Human Body AR: A Mobile Application for Teaching Anatomy for Elementary Students Using Augmented Reality

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Abstract. When the children arrive at the educational institution, they have prior knowledge of the world around them. These previous knowledge's are the product of their experiences, games, among other activities, and based on this knowledge, they can explain facts and natural phenomena. Traditional teaching methods do not allow adapting to the learning that students need, therefore the use of technological tools in education provides different learning opportunities for both students and teachers. The present research evaluates at the usability level an application that we have developed for the use of augmented reality to improve the anatomy teaching process, the use of this technology allowed us to improve the learning process, the validation of this research was carried out using a methodology to evaluate the didactic value of educational software, and this evaluation was carried out in a group of teachers.

Keywords: Augmented reality · Usability · Education · Anatomy

1 Introduction

This research focuses on carrying out a case study from the perspective of the educational usability of an augmented reality application for teaching anatomy. Usability is the degree to which users interact with an application that must be effective, efficient, and easy to learn. In the design of the application, we have taken as a basis the traditional method of teaching anatomy where different activities are used, which describe the different parts of the human body and begin with a general approach reaching specific topics. On the other hand, the use of augmented reality is carried out through the recognition of surfaces where after establishing reference points, either horizontal or vertical surfaces are created, and on these surfaces, 3D models of the different parts of the body will be generated. Finally, the case study was carried out with different participants who conducted a survey measuring the usability of the application at an educational level.

2 Augmented Reality

Augmented reality (AR) is a variation of virtual environments (VE) or virtual reality (VR). Figure 1 shows a vision of the continuity between virtuality and reality defined by

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Milgram in 1995 [1], where VE technologies completely immerse the user in a synthetic environment (right of the Fig. 1), not being aware of the real world that surrounds.

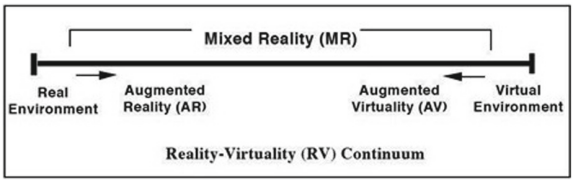

Fig. 1. Milgrams reality-virtuality continuum [2]

In contrast, AR allows the user to view virtual objects overlaid in the real world. Therefore, AR complements reality rather than completely replacing it [2]. Thus, Azuma defines AR as a technology that meets 3 characteristics [3]:

a. Combine virtual and real content.
b. Interactivity in real-time.
c. A union between a 3D environment of real and virtual objects.

There are different investigations of the use of augmented reality in education, of which we can highlight the following: In an investigation they analyzed the educational usability in the use of augmented reality and gamification for the teaching of zoology [3]. In another study, they proposed the use of tools such as the Kinect for the creation of educational virtual environments to teach anatomy concepts [4].

3 Teaching Anatomy

The Ministry of Education of Peru (MINEDU) proposes the use of learning routes to guide the correct teaching to students, as well as the faculty of articulating, integrating, and transferring knowledge through the exercise of a set of abilities and skills that allow the development of operations mental or actions on reality [5]. The indicators that children are expected to learn about the area of anatomy are:

1. Characteristics of the organs of the human body.
2. Functioning of the organs of the human body.
3. Identification of the systems of the human body.

For this reason, to achieve this learning, teachers make use of materials such as:

1. Metallic board and illustrated plates of the systems of the human body.
2. Cards with descriptions of the organs.
3. Paper, markers and adhesive tape.
4. Colored cards.
5. Science and Environment Book provided by MINEDU.

Biology, anatomy, physics and astronomy are important areas of study but difficult to teach since traditionally texts and images are used, but this type of content does not generate a correct immersion of the course towards the student. That is why through the use of AR, new learning opportunities are obtained thanks to the interaction of the real world with digital objects, in the area of anatomy it is possible to visualize the 3D models of the human body which may contain animations that show the different systems and the relationships that exist between them, providing greater interactivity in the student's learning process.

There are different investigations focused on the use of technologies for teach- ing anatomy, of which we can highlight: The development of a simple, light, and inexpensive three-dimensional visualization device based on MR, where doctors can see radiological examinations [6]. Other research focused on creating an interactive AR system to learn the structure of human anatomy [4]. An inves- tigation was also carried out on an AR mirror prototype [7], allowing intuitive viewing of realistic anatomical information. Another investigation was focused on a system that offers a real-time 3D representation of the human heart in an interactive VR environment [8]. Blum presents an AR mirror for teaching anatomy [9], which uses a depth camera to follow the posture of a user standing in front of a large screen, generating the illusion of being able to see the inside of a person's body and uses a gesture control with which it is possible to un- derstand the spatial relationships between the body and the virtual interaction plane. Another research focused on the effectiveness of VR-based learning in early childhood students [10].

4 Methodology

The tests were carried out on 20 children of 5 years old, their actions and attitudes towards the application were observed. With the help of the teacher in charge, the children were asked questions about each heuristic. The results were collected and a table of the level of usability of the application was built.

4.1 Stages of Heuristics

To develop a proposal for Heuristics based on Nielsen but focused on applications with AR, the Rusu Methodology [10, 11] was followed, who gradually defines a series of six stages to establish new usability heuristics.

1. Exploratory Stage: Serves to compile bibliography; A review of the literature related to usability evaluation, AR, and applied heuristics was made, considering the importance of the research according to the results and the problems faced.
2. Descriptive Stage: It serves to highlight the most important characteristics of the information previously collected; concepts of the heuristics used for the usability evaluation of an interface were refined and formalized.
3. Correlational Stage: It serves to identify the characteristics that the usability heuristics should have for specific applications; The main characteristics that a proposal for usability heuristics for an augmented reality application should consider were identified, based on Nielsen heuristics.

4. Explanatory Stage: The set of proposed heuristics is formally identified; Using a template, the proposed heuristics were specified with the following fields: Code, name, definition, and example of compliance or violation of heuristics.
5. Validation stage (experimental): An evaluation experiment is carried out to verify the new heuristics against the traditional heuristics; The evaluation was carried out with the proposed and traditional heuristics in the augmented reality application.
6. Refinement stage: A refinement of the proposed heuristics is carried out based on the validation stage.

4.2 Heuristics Specification

After performing the stages of Rusu's methodology [12], eighteen heuristics were obtained. The names of the proposed heuristics to evaluate the usability of an AR application is presented [11, 13, 14].

- HRA1-Confidence
- HRA2-Friendliness
- HRA3-System Status Visibility
- HRA4-Familiarity
- HRA5-Clarity
- HRA6-Accessibility
- HRA7-Interactivity
- HRA8-Navigability
- HRA9-User Control
- HRA10-Consistency and Standards
- HRA11-Error prevention
- HRA12-Minimize memory load
- HRA13-Visibility
- HRA14-Flexibility
- HRA15-Efficiency of use
- HRA16-Minimize irrelevant information
- HRA17-Ease and efficiency of Use
- HRA18-Help and documentation

5 Proposal

In recent years, applications allow students to improve their cognitive, intellectual, and personal skills, as well as other skills, beyond the technological and inclusive contribution provided by said educational support systems, it offers a possibility to enhance the acquisition of knowledge in different educational areas. Therefore, the objective of this system is to provide and reinforce educational knowledge based on augmented reality to ensure the inclusive education process for 5-year-old students on the anatomy course.

5.1 Functionalities

Login Window. The student must create an account to be able to use the application, with this account the progress of the activities can be saved, it is also possible that more than one person can enter the application with different accounts and be able to have different progress.

Missions Window. The application allows you to establish different missions that focus on activities to be carried out from the application, the progress of each mission is shown and the reward for completing it, if the mission has not yet been completed, a padlock icon is shown as seen in Fig. 2, additionally, at the top, you can see a diamond that indicates how many missions are still available.

Fig. 2. Missions window

Profile Window. The application displays student data such as name, score, coins, completed missions, and completed levels.

Connect Activity. In this activity, at the start, the human body, skeleton or muscle is visualized in a complete way where you can recognize the different parts that conform it and how they connect with each other, then the different parts are separated, and one must drag the different parts in the shaded image as seen in Fig. 3.

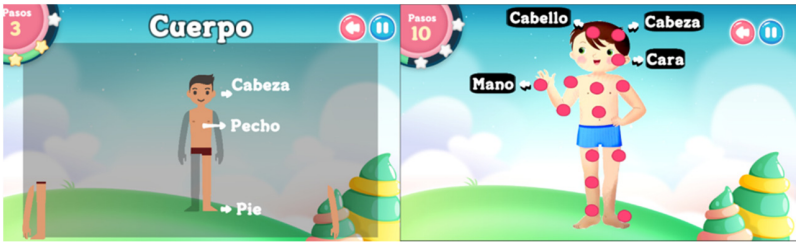

Fig. 3. Connect activity and auditory information activity

Auditory Information Activity. In this activity, you must click on the different red circles to obtain a greater description of the different concepts of anatomy, with which a description will be heard, a sound that characterizes it and the name of the body part will be shown. If the button is pressed again, the audio is heard again as shown in Fig. 3.

AR Activity. In this activity, AR is used to show the different parts of the human body through the device's camera. First, the physical environment where one is located must be analyzed to determine the surface. A list of reference points will be generated, with which a surface is determined where we can place the 3D models, after having created the surface, click on a point on the surface to make the 3D models appear as shown in Fig. 4.

Fig. 4. AR Activity completed

To complete the activity it is necessary to click on the different parts of the 3d model, which means that it is necessary to physically move in the area where the model is located and click on the different elements, after clicking on an element the name is displayed and its location is indicated, additionally the number of steps to complete the activity is reduced as seen in Fig. 4.

5.2 Implementation

The application was developed for mobile devices with the use of the camera to recognize the surfaces of the environments, reference points are used to find the surfaces, this application is aimed at initial students, where students through different activities interact with the parts of the human body which appear as 3D models Fig. 4.

6 Results

The sample size was the total test population (20 initial 5-year-olds).

Concerning the adaptation of Nielsen's heuristics [15], to evaluate the us- ability of the "Human Body AR" application, a scale has been developed that shows the measurement values that will be evaluated in each heuristic as seen in Fig. 5, taking into account Sánchez´[16] who carried out a website usability evaluation.

VALUE	MEASUREMENT	OBSERVATIONS
1	Strongly disagree	They do not perform the activity or do not understand the content.
2	Disagree	They carry out the activity or understand the content, but it is not useful.
3	Neutral	They do the activity or understand the content easily, but could be better.
4	Agree	They carry out the activity or understand the content with ease.
5	Strongly agree	They perform the activity or the content meets or exceeds theuser's expectation.

Fig. 5. Heuristics measurement scale value measurement

In the evaluation, 20 children were tested, to whom questions were asked about each heuristic, for this reason, a table was elaborated that provides value to the total of each heuristic and the total of the evaluation, the usability level of the application.

The scores for each question of the heuristics were synthesized in Fig. 6, which contains the total value of each heuristic and the total percentage of the evaluation, obtaining, as a result, the level of usability of the application "Human Body AR".

		Answers																			
HRA	Total	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	10	6	6	9	7	8	9	9	7	7	9	7	7	8	5	8	8	5	8	8	9
2	10	9	8	5	7	5	8	5	7	8	8	8	8	10	6	10	8	5	9	6	8
3	5	5	4	3	3	2	3	4	5	2	2	4	5	2	4	5	4	5	3	4	4
4	5	5	3	2	4	5	3	3	4	5	3	3	4	2	2	3	3	4	3	4	5
5	20	16	16	14	14	13	17	13	15	15	14	15	12	14	13	14	17	13	16	12	17
6	10	8	6	5	4	4	7	6	9	5	8	4	7	9	6	6	6	8	7	8	8
7	10	8	7	4	7	5	6	9	6	4	3	7	9	5	6	6	7	3	7	5	6
8	10	10	9	6	6	4	7	9	8	7	6	4	8	8	7	7	6	5	9	7	6
9	15	13	11	9	11	8	11	13	13	13	9	7	10	15	11	11	14	10	11	14	8
10	20	18	17	14	14	13	13	15	14	18	15	16	14	18	14	16	13	16	13	15	15
11	15	9	8	11	11	7	10	7	8	11	15	12	8	10	8	9	10	8	11	10	13
12	20	14	12	14	13	11	14	8	13	17	13	10	14	12	15	15	14	13	12	15	13
13	5	3	4	4	3	2	3	3	2	3	3	1	2	3	3	4	2	2	4	5	2
14	5	3	4	5	3	3	4	2	2	1	2	3	4	4	1	3	4	3	3	3	5
15	5	3	3	5	3	4	3	1	3	3	2	2	5	3	2	3	2	2	2	4	4
16	5	4	5	5	4	3	4	2	3	3	2	3	4	4	2	2	3	1	4	3	2
17	5	3	3	3	5	2	3	1	2	2	1	1	2	3	3	4	2	2	4	2	2
18	25	11	17	13	16	12	15	13	10	13	12	10	14	13	10	11	14	10	15	14	16
Total	200	148	143	131	135	111	140	123	131	137	127	117	137	143	118	137	137	115	141	139	143

Fig. 6. Results of the evaluation

The results show that, of the 20 evaluations, 16 obtained the value "Good", which means that there is no total satisfaction, so it was proposed to implement new improvements to the heuristics that had lower scores:

- Minimize the memory load: in this heuristic, it was observed that some users did not clearly identify the objects and the actions they performed, the screen is in simple form but the users cannot distinguish it by some images that distract them.

- Error prevention: users made mistakes when entering the application so they immediately left the application and their information was not saved, as well as when they wanted to return to the main menu they left the screen completely.
- Ease of use: the application expresses error messages through sounds, however, it does not suggest a solution for the user so they should ask an adult for help.
- Help and documentation: The user does not have a series of steps to follow to provide help in the application, likewise the application does not have tutorials that imitate the lessons in the classroom.

7 Conclusions and Future Work

7.1 Conclusions

The heuristics proposal provides a more efficient usability evaluation compared to traditional heuristics.

During the evaluation carried out in the development of the applications, several design problems were found including the use of AR techniques in the application. When the end-user of the application is children, it is advisable not to use markers for the recognition of 3D elements, it was difficult to keep their attention in pointing to the marker and at the same time seeing the recognition image. Therefore, it is concluded that choosing the interaction techniques depends on the requirements of the application. The same set of techniques will not work well in all situations.

The physical environment used for the usability evaluation was controlled. The tests were carried out in the classroom of the 5-year-old children, then they executed the applications with the supervision of the evaluators. One of the methods used was the Laboratory evaluation, which made it possible to record the actions and attitudes of the children when they used the application to later discuss what was observed, improving the specification of the problems found by the evaluators.

The heuristics proposal provides a more efficient usability evaluation com- pared to traditional heuristics.

7.2 Future Works

It is important to consider the unfulfilled heuristics such as error prevention, ease of use, help, and documentation according to the proposed Heuristics, so that they are addressed and the child's development is improved when interacting with objects superimposed in the real world in size, avoiding spatial problems and location in the child's environment.

Carry out tests using the evaluation proposal presented to evaluate new virtual contents and the use of other types of 3D interactivity techniques or sensors.

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