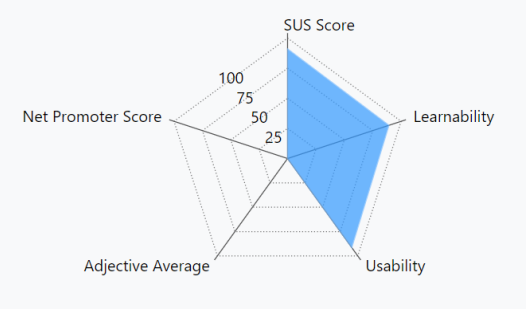


Fig. 9

After the post-usage questionnaire, the overall Learnability Score is 89.3 while the Usability Score is 91.5. The overall SUS Score comes to a total of 91.1 which is shown in the above graph

Using the open-ended Google Form using the five-point Likert scale we were able to test the application upon parameters like Visualization, Information, User Interface (UI), and the overall experience.

Fig. 10 shows that almost all the participants were able to visualize the organs better after using the application than the traditional approach of textbooks.

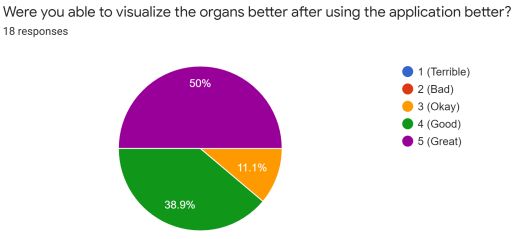


Fig. 10

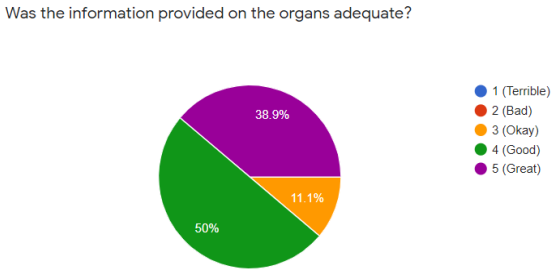


Fig. 11

Fig. 11 shows that almost all the participants were able to get adequate information needed about the various organs after using the application.

Fig. 12 shows that more than 80% of the participants liked the User Interface of the application and were able to use the application conveniently.

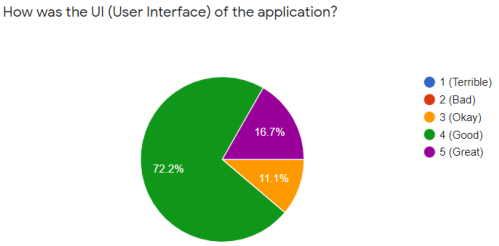


Fig. 12

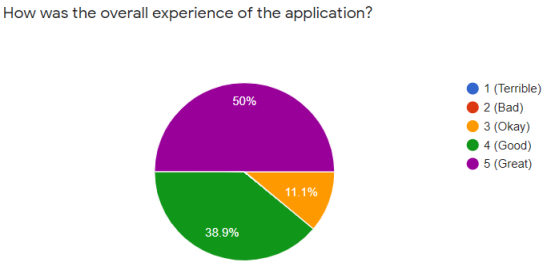


Fig. 13

Fig. 13 shows that the overall experience of almost all the participants was more than satisfactory. This shows that the participants were satisfied with the prototype of the application. Therefore, using the AR Human Anatomy application has been beneficial for the students and has a positive impact. Both students, as well as teachers, were motivated while using the application for studying or teaching purposes.

6. Conclusion

The objective of this research was to showcase an Augmented Reality application that helps in effective learning of Human Anatomy for secondary school students and to understand its impact. The literature indicated that there is insufficient research on the impact of using mobile AR in education, and there is room to explore the potential of AR to improve student learning motivation and contribute to improved academic achievement [9]. Augmented reality (AR) was defined as combining real and virtual worlds, supplementing the real world with computer-generated virtual objects in real-time, and AR was explained in the context of education. Mobile AR was discussed given that AR may easily be used through mobile devices

The Literature Review looked at the use of AR in Education followed by an overview of some previous studies which used AR applications. AR in Healthcare Education was also seen where it was followed by acceptance of AR as a learning medium which helps in a personalized and explorative learning experience.

The Methodology and the Prototype of the AR Application were discussed in detail. In-depth detail of how the application has to be handled was showcased. All the features of the application were discussed along with their pictorial representation.

The Prototype of the AR Application was well-received by the users. Compared to the current AR applications which are available the AR Human Anatomy provides many more features. Currently, the applications that are available on AR usually use multiple flashcards as markers. But, this can be much more cumbersome for the user. Compared to that our application is much more versatile and uses only 1 marker. Also, a lot of AR applications only show the model to the users and never give additional information to them. On the other hand, the AR Human Anatomy application gives a detailed explanation along with visualization experience to the users.

Analysis of the results shows that there has been a positive impact on the participants after using the application and is beneficial for both students and teachers. Further work has to be done to improve the application as has been said by Participant X, "Functions of the organs can also be added in short while labeling the organ name. Also, the connection between the organs should be told when the organ is displayed at the beginning."

7. Future Work

Future Working can be done on the application in various forms. Currently, markerless technology is available for users using the Google ARCore SDK but the stability of the markerless technology is still not good for Android devices. Additionally, SDK's like Google ARCore are only available on higher-end Android devices which can be more expensive for the general users. Since this application is for the general public of all communities markerless technology has not been incorporated yet but can be put into consideration for future purposes.

Additionally, for future work, we can incorporate features like Body-Tracking where the user has to scan a person and the scanned area will show about the organ. This way much more models and additional features can be added to the application.

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