Mobile Application with Augmented Reality Focused on the Study of Human Anatomy

https://doi.org/10.3991/ijim.v16i24.34709

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Abstract—Education in current times has taken leaps and bounds, so the use of traditional classrooms in conjunction with textbooks and static 2D images is no longer enough, even more so in teaching human anatomy, which requires images and didactic methods, and easy understanding. In that sense, Augmented Reality (AR) is a technological tool that takes on great importance in various areas and education is no exception. For this reason, this research describes the results of the development of an application with AR focused on helping in the study of human anatomy, being developed with ARCore technology and the Unity IDE, following the Mobile-D methodology. The results were analyzed in 3 indicators (amount of light required, time required for surface recognition, and ease of use of the application), of which in the first indicator a good performance was obtained requiring only 30 lux for recognition of illuminated flat surfaces; for the second indicator, it was obtained that the delay time is 3 seconds, which makes it acceptable; for the third indicator, it was obtained that 93% of participants interviewed in the research agreed that the application is easy to use and very easy to use. From the developed application was concluded that this generally has good performance in the sections of the amount of light required, the time required, and ease of use.

Keywords—augmented reality, mobile-d methodology, mobile application, learning, human anatomy

1 Introduction

Education is an important human right, being this an engine for development that is able to guarantee equality of opportunity by reducing poverty, and improving the quality of life [1], because it helps to develop personal skills becoming the key to success [2].

The virtualization originated by covid-19 has led to new challenges in education, both for teachers and students [3] thus opening a new era in the educational system, where to obtain fluency in computational thinking [4], it is important to generate habits in students from an early age [5], [6] and to understand that technology is not only for entertainment and games but that there is also a world for education [7], [8], [9].

The boom of mobile devices originated by technological progress has made it possible for Augmented Reality (AR) to be much more powerful than in the past, becoming a great study tool for students, although its implementation in the classroom is still a great challenge. According to [10], [11], [12] this emerging technology offers us, thanks to the multiple sensors that mobile devices currently incorporate, the possibility of enjoying new experiences in which we are able to add digital content to the real world, allowing us to add text, images, audio video, 3D objects, among others.

A subject within education that is not absent from that reality is human anatomy, which is based on the study of the structure of the body, likewise, it has important elements such as the different systems present in the body, and although there is enough information about anatomy, this is still insufficient for learning because the content is usually not easily observable making it difficult to conceptualize the subject [13].

Human anatomy is based on the study of the structure of the body being considered basic in some branches of science, becoming important knowledge from an early age, because it allows us to know about the basic functions of our body, at the same time that would help the prevention and care of the human body. While there is a vast amount of literature regarding the field of human anatomy, presenting 2D graphics can become a not very optimal support tool; this is where the great capacity of AR is supposed to be a great support tool for the study of human anatomy [14], this is because it presents diverse multimedia content including 3D models, being more interactive and fun even more for children.

The proposed application aims to provide dynamic learning based on the use of AR focused on the study of human anatomy in primary school children, in order to provide an easy-to-use technological tool that allows them to better understand the Anatomy course. This will be achieved by analyzing different components that complement the performance of the AR technology, such as the light required to identify the flat surface where the 3D objects will be displayed, the time it takes to recognize the flat surface, and finally the ease of use of the application. Providing new technological solutions for the educational sector, supporting science learning in children.

This article has been organized into six different sections for a better understanding: Section II contains the literature review, carried out after the study of previous research related to the subject under study. Section III details the development of the applied methodology, as well as the development of the proposed system. Section IV shows the results obtained from the pre and post-implementation of the system, as well as the discussions of the results. Section VI details the conclusions obtained from the development and implementation of the system, as well as contributions for future work.

2 Review of the literature

The technology has proven to be a very efficient and beneficial tool for users of different ages [15], [16]. Immersing children in the use of technologies in their teaching-learning process provides a greater understanding of achieving effective results for their education [17], [18], in that sense, AR technology has been shown to bring productivity, efficiency as well as increase children's interest in the areas where it is performed, making way for their self-instruction [11].

Nowadays, Smartphones became of great necessity for day to day, this caused the demand for different services offered by the devices to increase, thus bringing more and more sophisticated devices facilitating the use of AR [19], which would be a great benefit to be applied in the area of education, this is given because it allows us an improved interaction with our environment [20], since this resource provides great contributions in teaching and learning, generating greater interactivity between teachers and students, better academic and practical performance, greater understanding and motivation [21].

Previously, different applications have been developed using AR technology as an interaction tool, showing outstanding results after its implementation. In the research article [8], the development of an AR application for the learning of pre-Inca cultures implemented in 3rd-grade elementary students was shown, obtaining that their academic performance in the course increased by 33%. Likewise in the research [22], a book was developed based on AR for autistic children to help them recognize facial expressions, taking into account the difficulty of the users, a score of 83% was obtained in usability tests and 87% in learning, demonstrating that the use of AR achieved that child could understand what they were taught more quickly and easily.

The field of medicine usually employs various traditional methods for its understanding and teaching, however, this field requires didactic strategies, so the use of AR can provide greater practicality in the visualization of human anatomy through 3D images [23]. Considering the above, teaching a child anatomy allows him to know more about his body, understanding the basic way it's functioning, leading him to better care of it and to salutary lifestyles [24]. The above references highlight the benefit of using AR for teaching human anatomy, as well as the need to jump from textbooks to 3D animations; however, the results of user testing are not shown, so it cannot be assured whether the proposed objectives were met. The above references highlight the benefit of using AR for teaching human anatomy, as well as the need to jump from textbooks to 3D animations; however, the results of user testing are not shown, so it cannot be assured that the proposed objectives have been achieved.

In this article [25] an augmented reality tool was developed for teaching and learning how the human body works, especially the heart. The application was evaluated in different ways, obtaining, as a result, the general acceptance of this tool by the users. This showed the great contributions of AR in human anatomy, as well as the need to integrate new dynamic strategies, which improve learning and provide greater interaction, experience, engagement, and immersion of students [26].

The technological tool proposed in this research aims to fill the missing gaps of previous research, evaluating three indicators that allow us to obtain concise information on the functioning of the developed application, evidencing with results the benefits of AR and its ease of use for students.

3 Methodology

For the realization of this project, the Mobile-D methodology was used, since this agile methodology allows continuous testing of the developed interfaces as well as user integration [27], this methodology focuses on the development of mobile applications, which consists of 5 phases.

3.1 Mobile-D methodology

Exploration. In this phase it was decided to develop the application with AR called "Anatomy-3D", for which the stakeholders, requirements, and scope of the project were established which is aimed at students of human anatomy who have a Smartphone or Tablet to visualize the content, serving as support for the course.

Initialization. All the necessary resources were prepared during the development of the product, both in hardware and software. We proceeded to prototype the application and its architecture.

Application architecture. The application by using the mobile device camera captures an image of the real world for analysis, once the image is captured, the ARCore SDK processes the image in search of recognizing the flat surface, once the surface is recognized it proceeds to generate the 3D object to be displayed on the screen while updating the application logic, as shown in Figure 1.

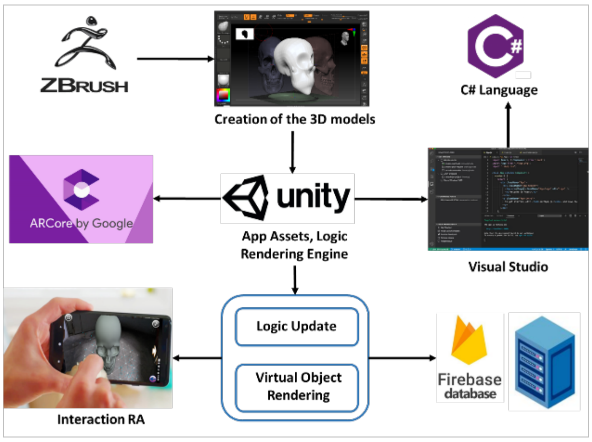

Fig. 1. Application architecture design

Navigation Scheme. The *prototyping* of the application was carried out, as well as its navigation scheme visualized in Figure 2, where the operation of the application was designed, as well as its respective menus, starting with the main menu where the option to learn is found, giving way to the AR content according to the chosen topic and ending with the questionnaire of questions.

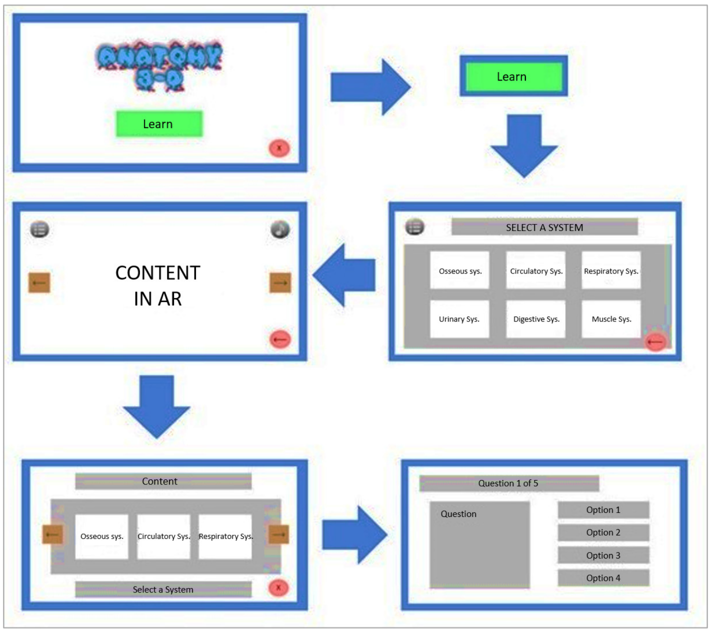

Fig. 2. Application navigation schematic

Production. In this phase, the application interfaces were developed based on the previously obtained requirements.

Figure 3 shows the interfaces developed for the application implementing AR technology. Figure 3(a) shows the start of the application which is given in the interface that shows a button with the option "Learn" which will take us inside the application, it also shows another button represented by an "X" which closes the application.

Once inside the application, Figure 3(b) shows the topics interface where one proceeds to select one of the six topics available within the application, which are: Bone System, Circulatory System, Respiratory System, Urinary System, Digestive System, Muscular System.

Once the subject has been selected, the application evaluates in a matter of seconds the flat surface as well as the illumination of the environment to subsequently display the 3D images of the organs related to the previously selected subject, as shown in Figure 3(c).

At the time of performing a test, the system to be evaluated is selected, being considered the 6 previously mentioned. Once the topic is selected, the question interface is shown in Figure 3(d), where 5 questions related to the selected topic are asked. Finally, Figure 3(e) shows the resulting interface, where the stars obtained after counting the correct answers are displayed.

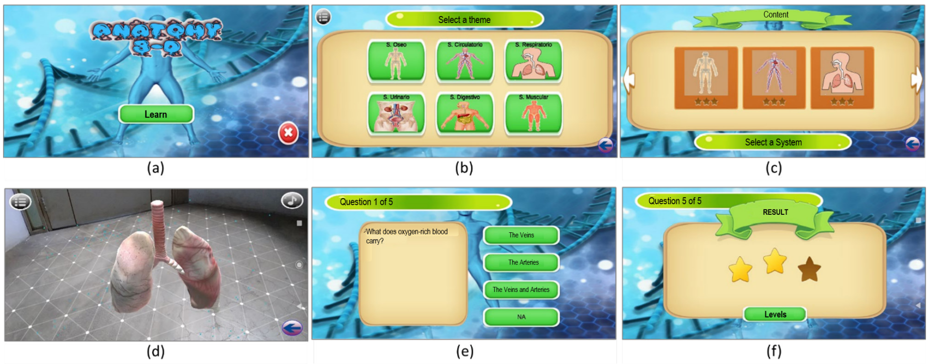

Fig. 3. Anatomy-3D application interfaces

Stabilization. In this phase all the developed modules were integrated. Figure 4 shows the coding in Visual Studios software of the 3D models within the application.

```
public class alternativaCirculatorio : MonoBehaviour{
    private Sonidos sonidos;
    private int nota = 0;
    private int cont = 0;

    void Start(){
        sonidos = FindObjectOfType(typeof(Sonidos)) as Sonidos;
    }

    public void botonRpt(Text Valor){
        Debug.Log(Valor.text);
        if(cont==0){
            if(Valor.text == "Las Venas"){
                sonidos.playAcierto();
                nota++;
            }else{
                sonidos.playError();
            }
        } else if(cont == 1){
            if(Valor.text == "Las Venas"){
                sonidos.playAcierto();
                nota++;
            }else{
                sonidos.playError();
            }
        } else if(cont == 2){
            if(Valor.text == "Las Arterias"){
                sonidos.playAcierto();
                nota++;
            }else{
                sonidos.playError();
            }
        } else if(cont == 3){
            if(Valor.text == "Nutrientes y Oxígenos"){
                sonidos.playAcierto();
                nota++;
            }else{
                sonidos.playError();
            }
        } else if(cont == 4){
            if(Valor.text == "Circulacion"){
                sonidos.playAcierto();
                nota++;
            }else{
                sonidos.playError();
            }
        }
        cont++;
    }
```

Fig. 4. 3D model code

Testing. It was verified that the developed product complies with the requirements established in the first phase, with the objective of guaranteeing compliance with the functional requirements in order to achieve user satisfaction, with a correct operation of the developed mobile application. In this phase the respective test cases were performed.

Verification and Validation. The AD-HOC methodology, which is an environmental impact assessment method [28], was used to verify and validate the evidence obtained, with the steps detailed below.

- The environments in which the tests were to be carried out were established.
- The number of tests to be performed for each objective was determined. (Table 1)
- The instruments to be used in each test were established.
- The tests for each objective were performed
- The data were obtained and interpreted.

Table 1. Research objectives

Objective	N° of Tests
KPI-1: ARCore API requires little light for recognition of a flat surface	22 tests
KPI-2: The use of Markerless technology requires little time for the recognition of a flat area.	30 tests
KPI-3: The ease of use of the mobile application with augmented reality to study human anatomy is high.	20 tests

4 Results

After the corresponding tests, the necessary techniques were used and the following statistical results were obtained

4.1 Results of KPI-1

These tests were performed using the mobile application developed a number of 22 times together with a light meter, in charge of measuring the surface illumination level (Lux), all this in order to identify if the ARCore technology is adequate. Once the tests were completed, the following results were obtained:

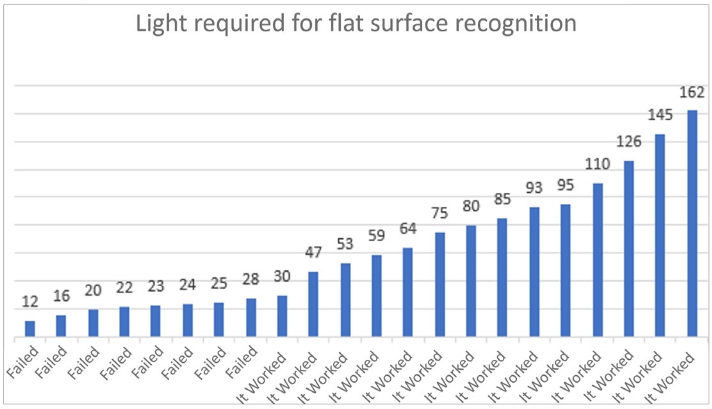

Fig. 5. Light required for recognition of flat surfaces

From the tests carried out, it can be observed that the application is able to work correctly as long as the amount of light on a surface exceeds 30 Lux, otherwise, the application starts to present errors when performing the recognition of flat surfaces.

4.2 Results of KPI-2

The tests were performed using the mobile application 30 times by recording the smartphone screen while using the area recognition function. Subsequently, the recording was cut with Camtasia Studio to find out how long it takes for the application to recognize a flat area. Once the tests were completed, the following results were obtained.

From the results obtained for the flat surface recognition time test shown in Figure 6, it can be observed that the average time for flat surface recognition by the application is 2.52 seconds.

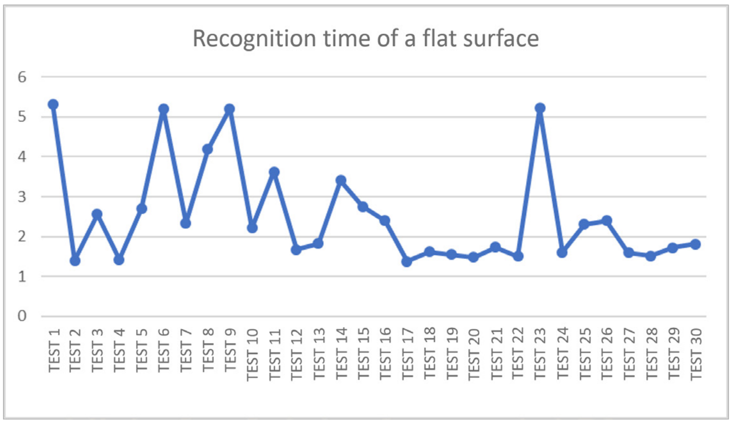

Fig. 6. Recognition time of flat surfaces

4.3 Results of KPI-3

These tests were carried out with 20 people who were asked to use the mobile application and when they finished using it, they were given a questionnaire, where they were asked if they found the application easy, very easy, difficult or very difficult. Once the tests were completed, the following results were obtained.

Figure 7 shows the results of the ease level in which 53% of the tests showed that it is very easy to use the application, 40% of the tests found it easy, while 7% of the tests found it Difficult.

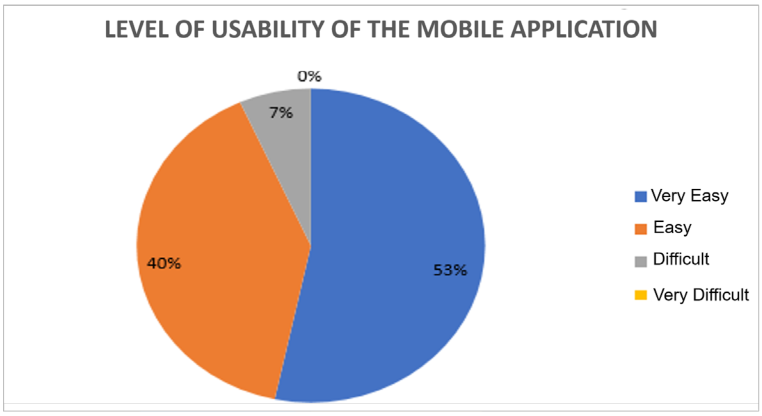

Fig. 7. Percentage obtained for the ease of use of the mobile app

5 Conclusions and future work

The main objective of this research was the development and implementation of a mobile application with AR focused on the study of human anatomy, in order to provide dynamic learning in the course, aimed at elementary school children. Which the light required to identify the flat surface where the 3D objects are shown, the time it takes to recognize the flat surface, and finally the ease of use of the application evaluated by the users was taken into account.

Regarding KPI-1, the ARCore API has a good recognition performance of flat surfaces illuminated with more than 30 lux, which makes it acceptable.

Regarding KPI-2, the Markerless technology used in the research in order to recognize flat surfaces has an optimal recognition time, being mostly no more than 3 seconds, which makes it acceptable.

Regarding KPI-3, 93% of the participants interviewed in the research agreed that the mobile application developed is easy and very easy to use, which makes it acceptable.

The developed application concluded that, in general terms, it has good performance in the sections of the amount of light required, the time required, and ease of use. Highlighting the results obtained on the research [15], [16] mentioned in section 2, supporting the reliability of the use of AR in the teaching of human anatomy.

The scientific contribution provided by this work serves as a basis for future research related to the implementation of technologies in the field of education. For future work, it is recommended to implement technologies such as Virtual Reality, which would complement AR, in the development of laboratory scenarios, for better interaction with students.

Finally, it is recommended to install the application on mid-range phones upwards, this is due to the use of the ARCore API used in this research which may represent a drawback if you want to work with low-end cell phones, incompatibility problems.

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Article submitted 2022-08-14. Resubmitted 2022-10-13. Final acceptance 2022-10-15. Final version published as submitted by the authors.