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Development of Augmented Reality Application for Biology Education

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ABSTRACT

In biology education which is an inseparable discipline of medical and veterinary education, it is of great importance that enabling students to make practice in real conditions and gain knowledge and skills related to their professional fields during their education. It is necessary to adapt the new technologies rapidly to education rather than the use of cadavers or laboratory animals, especially when making practice directly related in human and animal anatomy. For this purpose, virtual and augmented reality applications, which have been developed rapidly in recent years, come to the fore as a highly effective technique with the possibility of interacting visually with the objects they give to the user. In this study, the techniques were examined that used in order to increase the learning performance in biology, anatomy, physiology and experimental animals and the process was examined to develop a specific mobile application on Unity3D application. It is envisaged that the difficulties in providing materials for students and ethical debates on the use of experimental animals can be overcome with the dissemination of augmented reality applications and virtual laboratories developed as a result of procedures such as the needs analysis, lesson or course content and scenario writing processes in addition to software development

Keywords: Virtual Reality, augmented reality, biology education, anatomy.

INTRODUCTION

Nowadays, biology education which is an inseparable discipline of medicine and veterinary education propounds great importance for students to be able to practice in real conditions and gain knowledge and skills related to their professional fields during their education. New technologies need to be adapted to education rather than the use of cadaver or experimental animals, especially when practicing issues directly related to human and animal anatomy. For this purpose, virtual reality (VR) and augmented reality (AR) applications, which have started to be developed rapidly in recent years, come to the forefront as a very

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effective technique with the opportunity of visual interaction with the objects given to the user (Kofoglu et al., 2019; Emreli et al., 2019; Diaz Nougera et al., 2019). Again, in recent years, AR applications processed with mobile devices due to ease of portability and increased processor power. The literature review of this study, which is aimed at developing an original application for education, consists of AR technologies and their usege in biology education. In their study, Yılmaz et al. (2018) conducted a literature review for AR technology and its use in education. It was seen that AR technology has been applied in the natural sciences, computer and information sciences, mathematics, engineering and humanities. It was revealed from the literature that was effectively used especially in the field of medicine, biology, physics, chemistry, geometry education, astronomy and museums, story-making activities, teaching cultural information, engineering and disability education. In these areas, it is determined that it is used in situations such as teaching of objects and events that are not visible, demonstrating dangerous situations, concretizing abstract concepts, presenting information levels where there is a lot of confusion. Nesterov et al. (2017) stated that AR technologies are replacing expensive laboratory equipment and students' level of interest increases due to the interaction of these technologies with students. In their study, Martin et al. (2015) investigated the relationship between education and perception by using theoretical knowledge with AR-supported laboratory practices. In the resulting evaluations; students feel comfortable when using AR environments and think that content learning, performance training, and design of facilities and machines are easy, useful and convenient for their purpose. In their study, Akçayır et al. (2016) investigated the effects of AR applications on laboratory skills and attitudes towards laboratory of university students. The quasi-experimental pre-test/post-test control group design was used. The results showed that AR technology significantly increased the development of laboratory skills of university students. Baloch et al. (2018) aimed to encourage students to use such kits with a user manual supported by AR applications in their research, thereby increasing the interest and ease of learning and reducing the workload of laboratory instructors.

One of the first examples of AR technology began with producing physical models for complex biological molecules through the 3D printing method. Physical model is transferred to computer environment by 3D scanning or computer modelling. Then, models advanced in computer with an interface developed for manipulating physical models and data computation and editing are printed with a 3D printer (Gillet et al., 2004). In a study by Weng et al. (2016), an AR technology using application was investigated that involve the topics of mitosis, meiosis, respiration and their systematic relationships for Biological Science in Malaysian secondary schools. In this application, the lessons are presented in special stereoscopic and photo-realistic views and thus the students are enabled to realize, memorize and understand the concepts of Biology. In the evaluations, the use of AR applications in the courses are told to have many advantages such as flexibility provided by the system, being safe, intuitive and interactive, enabling students to learn effectively by doing and interacting with the system as they learn complex processes can improve the sense of existence.

The use of AR applications as both educational and supportive technology in surgical interventions in humans or animals is becoming widespread. In many studies, it is mentioned that different AR technologies are used in medical and veterinary education, especially in the practice of surgical operations in addition to their use in medical and biology education (Nakamoto et al., 2008; Moro et al, 2017; Küçük et al, 2016; Ferrer et al, 2015).

In their study, Safadel and White (2019) introduced a method that demonstrates the use of AR and data from the protein database to facilitate the teaching of macromolecules in biology. Users can easily convert the molecular structures obtained from the protein database into 3D format and use them with an AR application to examine the molecules from different angles. A sample of 60 university students was randomly assigned to one of two conditions as

2D and AR. At the end of the experiment, participants completed a comprehensive test followed by a satisfaction survey. The results of the study showed a significant difference between 2D and AR in terms of satisfaction, media usage, perception and comprehension.

Saidin et al. (2015) investigated the studies on the use of AR in education. According to the investigation, since its introduction, AR applications have been shown to have good potential to make the learning process more active, effective and meaningful. This is because advanced technology enables users to interact with virtual and real-time applications and bring natural experiences to the user. In addition, the AR's merge with education has attracted the attention of research as it allows students to interact themselves in realistic experiences. It was seen that AR applications have a positive potential and advantages that can adapted to education compared to traditional technology (such as e-learning and educational software) and traditional teaching methods (speech and traditional books) in various fields such as Medicine, Chemistry, Mathematics, Physics, Geography, Biology, Astronomy and History. Huerta et al. (2019) developed an original mobile AR application within the scope of an international project in order to improve the technical performance of the people in Technical Drawing. In this context, Unity3D has been developed as a mobile AR application on the most needed issues. In practice, it is aimed to transfer Technical Drawing subjects from 2D papers to 3D environment so that they can be easily understood and taught.

In this paper, the authors present development of 3D interactive mobile based AR teaching system to help biology students improve on critical and complex topics such as biology, anatomy, physiology and experimental animals according to a learner needs.

METHODS

In such AR application development studies, it is important to correctly determine the content of the application. This study consisted of the "needs analysis" and material development stages in order to determine the limits of content and application. In line with the identified needs, these stages cover the development of training programs/scenarios (content) and the development of AR applications according to the scenarios determined with priority issues.

During this phase, these possible scenarios were actively used to understand how to best meet the user's requirements. Once the content and experience specifications were defined through storyboarding, the content and applications were developed using the AR design and development process (See Figure 1).

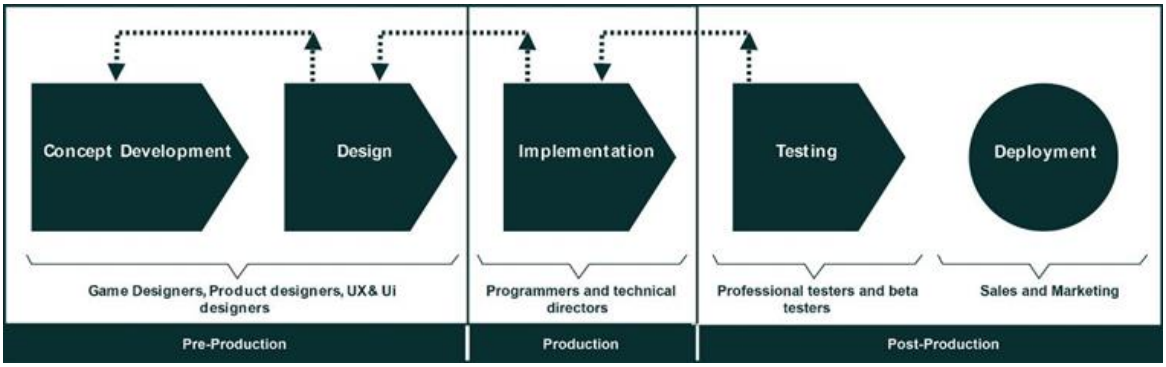

Figure 1. AR development process (Huerta et al., 2020)

a) Needs Analysis

The first stage of this study consisted of a survey conducted to help students identify the priority issues needed and awareness about AR applications in Biology education. In order for the needs analysis to be placed on a healthy basis, the scope and target audience of the subject were determined at first. 53 randomly selected students participated in needs analysis study. 6 of these participant are undergraduate Biology, 32 are Vocational School Laboratory-Health Technician program and 15 are High School students.

The need is the difference between the current situation and the desired or needed situation. Besides, analysis is a process that will be followed in order to reveal the difference between the current situation and the desired situation to be achieved in relation to the studies to be carried out for the educational program and material development in the subjects and areas with the propounded deficiencies. In this study, first of all, a questionnaire that does not include guiding provisions and judgments was developed and "The Differences Approach" was used to reveal the difference between observed and expected levels in the analysis of the data.

b) Development of AR Applications

The concept of AR is to present real-life images on the computer screen by adding objects created on the computer. With "Unity3D" software, which is widely used in AR applications, "vuforia" is frequently used to develop AR application and there also is available auxiliary packages such as AR Kit, Google AR Core, AR tools. This package includes ready-to-use code such as AR Camera, ImageTarget, MultiTarget, ObjectTarget (Kofoglu et al., 2018). The manipulation of the virtual environment in the real environment creates a new learning environment between teachers and students. AR emerges as a technology that will help students develop their perception, learning and visualization skills and become interactive teaching materials with a high rate of information transfer for teachers (Ali et al., 2017). Therefore, when developing AR application, it is important for both learners and teachers to choose software and hardware tools that are easy to use and provide high performance. A marker is often needed in AR applications. When this pointer appears on the camera of the device, it triggers the creation of virtual objects, and if the pointer cannot be traced for any reason, the virtual object disappears and the application becomes unstable. Unlike other AR tools for the positioning of virtual objects in 3D environment, ARCore uses the movement of the camera in the environment, the flat surfaces in the environment, the light of the environment and the position information of the device. Thus, there is no need for an external pointer (Güngör., 2017). ARCore infrastructure was preferred in this study considering these advantages and compatibility with the content to be developed

FINDINGS

In the Needs Analysis, there are 10 survey questions were used in 5-pointed Likert scale and 5 open-ended questions. The survey was directed to all parties identified in the target audience/ stakeholder study through the Google survey application. During the analysis, first of all, with the question groups, it was possible to examine the findings such as education levels and awareness-need relationship, education levels-expectations etc. The graph of the average of the answers given to the first 10 questions of needs analysis out of 5 is given in Figure 2.

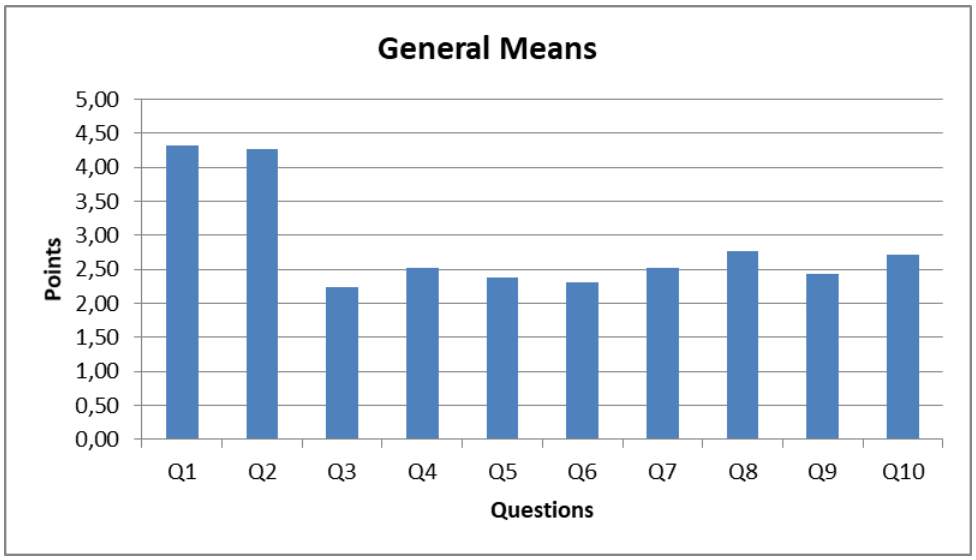

Figure 2. Means of answers to the top 10 questions of needs analysis

Based on the graph given in Figure 2, the following comments can be made when the headings are evaluated for the completed statement as "I think, you …" and the responds evaluated in range of "totally agree to totally disagree" on the 5-point Likert scale.

In the first question, the average of the answers of the students was quite high and 86% as expected to the given statement "in biology education, it is important to be able to practice in real conditions". Similarly, the average of the answers is 85% in the second question to the given statement as "good understanding of theoretical knowledge is important in biology education". It is clear that there is a need to carry out studies to cover the 15% lack of perception in these two statements. When these two questions are evaluated according to participant's education levels, it is seen that associate degree students are more familiar with the subject than the high school students and pointed that the applications are more important in the courses.

In the third question, the percentage of answers was determined as 45% to the statement as "Books used in biology education are sufficient". This result reveals the important need for a serious resource book for biology education. In other words, it reveals that the available resources are insufficient. In the fourth question which supports this analysis, it was seen that there is a 50% deficit that should be met in the statement as "there are enough images in the books used in biology education". This can be interpreted as a conclusion that biology courses should be based on visuality and practice similar to previous question.

In the fifth and sixth question, the percentage of the answers given to the statement as "in biology education, video with enough animation/real material is used" is very close to each other and on average 47%. This result shows that biology courses are taught with theoretical emphasis in schools from all levels. With another interpretation, the need for visual learning materials is at the level of 53%.

The average of the results is 52% to the given statement as "real materials/subjects are used in Anatomy/Histology trainings". In addition to theoretical knowledge, these courses are also requiring applications such as microscopic examination, dissection, demonstration of tissues and organs from the model. Therefore, the results can be interpreted as there is a need for the application lessons using more real materials.

Again, the average response of the participants is 48% to the statement as "real laboratory environments are used in laboratory training". In the laboratory, there are many courses from analysis to blood collection. These courses provide high persistent information when delivered both in a real laboratory environment created with tools and chemicals, and

using models, models or live materials to make practice. According to the results of the survey, it is seen that there is a more need for these kinds of laboratory environments. In the tenth question, the average of the answers is 54% to the given statement as "real materials are used in experimental animal course". The results show that there is not enough visual and application material in laboratory/experimental animal lessons. One of the starting points of this study is to meet the needs in this field with AR applications.

When the answers given to the open-ended questions of the Needs Analysis were grouped and evaluated, the following determinations were made;

79% of the students answered as "No" to the question as "Have you used AR applications for gaming or educational purposes?". This ratio is quite thought-provoking in terms of recognizing a current technology. Those who answered as "Yes" stated that they mostly used these applications in the playground.

Significant number of participants responded as "being more real and effective" to the question as "What role do you think AR applications, which are a realistic visualization of objects in a virtual environment, can play a role in education?".Some students underlined the necessity of practice by mentioning that learning with visual memory will be more efficient. Interestingly, some participants stated that it would be better to use live material instead of a digital application.

The majority of the students responded positively to the question as "What do you think about using biology applications on your mobile phone with AR?". The students pointed that this kind of applications might arouse curiosity in them.

Some of the participants declared that it would be useful and may be necessary to reduce the use of live animals and subjects when they introduced the question as "What do you think about the application of virtual surgery with AR applications instead of real material (cadaver, experimental animal etc.) in the courses where small surgical interventions are explained?". However, others declared that they would not replace with actual cadavers and live materials in practice.

Finally, the lack of practice in anatomy, physiology courses was mentioned in response to the question, "What are your suggestions about the topics in biology and biology related courses that you feel the absence and should be developed?". It was also stated that biology courses should be held in laboratories and laboratory conditions should be improved in schools.

MATERIAL DEVELOPMENT

a) Content and Scenario Development

The results of the needs analysis were evaluated together with the scope of the study and the targeted AR application, the content and scenarios to be used in the AR application were written and different scenarios were developed for the students to understand the subject. In the last phase of the scenario development, the voice texts were written which used on the AR applications. Below are examples of scenarios based on the AR application developed within the scope of the study.

Scenario 1: A cell model is selected for basic biology education. Then, it is written on the edges of the arrows appearing from the organelles of the cell by zooming the cell with finger movements. When the nucleus part was reached at last, both the double helix structure of the DNA model inside the nucleus can be examined and the duplication event can be observed by double click.

Scenario 2: In Biology - Anatomy courses, a model animal is selected for AR application to examine the anatomical structure of animals. In the first stage, the screen where

the whole musculoskeletal structure of this animal can be seen is moved by using the application in or on the virtual model. This will essentially provide an opportunity to see and examine all the limbs of the animal. In this way, the user can both see the organs of the animal and determine their position in the body.

Scenario 3: By clicking on an icon in application, the organs of the animal are separated from each other and the explanatory text appears if user clicks on an organ with the finger. Thus, the organs and their functions are explained briefly. At this stage, it may also be possible to make the explanations through voiceover.

Scenario 4: An icon (dissection tool) is used on the application at this stage to describe the dissection process. When this icon is clicked, the bottom view of the frog (lying on its back) is brought closer to the screen and the cutting process is done by holding the forceps with one hand and the scissors with one hand. And gradually the internal organs appear. Then, with the help of forceps, the internal organs can be shown in the boxes that appear on the side. As shown in below, a dissecting bag can be placed on the screen and the materials can be extracted one by one.

b) Case Study of AR Applications in Biology Field

The frog model used in the applications was obtained from the Unity3D library. In order to animate the scenarios, the tracks were recorded as three-dimensional animations in different scenes. After the animations are completed, the ARCore plugin is added to Unity. Within the scope of the study, an AR application was developed as in the screenshot given in Figure 3. A completed stage and an application development work in accordance with the scenario in Unity environment can be seen in Figure 4.

Figure 3. Menu content of the application

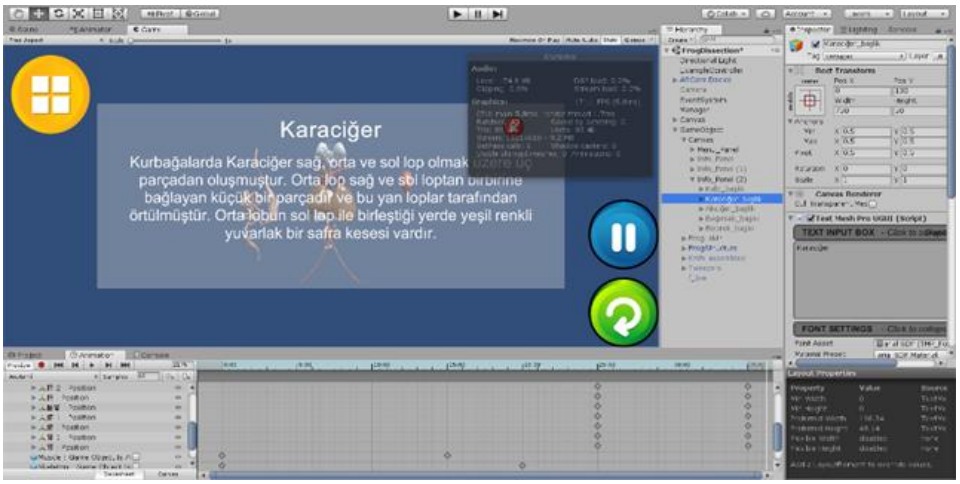

Figure 4. Developing scenario-appropriate applications in Unity environment

During the development phase, the interface of the application was designed and animations were prepared according to the scenarios.

Figure 1. Positioning the three-dimensional model on the mobile screen

After the appropriate animations were defined for the scenarios, the codes were written to keys to provide the transitions between the animations. After the changes were tested on the computer, the application was compiled as APK. OnePlus 5T, Samsung S8 Plus and Samsung S7 devices were used to test the application on mobile devices.

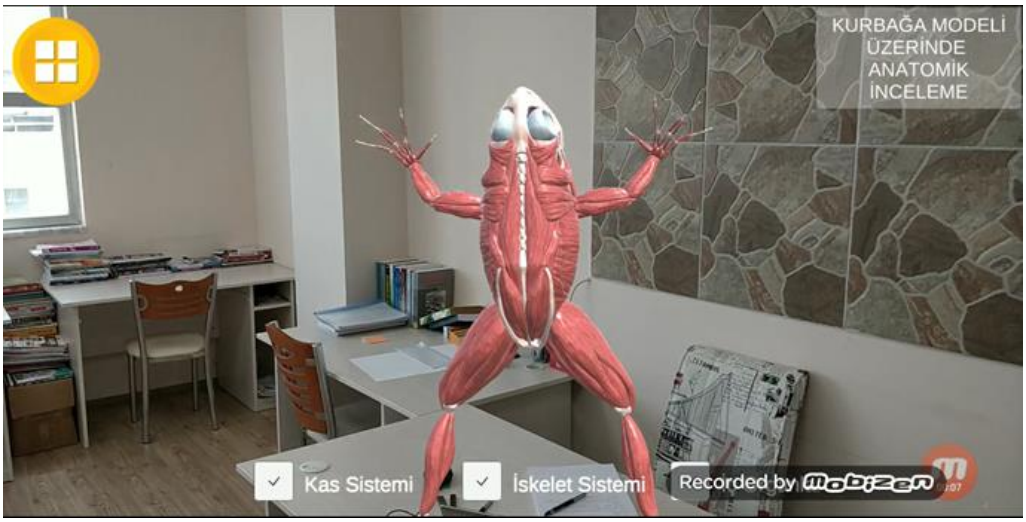

Figure 6. Demonstration of skeletal and muscular system with AR

DISCUSSION AND CONCLUSIONS

In this study, an original AR application was developed to support learning performance in courses such as biology, anatomy, physiology and experimental animals. Following the development phase of the application, implementation, testing and improvement stages were initiated. In the test phase of the study, a limited number of user (3 professionals and 3 students) were interviewed in order to provide a basis for measuring the impact of the ongoing development of AR application on learning performance. In the study carried out by face-to-face interview method, the opinions of professional and students about the use of the developed application in biology courses were taken. The collected data were subjected to content analysis and evaluated. Accordingly, use of AR application:

- It facilitates understanding with a 3D laboratory environment and increases students' motivation to learn.
- It increases the students' success in biology and especially experimental animal's courses as it increases their ability to animate events in a virtual environment.
- The application was found successful by all students.
- It was found insufficient to include the limited subject as it is.
- More topics and content should be developed, especially the basic biology concepts.
- The fact that it is aimed at mobile devices is successful in terms of accessibility and easy use.
- It is very useful in terms of performing experiments in virtual environment instead of real material, especially in courses where basic surgical interventions are explained.

According to user's feedback, some of improvements has been done on AR application as follows:

- In order to increase the user's interaction with the application, some organs was given the ability to access information panels containing more information by clicking.
- According to the normal operation, the object in the AR environment was fixed at the camera angle and the user could see the details around the object. Since this situation causes difficulties in the classroom environment, the application was given the ability to rotate the object on the horizontal and vertical axis by touching with the finger.

- Again, for the enlargement-reduction details of the part, it was necessary to pull the mobile phone back and forth. In order to eliminate this problem, the ability to enlarge and reduce with finger movements was added to the application.

The use of AR/VR in education is promising and useful in Teaching Learning. A multi-disciplinary approach is crucial. This approach brings a different perspective to Teaching learning methods and content development which results in a better experience for students. Students are more accustomed to using 3D games with a high level of visual detail where a substantial amount of investment may have been available for commercial projects. Therefore, a careful consideration of end-user requirements and expectations is needed to engage students. (Huerta et al., 2019)

The current study has not employed performance assessment of this AR application; although the user's initial reactions were positive. Future studies should evaluate and assess the usability of this AR application. For this aim, in the next phase of the study, the application will be evaluated by contribution measurements to the learning performance where the basic biology and anatomy issues are transferred to the virtual environment. At the end of this evaluation and improvement process, AR application is expected to fill an important gap in biology education. In this way, it was anticipated that difficulties in providing material for students and ethical discussions about the use of experimental animals can be overcome.

In future studies, capabilities such as development of mixed reality (MR) application in which both AR and VR can be used together and users can touch virtual organs and perform surgical procedures can be added by using VR glasses and equipment in order to increase the students' interaction with the application.

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