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PAPER

Mobile Application with Augmented Reality and its Impact on Anatomy Learning in Human Medicine Students

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ABSTRACT

This paper presents the development of an augmented reality (AR) mobile application to display 3D structures of the human body and evaluate its impact on anatomy learning in students of the Faculty of Human Medicine of a university in northern Peru. The need to improve educational quality is addressed, given that traditional methods often lack adequate resources and effective motivation for students. Through the application, which uses the Mobile-D methodology, 3D anatomical models, a database, and a supporting web page were created. The results indicate that the AR mobile application had a positive impact on the learning of first-year Human Medicine students with a significant improvement of 0.88 in the averages, since it provides them with the basic knowledge for the introduction to this subject, in addition to improving their motivation and being considered as a learning and feedback tool.

KEYWORDS

augmented reality (AR), human anatomy, mobile application, learning, motivation, human medicine, mobile-D

1 INTRODUCTION

In today's knowledge-driven society, continuous learning is emphasized, requiring a dynamic approach to education where the focus shifts from simply knowing to the ability to learn [1]. This is particularly crucial for higher education students, who must be equipped with quality education to thrive in a rapidly advancing and competitive world. As a result, there is a growing demand to leverage new technologies, such as augmented reality (AR), to enhance learning experiences. AR is a technology that overlays digital elements on the real world using devices such as smartphones and tablets, allowing users to interact with additional information

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in their environment. In education, AR makes learning more dynamic and interactive, improving information retention and facilitating the development of practical skills. In the teaching of human anatomy, for example, it allows students to visualize complex structures in 3D, better understanding their layout and function [2], [3], [4].

In Peru, educational quality is perceived as a major issue, ranking alongside citizen insecurity and corruption [5], [6]. This is evidenced by Peru's poor performance in the 2015 PISA test, where it was placed second to last in Latin America [7]. Many educational institutions, both private and public, continue to rely on traditional, rote-based teaching models, resulting in low proficiency in reading comprehension, mathematics, and science. Key challenges include unequal access and the low quality of education provided [8]. Despite these challenges, technological advancements have enabled the implementation of AR technologies in Peruvian education, as seen in a project aimed at developing journalistic text production skills in a Lima-based institution [9].

At the National University of Cajamarca, teaching models are predominantly passive, with information being transferred from teacher to student through traditional methods. This often results in students memorizing information without engaging in interactive learning experiences. Specifically, in the Faculty of Medicine, students lack access to necessary materials such as anatomical models for practical learning in human anatomy. To address this, our study investigates the question: How does the use of a mobile application based on AR impact the learning of human anatomy among medical students at the National University of Cajamarca? We hypothesize that implementing such an application will positively influence anatomy learning outcomes for these students. Practically, the project aims to enhance anatomy education by employing AR technology, thereby utilizing widely accessible devices like smartphones to introduce a novel learning paradigm. Socially, it seeks to produce a comprehensive documentary investigation and a system ready for implementation, assessing AR's impact on education and laying the groundwork for future research and projects. Professionally, the focus is on applying acquired knowledge and exploring technological tools, both software and hardware, for mobile application development.

Ferrer et al. [10] explored the application of AR in health sciences education in their doctoral thesis. The objective was to allow students to view anatomical drawings of the leg and foot in three dimensions on computer screens using AR technology. The results demonstrated that AR technology positively impacts first-year podiatry students' performance by enhancing their understanding of the material. Survey results indicated that students found AR to be a motivating tool, useful, interesting, satisfying, and enjoyable to use. This work is pertinent as it examines AR as an innovative approach to teaching anatomy, providing documented outcomes for comparison with other studies. Buenaventura [11] analyzed and implemented an AR system as a didactic strategy in a research project. The project involved using tablets to teach natural science topics related to the Earth's characteristics. The application was tested in a classroom setting, where it received positive feedback from students, who expressed increased attentiveness and a desire for more frequent use of the tool. This project is relevant to the research as it applies an agile methodology for developing an AR application, providing foundational insights for designing and developing similar systems.

Sedano [12] aimed to investigate AR and develop an AR-based application to enhance concept learning through mobile devices in his research project, which resulted in a prototype AR application focused on education, specifically in physics. The prototype demonstrated the potential of AR to facilitate learning and serve as a basis for future educational applications. The study concluded that software tools such as Unity, Blender, and Vuforia are valuable for developing AR applications. This study aids in understanding AR concepts and tools and highlights the educational benefits of AR systems. Chisag [13] proposed using technological tools in his project aimed at overcoming time and space barriers by using AR as a pedagogical tool to facilitate meaningful learning. The use of "Aumentaty" and 3D animations was highlighted for their advantages in promoting abstract reasoning, self-learning, interaction, skill development, and continuous teacher-student interaction. The study concluded that traditional teaching methods were monotonous and did not foster creativity, while the proposed AR application improved the teaching-learning process. This work guides research on educational challenges and the advantages of AR as a learning method for university students.

Cano and Mateus [14] conducted a project aiming to integrate AR into learning objects for computer engineering courses at Politécnico Colombiano "Jaime Isaza Cadavid." The project highlights how AR facilitates interaction between real and virtual elements, enhancing students' comprehension of course content. The study concluded that there is significant interest among educators in applying AR, which contributes dynamically to education. This work is relevant to the current research as it explores AR's role in educational content delivery, improving comprehension for higher education students. Alcarria [15], in his project, focused on implementing and validating an AR system on mobile devices to aid in treating phobias related to small animals, such as insects. The study included an overview of mobile AR advancements, libraries for development, and key scientific milestones enabling AR on mobile platforms. The conclusion suggests that AR systems on mobile devices can perform comparably to those on more resource-intensive platforms, facilitating new forms of user interaction. This research is pertinent as it aligns with the goal of implementing AR on mobile devices and provides insights into software tools for AR development.

Reque [16], in his project, "aimed to improve the management of sports championships by developing a mobile application for accurate registration and tracking. Utilizing the MOBILE-D methodology and ISO 9126 quality metrics, the project concluded that the application effectively enhanced championship management, achieving its objectives. This study is significant for current research as it applies the same methodology, offering a foundation for mobile application development. Córdoba et al. [17], in his study, aimed to determine AR's impact on cognitive skills among secondary students at Nuestra Señora del Carmen school. The study employed a pre-test and post-test with experimental and control groups, concluding that AR applications improved cognitive skills in students. This work is considered relevant as it supports using AR as a learning method, providing a model for structuring the current research. Salazar [18], in his thesis, developed an interactive tourism information source using AR to display 3D images of Peruvian tourist sites through a marker-based system. The study concluded that the AR development tool performed optimally, with 100% of users appreciating the application and 93% willing to use it frequently. This thesis is crucial for current research as it provides a foundation for analyzing AR development tools and designing application interfaces.

The aim of this study is to determine the influence of a mobile application with AR on the learning of human anatomy in medical students at a university in northern Peru.

2 METHODOLOGY

The study population includes students from the Faculty of Human Medicine of the Universidad Nacional de Cajamarca (UNC) who meet the exclusion criteria, that is, students from the faculty who have not yet taken the Human Anatomy course, being a total of 56 students, of which two sections of the II cycle of the Faculty of Human Medicine of the academic period will be taken as a study sample; of the attending students, a control group (A) of 26 students and an experimental group (B) with 25 students were formed. Where: A is a traditional method applied, and B is an AR method applied.

Since the sample is less than 30, it is feasible to use the Student T test for independent samples, which is most used for samples that are small in size, which compares the means of two groups of cases. Two questionnaires were applied to measure both the independent variable, through the usability and feasibility of implementation of the AREA mobile application, as well as the dependent variable, through the knowledge, motivation, and learning strategy of the students. The instruments were applied to two groups: one control (A) and one experimental (B).

A survey is applied using the Likert scale or cumulative rating scale, due to the advantages of its easy construction and the ease of measuring the negative, positive, and neutral degree of each statement. The survey is applied to the experimental group that uses the application in AR, where the first six questions are oriented to measure the feasibility of implementing the system, loading times, assessment of opinions regarding the design of the anatomical models, knowing the degree of conformity of the content developed in the application, and usability.

Surveys are applied on the Likert scale, to assess the motivation of the students; for this, a survey is posed to the control group with four questions, and for the experimental group, which corresponds to the last four questions. The survey is rated from 5 to 1. To collect information about learning, two assessment tests have been prepared, consisting of 10 questions, in which each question is worth one point, prepared according to the contents of the Human Anatomy subject, for both the control and experimental groups. However, for the experimental group, the questions are posed using AR through an "AREATEST" application that was developed for the assessment.

Before the assessment, for group A (control), in which a traditional method is used, a human anatomy sheet is applied, while for group B (experimental), in which AR is used, a human anatomy sheet is also applied, in addition to the "AREA" application, so that both groups develop the same contents prior to the questionnaire.

The reliability of the surveys used was carried out using the SPSS statistical program for a test group. A reliability of 0.855 was obtained for the survey of the control group, which is considered good, and a reliability of 0.9 for the survey of the experimental group, which is considered excellent. Figure 1 presents the proposed architecture of the structure and operation of the developed application. The application will be installed on a smartphone or mobile device with an Android operating system, which must have a camera to view AR. When the predetermined marker is recognized with the camera, the anatomical model is generated, and the connection to the database is established, which displays the corresponding information for each model.

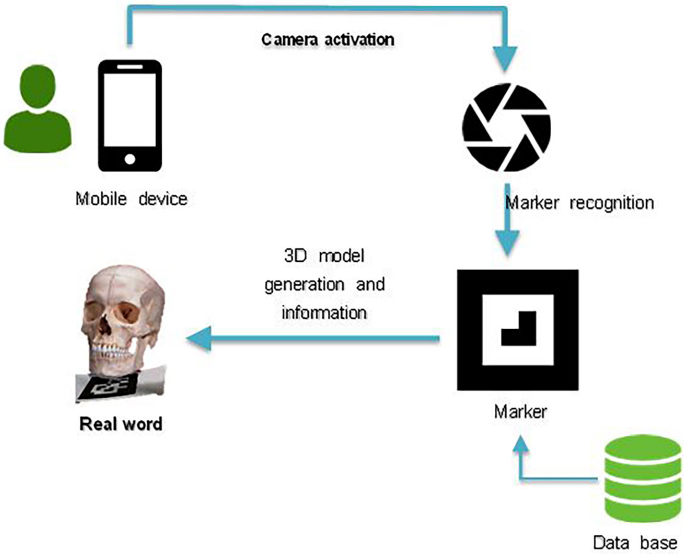

Fig. 1. Mobile application architecture

The development of the 3D models of the human body was carried out using the MAYA 3D software (see Figure 2). This tool allows for the use of triangles (tris) and quadrilaterals (quads) in modeling, with quads being chosen for this project due to their ability to maintain cleaner models and achieve better subdivisions. This phase of production is highly complex and time-consuming, given the detailed characteristics of each anatomical structure and the extensive number of models included in the application. For the 3D modeling process, extensive research was conducted using anatomical plans in the x, y, and z axes, based on human anatomy books and atlases. The characteristics of each model were defined, including aspects such as lighting, materials, scene placement, and textures, to ensure accuracy and realism. The design of the marker is based on the logo of the AR application "AREA." The marker features a dark border surrounding the logo to ensure a high contrast between bright and dark regions, as well as to introduce randomness. This design approach facilitates the Vuforia AR libraries in creating a greater number of recognition points on the image, enhancing the marker's effectiveness for accurate detection. The application was developed with Unity, as shown in Figure 3.

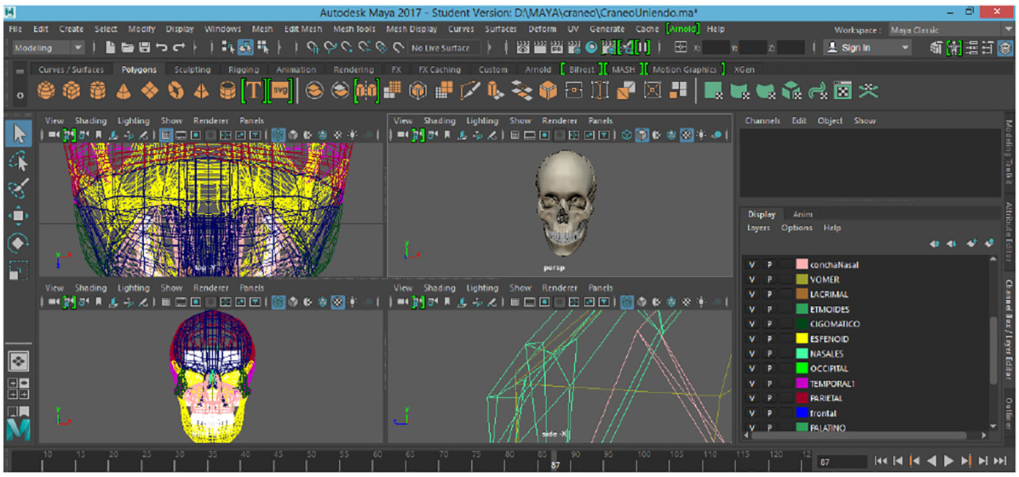

Fig. 2. 3D modeling of head bones

Fig. 3. Home screen development

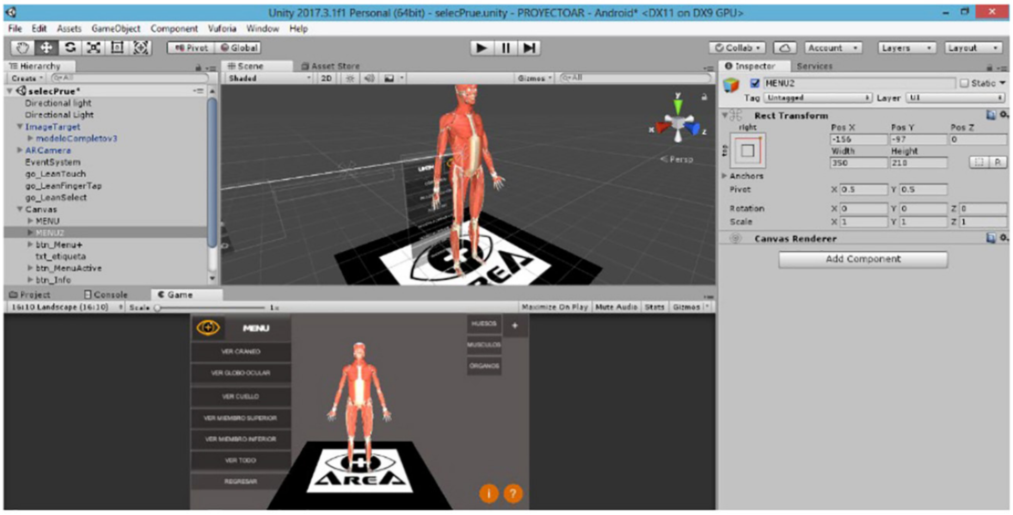

Fig. 4. Application operation with integrated modules

In this phase, the final actions involve integrating the implemented functionalities and correcting any errors that arise. The product is completed, quality improvements are made, and the project documentation is finalized. The stabilization phase ensures the system operates cohesively as a whole, as illustrated in Figure 4.

3 RESULTS

Below, in Figures 5–9, are the most representative screenshots of the mobile application.

Fig. 5. Informative web page of the "AREA" application

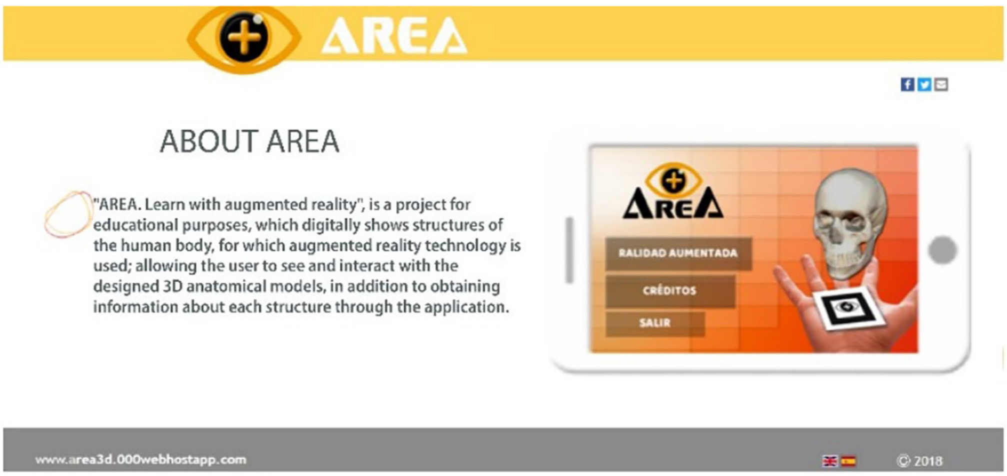

Fig. 6. Homepage

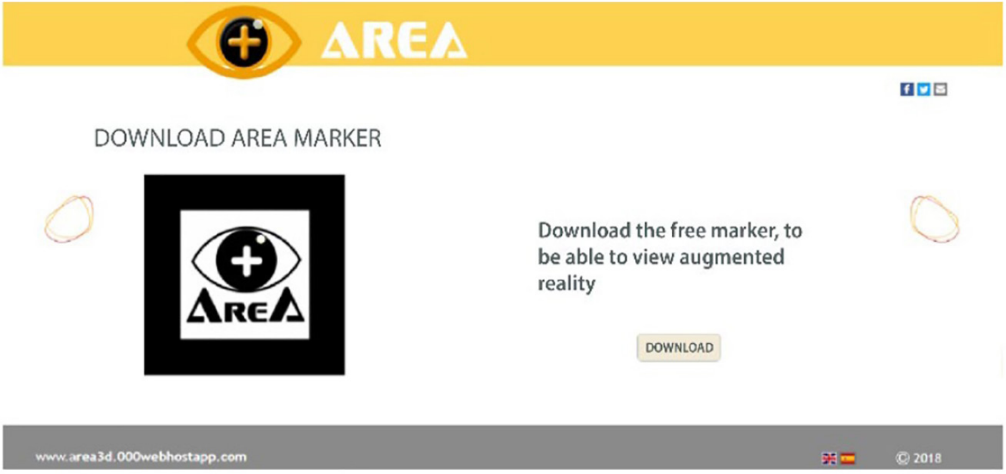

Fig. 7. Bookmarks section

Fig. 8. Human medicine students using the "AREA" application

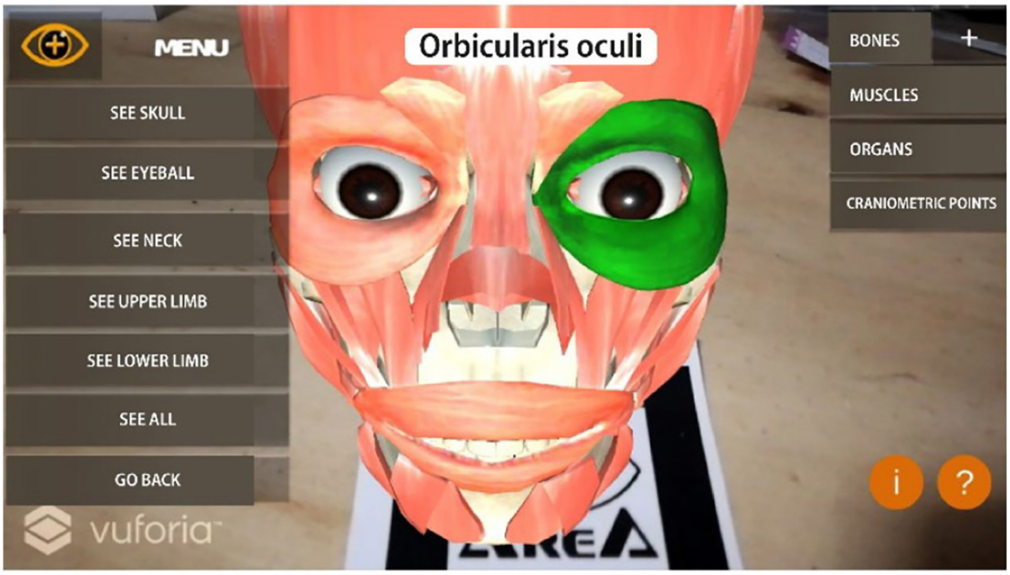

Fig. 9. 3D model scalar test

A survey is applied to group B (experimental), in which the AR methodology is used to measure the usability and feasibility of the "AREA" application. The results obtained from the collection of instruments are the following. In Figure 10, the usability survey results for the "AREA" mobile application are presented, showing the responses from 25 students. For the criterion regarding the application's load times, 16% of students strongly agreed, 52% agreed, 12% were neutral, 16% disagreed, and 4% strongly disagreed. Regarding the anatomical models displayed in the application, 28% were strongly in agreement, 68% agreed, and 4% were neutral. In terms of content presented, 44% strongly agreed, 48% agreed, and 8% were neutral. For the usefulness of the information provided, 60% of students strongly agreed, 32% agreed, and 8% were neutral. Lastly, concerning the application's ease of use, 40% of students strongly agreed, 28% agreed, another 28% were neutral, and 4% disagreed. Overall, most respondents approved of the application's usability across all criteria.

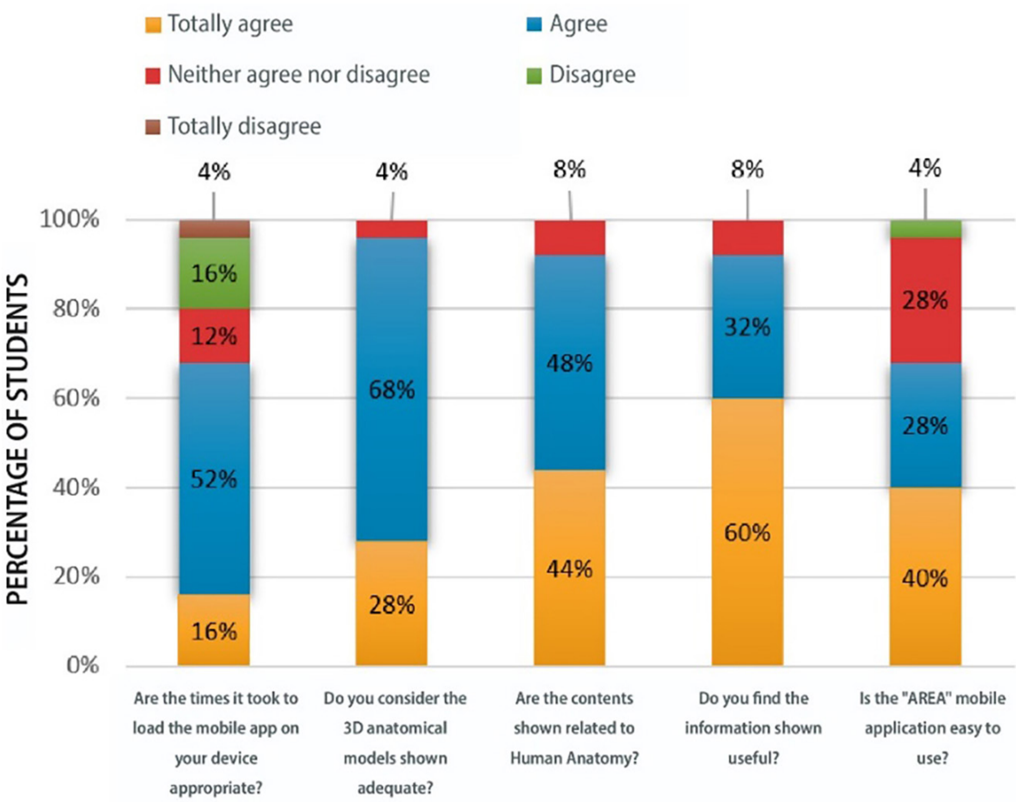

Fig. 10. Usability criteria of the "AREA" application

In Figure 11, the survey results for the control group, consisting of 26 students, are detailed regarding their perceptions of traditional teaching methods in human anatomy. When asked if the traditional method motivates their learning, 19% of students strongly agreed, 31% agreed, 35% were neutral, 12% disagreed, and 4% strongly disagreed. Regarding satisfaction with the traditional method, 4% strongly agreed, 42% agreed, 42% were neutral, 8% disagreed, and 4% strongly disagreed. When considering if they would use AR as a learning strategy or feedback mechanism, 12% were strongly in favor, 38% agreed, 23% were neutral, and 27% disagreed. Lastly, regarding whether they would recommend the traditional method as a learning strategy, 8% strongly agreed, 31% agreed, 23% were neutral, 35% disagreed, and 4% strongly disagreed. Overall, most students in the experimental group favored the criteria of motivation provided by augmented reality.

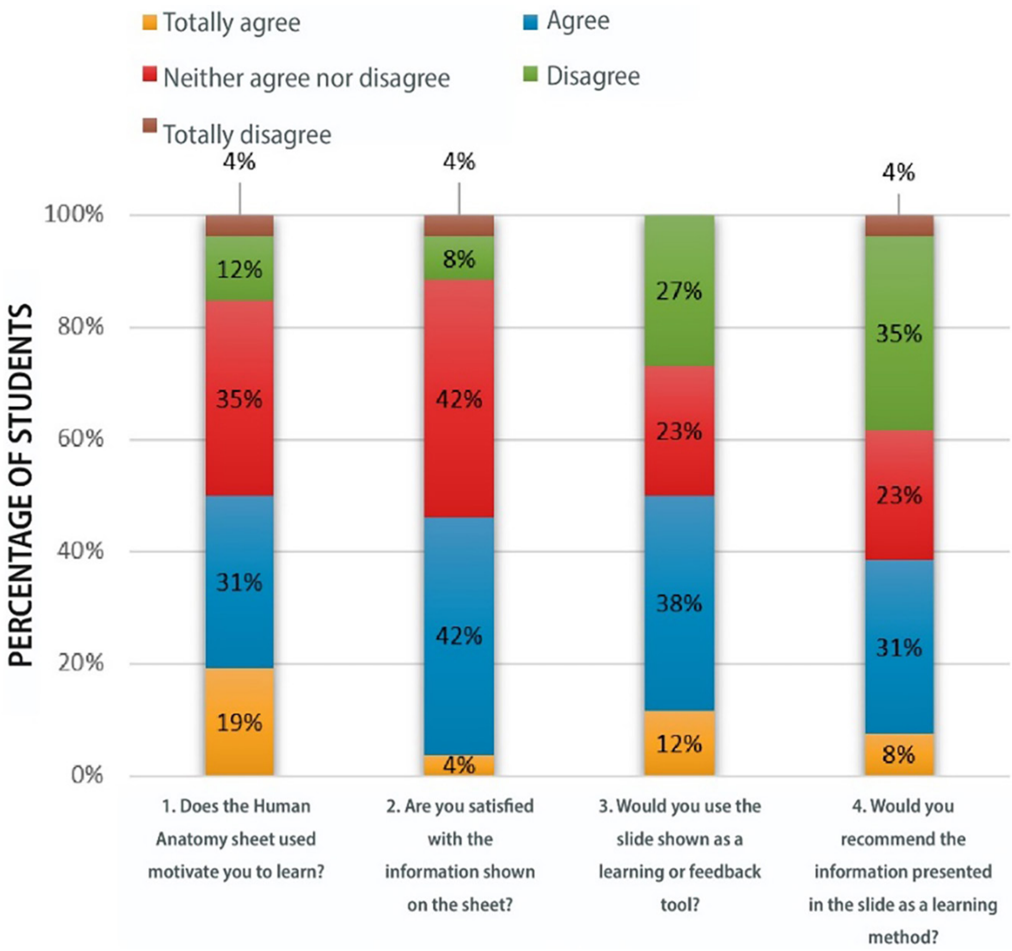

Fig. 11. Control group motivation criteria

In Figure 12, the survey results for the experimental group, consisting of 25 students, demonstrate their perceptions of using the mobile application for learning human anatomy. When asked if the application motivates their learning, 36% of students strongly agreed, 60% agreed, and 4% were neutral. Regarding satisfaction with the application, 24% strongly agreed, 52% agreed, 12% were neutral, and 12% disagreed. When considering if they would use AR as a learning strategy or feedback mechanism, 40% strongly agreed, 40% agreed, and 20% were neutral. Lastly, regarding whether they would recommend AR as a learning strategy, 36% strongly agreed, 40% agreed, 20% were neutral, and 4% strongly disagreed. Overall, most students in the experimental group approved of the motivational aspects of the application.

Figure 13 presents the results of the knowledge questionnaire for both the control and experimental groups. No student in either group scored below 4. In the control group, consisting of 26 students, 12% scored a five, 12% scored a six, 8% scored a seven, 15% scored an eight, 31% scored a nine, and 23% scored a 10. In the experimental group, with 25 students, no one scored a five or six, 16% scored a seven, 24% scored an eight, 8% scored a nine, and 52% achieved a perfect score of 10. These results suggest that students in the experimental group, who used the AR application, tended to achieve higher scores compared to those in the control group.

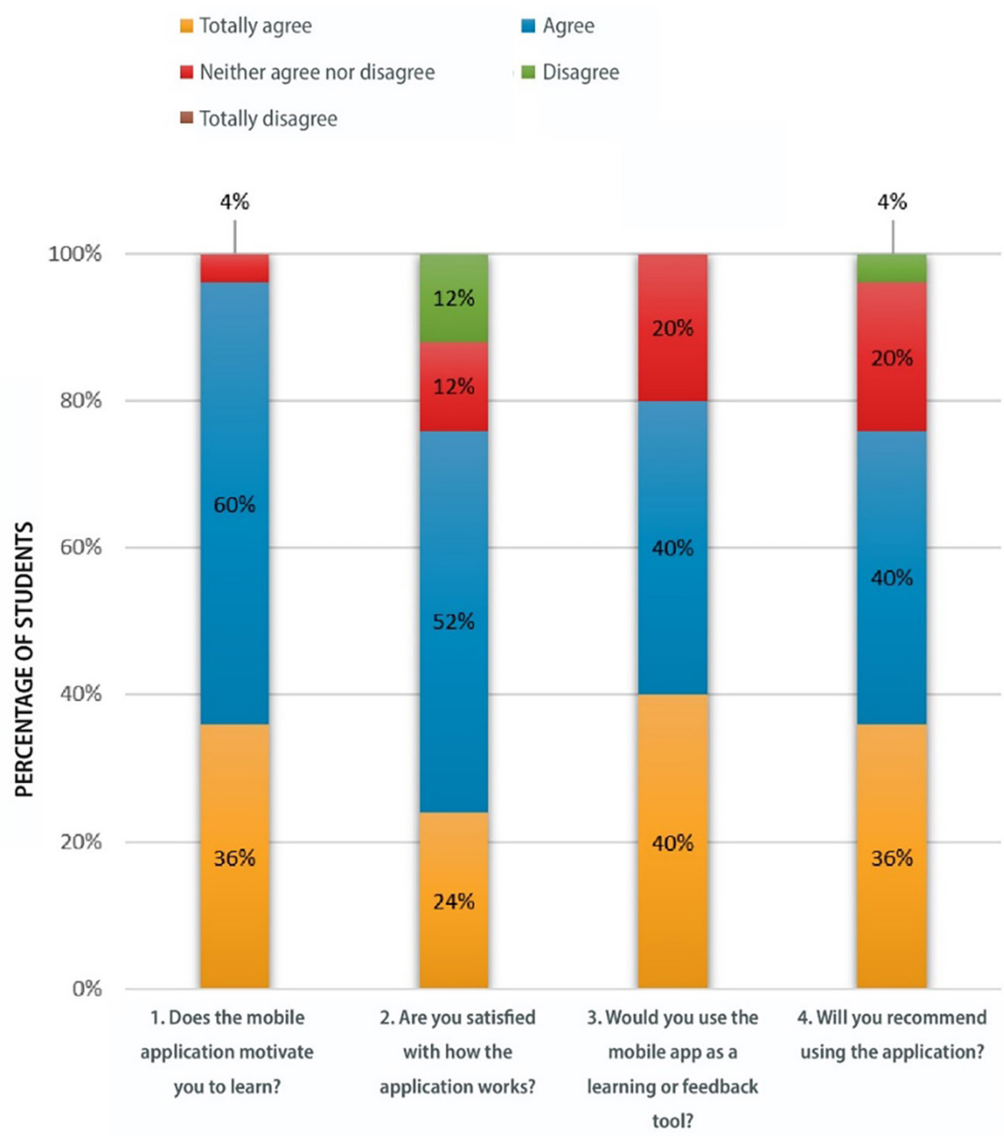

Fig. 12. Motivation criteria of experimental group

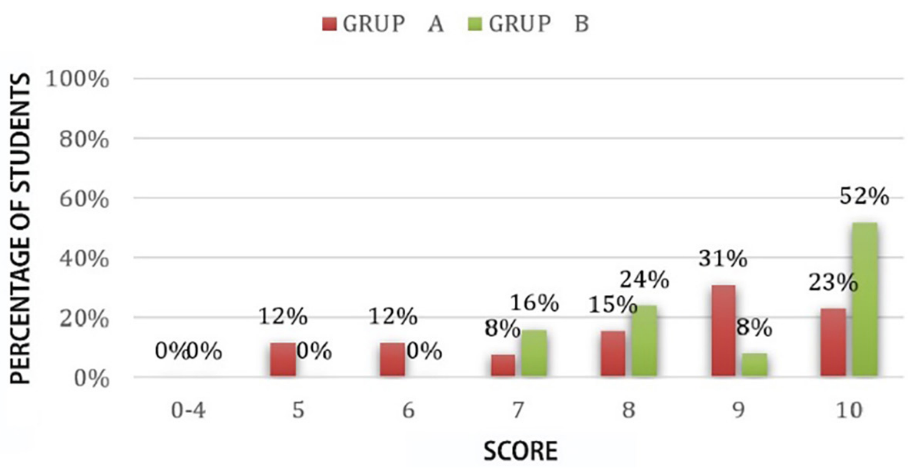

Fig. 13. Percentage of students by score

The value of t = –2.14 is not in the acceptance region, so the null hypothesis (H0) is rejected and the alternative hypothesis (H1) is accepted, which is why the use of an AR mobile application positively influences the learning of medical students at the National University of Cajamarca (see Figure 14).

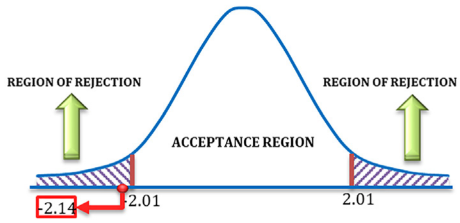

Fig. 14. Distribution graph for learning

The value of t = –3.76 is not in the acceptance region, so the null hypothesis (H0) is rejected and the alternative hypothesis (H1) is accepted, which is why the use of an AR mobile application improves the motivation of medical students at the National University of Cajamarca (see Figure 15).

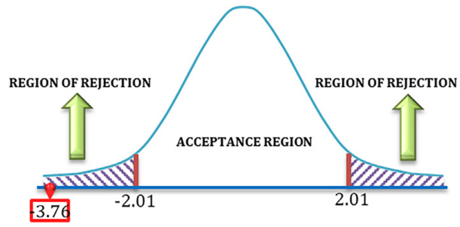

Fig. 15. Distribution graph for motivation

The results obtained are like those evidenced in previous research, such as that of Ferrer et al. [10], who concluded that AR is a tool that motivates and improves the academic performance of students in the study of the anatomy of the leg and foot in the teaching of health sciences. Another research with similar results is that of Chisag [13], who finds that AR does improve the development of learning for students of the faculty of human sciences. Likewise, Córdoba [17] concludes that the application of an AR system improves the achievement of the cognitive abilities of students of an educational institution.

According to the results of the survey carried out, AR can be used as a learning strategy, as demonstrated in his research by Buenaventura [11], who proposes AR as a teaching strategy in the natural sciences course for primary school students. It can also be used as a support tool for teachers, as demonstrated in their research by Flores Cani et al. [14] on higher education students. In addition, most students would not only use AR as a learning strategy and recommend it, but also those surveyed felt satisfied with the "AREA" application, as demonstrated by the similar results of Salazar's research [18], in which he found that 100% of users liked the application and would use it frequently.

We agree with Sedano [12], who, according to the prototype of an application based on AR that he developed, concludes that the computer tools Unity and Vuforia are very useful and facilitate the development of applications in AR; however, for this research, the use of MA-YA as 3D modeling software was chosen and not Blender as proposed.

The MOBILE-D methodology used for the development of the mobile application has an iterative cycle that allows obtaining functional deliveries that enable correcting development errors. The same is suggested by Reque [16] in his project, who uses the same methodology and concludes that MOBILE-D allows the development of a quality system since it focuses on the user and its development based on tests.

In addition, it coincides with what was proposed by Alcarria [15], who concludes that it is possible for the development of an AR system on mobile devices to work as well as a device with greater resources; however, although the developed application "AREA" works on most Android devices, it is necessary that these meet certain requirements for it to perform correctly, that is, to achieve good marker recognition and adequate loading times.

4 CONCLUSIONS

The work carried out represents a valuable contribution to the field of education in medical sciences, specifically in the learning of human anatomy. The proposal of a mobile application based on AR responds to the need to explore innovative methods that motivate students and provide them with more interactive and accessible resources. By using 3D structures of the human body, the study not only enriches learning but also aligns with current demands for digitalization in education. This approach has a positive impact on educational quality, as it counteracts the limitations of traditional methods and their lack of adequate teaching materials, such as physical anatomical models.

It is relevant to indicate that the results allowed us to verify that the educational tool based on AR achieved its purpose of significantly improving the learning and motivation of first-year medical students at the National University of Cajamarca, in addition to serving as a basis for future research and improvements in the application of immersive technologies in medical teaching.

The AR mobile system was developed using the agile Mobile-D methodology, which allowed functional deliveries of the mobile application; it was also implemented in the students, of whom most of them positively value the usability criteria.

Augmented reality was investigated, a technology that combines reality with virtual, which has multiple functionalities, of which it facilitates a 3D view of models and can be applied to various fields, one of the most outstanding in which it was applied is in the educational field.

The software requirements set out in the initial stage of the research were analyzed and met so that the contents of the mobile application are in accordance with the modules developed in the Human Anatomy subject and that the 3D anatomical models are also displayed in a student-friendly interface that is interactive and provides information.

In the development of the AR mobile application, there are several options for technological tools. For this project, an analysis of the main AR development platforms and tools was carried out to choose the most appropriate ones. Of these, Unity, Vuforia, and Maya were selected, which are very complete tools that allow free use.

It is suggested to use AR as a support tool for learning and motivating students in educational institutions.

Augmented reality needs certain technical resources to function properly, so it is recommended to use it on devices with a good processor (such as Dual Core), in addition to focusing the camera of the mobile device on the marker for recognition in a well-lit place, ensuring that it is in good condition and working correctly.

It is recommended to evaluate the creation of new modules and 3D models in AR that were not covered in this research, nerves, arteries, or veins, in addition to developing more specific and detailed mobile applications for each topic, such as neuroanatomy.

Augmented reality has many functionalities, such as facial recognition or GPS, which can be used in addition to the use of other platforms such as Google Cardboard or virtual reality headsets.

It is suggested to continue improving the functioning of the developed mobile application through the creation of new versions.

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