An Educational Augmented Reality Application for Elementary School Students Focusing on the Human Skeletal System

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ABSTRACT

Augmented Reality (AR) as a new field regarding Human Computing Interaction (HCI) has been gaining momentum in the last few years. Being able to project interactive graphics into real-life environments can be applied in various fields, research and commercial goals. In the field of education, textbooks are still considered to be the primary tool used by students to learn about new topics. Since AR requires interaction and exploration, it brings a ludic component that is hard to replicate using regular textbooks. The application we developed allows elementary school students to interact with a fully three-dimensional human skeleton model, using specialized virtual buttons. Students can understand this complex structure and learn the names of important bones just by using a tablet, a picture and their hands. Results show that the majority of students consider that our AR application helped them visualize and learn more about the human skeletal system. Additionally, the data we gathered shows that there was a 16% increase in correct responses regarding bone names after using our AR application. Our AR application successfully helped the students learn about the human skeletal system by introducing them to AR technologies.

Index Terms: Augmented Reality—Human Computer Interaction (HCI)—Education—Elementary School—Skeleton System—3D object.

1 INTRODUCTION

The current advancements in computing technologies have spearheaded the development of AR technologies in recent years. AR technology allows users to see the real world with superimposed computer-generated objects that serve a specific purpose [11]. This industry has existed for several decades but has become more relevant in the past five years, with AR applications widely available and easily accessible given the use of smartphones, PC's and tablets. Thus, given the large number of AR capable iOS and Android devices available, users can simply explore and project virtual 3D objects into real-world images.

The popularity of AR technology has created lots of interest among educational institutions with it currently being introduced to students in the school system [11]. As a result, AR technology is bringing new meaning to learning in the classroom. * In contrast to the traditional paper and pencil methods, students can immerse themselves with AR technologies and be able to visualize objects in 3D. This, in conjunction with HCI methodologies can be used to assess student learning comprehension and help evaluate the successfulness of AR technology in the classroom. The purpose of our project is to encourage supplemental learning in the classroom by utilizing an AR application.

We hypothesize that an AR application with an interactive, tridimensional model of the human skeletal system will help students visualize and make sense of this complex structure, while at the same time helping them learn and memorize the names of important bones.

In our study students use tablets to interact with 3D diagrams of skeletal systems and virtual buttons. Hence, students will be able to visualize concepts more effectively while using AR technology as a supplement for learning about skeletal systems using a static textbook.

The paper is organized as follows: *section 2*, is a literature review of AR, as a tool in the classroom, which helped us understand and identify the research gaps. *Section 3*, describes the methodology, covering the steps completed to developing and showcasing the application. In this section we also mention what makes this application unique. *Section 4*, presents the results of the surveys before and after the implementation *Section 5*, discusses the results from the implementation of the application and conclusions were deducted. *Section 6* discusses some limitations of this study and section 7 offers some directions for future work *Finally, section 8* concludes the paper and summarizes our findings.

2 RELATED WORK

Previous research has already shown the high potential of AR as a tool in the classroom, it is important for us to understand how AR has already impacted students.

Radu [1] conducted a literature review of various research papers and publications and identified the positive and negative effects that AR has on learners. Many of the surveyed papers indicate that AR provided increased content understanding when learning about spatial domains like geometrical shapes, chemical structures, mechanical machinery, astronomy configurations and also when learning the meaning of written words and other symbolic associations. As per negative learning effects, it is shown that AR

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experiences demand a higher level of attention. Some students might get distracted and ignore important parts of the experience, this could lead to them feeling unable to properly perform team tasks.

Amaia et al. [2] developed an AR application to teach a second language to early childhood students. They placed 2D markers into two cubes that the students need to rotate in order to select their answer. Every side of the cube will generate a different 3D Model. A correct answer triggers an audio cue depicting the correct pronunciation of the word.

Diaz et al. [4] tested if having static versus dynamic AR content can have an impact in the learning experience. A survey showed 90% of the students surveyed agreed that AR made it easier to learn new topics, an 80% agreed that the concepts are easier to understand when interactive animations are implemented.

Bratitsis et al. [6] developed an AR application used to depict the "Water Cycle" in an effort to help students struggling to understand the concept. After the students interacted with the application, they fully understood the sequence in the cycle and how water transforms in all the stages. In the end, the study needs to be expanded to more students and schools to fully test its teaching effectiveness

See Me Roar, is an AR social game aimed at teaching mathematics to students aged 7 to 8 created by Li et al. [7]. The game was designed using elements from the Self–Determination Theory (SDT) and the Playful Experience Framework (PLEX) focusing on the sense of autonomy, competence and relatedness. It was co-designed and tested by two primary school students and one teacher.

Thompson et al. [8] conducted a multi-year study exploring the space of educational AR experiences for STEM education targeted at students of various ages and abilities. Students, parents and teachers were active participants in the study, iteratively designing, building, and evaluating six AR prototypes. The successful results lead the authors to believe that these kinds of applications should be embedded into the curriculum.

MAPILS is an AR application developed by Ahmed et al. [9]. It was used to conduct plant inquiry-based learning activities inside the classroom. They evaluated their system with students from grade 8 using a questionnaire and semi-structured interviews. The results show that the system was enjoyed by students with some concerns placed on its interactivity.

The paper by Abbasi et al. [10] sets out to help struggling chemistry students and proposes an algorithm that uses marker-based AR technology to easily demonstrate the phenomenon of chemical hybridization. The application was tested along with a pre and post-test. The results showed increased interest and content understanding by the students.

We used the techniques and procedures explained in this related works to get a better understanding of the necessities and challenges of our research problem. This ranges from determining how to better integrate the 2D markers and 3D models into our application, to how to better structure the questions in our surveys.

We acknowledge that applications showing the different elements of the human body using a 3D model have already been developed. However, we consider that the added layer of interactivity provided by the virtual buttons used to highlight the different bones, while also projecting their names in digital space is a unique addition regarding projects in this field, targeting elementary school education.

3 METHODOLOGY

The participants in our study include students aged 10 and 11 from a 5th grade science class. There was a total of 30 students in this class and one teacher. The overall concept of our AR application is as follows, users point the mobile device to the correct page in their class text book and a 3D model of a skeleton appears on top of the book. Users can rotate the book to rotate the skeleton and be able to see it from different sides. We have selected 5 bones that the users can interact with. These bones are: skull, clavicle, ribs, femur, and pelvis.

As shown in Figure 1.1 through Figure 1.3, these bones have a grey color tint to them, as to be easily noticeable to the user. Additionally, when the user puts his finger above the picture on one of these bones, its name appears as a floating 3D word with the same color tint as the bone. We don't want names to overlap on the screen because this might cause confusion to the user.

To develop this application, we used Autodesk 3ds Max to create the 3D model of our skeleton and the words that represent the bone names, then we used the Unity game engine combined with the Vuforia Framework to get our model inside a mobile application environment. After taking a picture of the correct page from the student's textbook, we programmed the software to recognize this page as a marker so that we can display our 3D model on top of it. Later, we programmed the invisible buttons on top of the bones that will control the visibility of the 3D words.

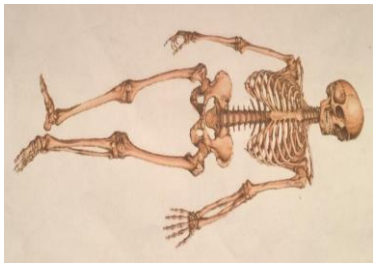

Figure 1.1: The marker.

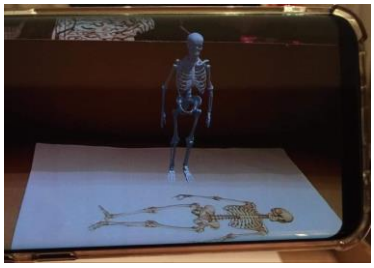

Figure 1.2: The marker as shown in the application.

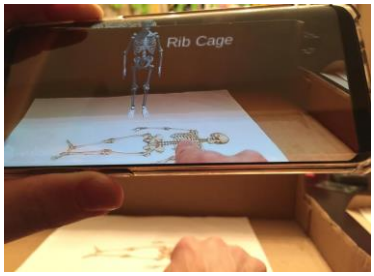

Figure 1.3: Pressing the virtual button on the marker results in the bone name appearing.

3.1 Showcasing our Application:

After receiving ethics approval from the university, we set a date for testing our application with the school's principal and the teacher. The day before the implementation, we met with the teacher and discussed the steps that will be followed. We determined that the teacher fully understood our AR application by answering her questions and addressing her concerns. Afterwards, we tested our application to make sure the AR functionality works correctly with the class textbook.

Along with explaining and demoing our application, we discussed with the teacher the three surveys that need to be completed. A pre-survey and post-survey were created to be completed by the students before and after they play our application, as well as a third survey to be completed by the teacher. In the student's survey we asked them simple questions about their knowledge of AR technology and the skeletal system, specifically the names of important bones inside it. Those two surveys are designed to provide us with the required data needed to check the student's knowledge before and after playing our application. The teacher's survey will help us understand her opinion from an educator's point of view to check if our application was useful. Finally, no names were collected.

On the day of the evaluation, the teacher explained our application to the students and had them filled out our first survey. Then she answered any questions the students had. The students proceeded to use the device as instructed. Once all the students from the class were done, the teacher passed around the second survey to be filled out. Afterwards, the teacher filled out her survey.

Finally, after all the surveys have been filled out, we collected them from the teacher. Moreover, we processed and analyzed the data obtained. Additionally, Tableau, a data visualization software, was used to create graphs to uncover hidden patterns in the data. The results from the graphs were used to compare the student's understanding of the human skeletal system before and after using our AR application.

We consider that what makes our AR application unique from other applications aimed at elementary school students is the following:

- We designed the application to be simple and easy to use, so that grade five students could use it without assistance.
- Our application offers an interactive way of visualizing bone names in a 3D space. Each bone has its own label appearing next to it without showing the other bone names.
- Our virtual buttons are activated while touching the correct bone on the textbook, this gives students another AR feature to experiment with.

4 Results

The participants in our study include 30 students in grade 5 science. In part 1 of our study (out of 2 parts), students were asked to complete a survey before and after using our AR application. The purpose of the first survey is to examine students experience with educational games and more importantly to assess their background knowledge of the human skeletal system. The second survey was used to examine students understanding of AR technology and the effectiveness of our application. The results of the first survey were as follows:

Table 1: Results of first survey.

Questions	Yes	No	Undecided
Do you like playing educational games?	100%	0%	0%
Do you think playing educational games helps you learn?	83%	17%	0%
Have you played Pokémon GO?	67%	33%	0%
Do you know what Augmented Reality is?	17%	70%	13%
Have you seen a 3 Dimensional (3D) representation of a human skeletal system?	23%	67%	10%
Do you like using tablets (i.e. iPads) in the classroom?	100%	0%	0%

Based on the results in the first survey, as shown in Table 1, all the students liked playing educational games and liked using tablets in the classroom. 83% students thought that playing educational games helps them learn. 67% of students had played Pokémon GO before. 70% of students did not know what AR is. 67% had not seen a 3D representation of a human skeletal system. The results of the second survey were as follows:

Table 2: Results of second survey.

Questions	Yes	No	Undecided
Did you like playing with this Augmented Reality application?	53%	30%	17%
Do you think playing the Augmented Reality application helped you learn more about the skeletal system?	70%	7%	23%
Did the application help you imagine/visualize the skeletal system better?	57%	43%	0%
Are you interested in playing similar Augmented Reality applications in the future?	46%	27%	27%
Is Pokémon GO an Augmented Reality Game?	73%	0%	27%

Intermediately after using our application, the students completed the second survey. The results of the second survey are in Table 2. The results found suggest that 53% of students liked playing our AR application. 70% thought that our AR application helped them learn more about the skeletal system. 57% considered that our application helped them better imagine/visualize the skeletal system. 46% were interested in playing similar AR applications in the future. Finally, 73% think that Pokémon GO is an AR Game.

The results of the teacher survey were as follows:

Table 3: Results of teacher survey.

Questions	Response
Was the application easy and simple to use?	Agree
Was the survey completed quickly after using the application?	Strongly Agree
Was the 3D skeletal model effective in helping students complete the survey?	Agree
Was the 3D skeletal model presented clearly	Agree
Did the application have all the necessary information?	Neutral

Based on the results in the teacher survey, as shown in Table 3, the AR application was easy to use and effective in helping students complete the second survey. The teacher commented that all students have used devices, including tablets, laptops (i.e. Chromebooks), and projectors in the classroom.

In part 2 of our study (out of 2 parts), multiple-choice questions were used to test the difference in students' knowledge of the human skeletal system before and after using our AR application. The multiple-choice questions were designed to assess students current knowledge of the names and locations of important bones. Then we assess if the students learned new bone names, using our app, by asking them the same bone name questions found in the first survey. The conclusions collected from the surveys assisted in determining whether our AR application can be used as a supplemental learning tool in the classroom. See Figure 2 through Figure 7 for the analysis of the survey results.

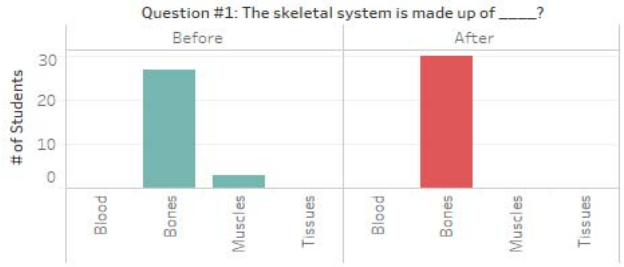

Figure 2: In question #1, the right answer is 'bones'. Before using our application, 27 out of 30 students answered the question correctly. After using our application, there was an increase of 10% in the number of correct answers.

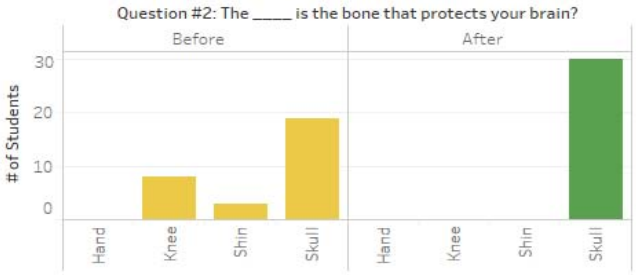

Figure 3: In question #2, the right answer is 'skull'. Before using our application, 19 out of 30 students answered the question correctly. After using our application, there was an increase of 37% in the number of correct answers.

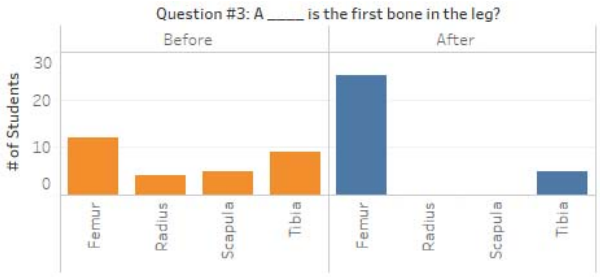

Figure 4: In question #3, the right answer is 'femur'. Before using our application, 12 out of 30 students answered the question correctly. After using our application, there was an increase of 43% in the number of correct answers.

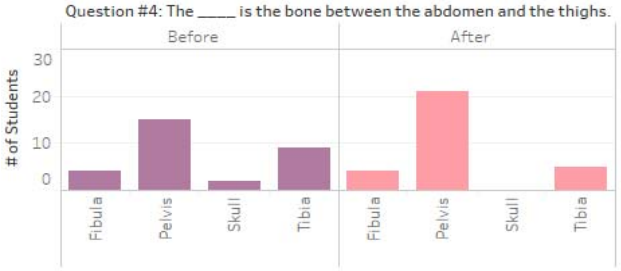

Figure 5: In question #4, the right answer is 'pelvis'. Before using our application, 15 out of 30 students answered the question correctly. After using our application, there was an increase of 20% in the number of correct answers.

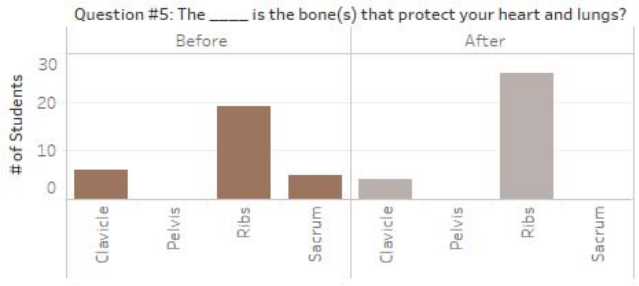

Figure 6: In question #5, the right answer is 'ribs'. Before using our application, 19 out of 30 students answered the question correctly. After using our application, there was an increase of 23% in the number of correct answers.

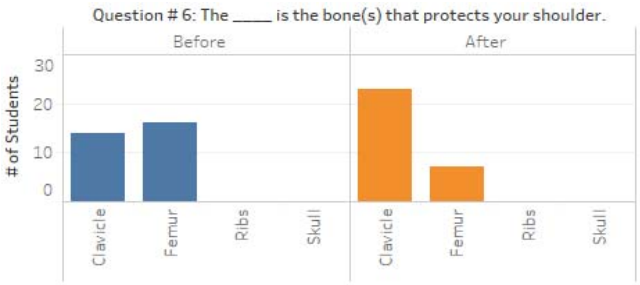

Figure 7: In question #6, the right answer is 'clavicle'. Before using our application, 14 out of 30 students answered the question correctly. After using our application, there was an increase of 30% in the number of correct answers.

5 Discussion

Our pre-analysis shows a high interest in games and using them as a learning tool. While many students claim that they don't know what AR is, most of them have already been exposed to AR through Pokémon GO so we believe that this makes it easier for them to understand how to use our application. Also, we learned that most students have never seen a three-dimensional representation of the human skeletal system. Finally, this pre-study shows that on average approximately 60% of students were able to answer correctly all the questions regarding bone names.

The data from our surveys showed that both the students and the teacher enjoyed using our AR application. Our post-study analysis shows that on average approximately 86% of students were able to answer correctly all the questions regarding bone names.

After comparing the results from the first and second surveys, our data analysis shows that there was an increase of 16% in correct answers. Even though not all students answered every question correctly, there was a visible performance increase in the student's knowledge as shown in the graphs.

In addition to the surveys, the teacher was asked to provide her feedback on the experiment. The teacher commented that AR can ultimately enhance students' learning depending on the subject being taught. Also, some suggested improvements in our application include increasing the response rate of the bone names appearing.

Based on the results obtained from this study, we were able to support our hypothesis. Adding AR technology to science lessons has resulted in more engaging classes. The students felt more attracted to the lesson when using AR technology. Adding virtual buttons to the skeletal system in our AR application made it more immersive, and easier to use than any other science AR application geared towards elementary school students.

Our results confirmed and expanded on ways that AR applications can help struggling students understand a difficult concept covered in class. When the lesson involves visualizing specific complex content like the skeleton system, the use of AR and virtual buttons will make information easier to understand.

6 Limitations

Moreover, we faced multiple limitations regarding our target age group and setting. Firstly, our user study was conducted only in one school. Thus, the results of our experiment cannot be generalized. Secondly, the students had to take additional time in managing to touch the bones and hold the tablet at the same time. Since our application was a prototype, the sensors that trigger the virtual buttons would sometimes fail due to the variation of the fingerprint.

The day of implementation, we couldn't install our application in the schools tablets due to a permission constraint within the school's IT department that would have created more delays. Instead we had to get our own tablet and give that to the teacher to run the test by approaching one student at a time.

7 Future Work

Furthermore, the results of the surveys and the overall reception of our AR application have encouraged us to continue working in the field of education. Initially we want to expand this application to accommodate the names of all the bones. This will allow students to fully learn about the human skeletal system. We want to take it to more schools to increase our user base and the accuracy of our results.

We also would want to meet with the teacher again and inquire about other science lessons that may benefit from the use of AR technologies. We assume that covering other complex systems of the human body like the digestive system or the circulatory system could be beneficial for students.

8 Conclusion

In summary, many elementary school students are not aware of the complex systems that make up the human body. Previous work proves that AR can turn regular classes into interesting new experiences. Using AR technology, we developed an interactive application that takes a 2D human skeleton model, that is printed on a piece of paper, and recreate the image as a virtual 3D model that students can interact with using a tablet. To further encourage

interaction with the 3D model, we added touch-enabled virtual buttons that project certain bone names as interactive 3D text. We consider the combination of virtual buttons with AR technology a unique feature that encourages students to learn more about a topic through interaction, immersing them in the content.

After conducting the first and second surveys, our results illustrate a 16% increase in the correct responses regarding bone names, proving that the students successfully learned about these bones using our AR application. More importantly, our surveys show a considerable interest in using similar AR applications in the future. The teacher survey highlighted the successfulness of our application it is shown that she was satisfied with the performance and interest shown by the students.

Overall, we strongly believe that the use of AR technology and smart devices is truly revolutionizing the educational field. We are confident that similar technologies will continue to get deeply integrated into the classroom experience.

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