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Development of ARTutor Prototype for Teaching Upper Limb Anatomy to Occupational Therapy Students

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Abstract. AR applications are typically available via mobile augmented reality (mAR) devices, such as smartphones and tablets, and use embedded cameras to integrate real-world environments with dynamic, conscious, and interactive digital content. The use of mAR allows for knowledge management for students, through developing innovative teaching methods. This paper focuses on the development of a prototype educational application called ARTutor: Functional Anatomy and Biomechanics of the Hand, utilizing mAR technology. The application is designed to aid students in understanding the anatomical elements of the upper limb and the types of grasps essential for daily functional activities. The theoretical framework for this development draws from Bloom's Taxonomy, ensuring structured cognitive development throughout the learning process. For assessment, we utilize the Instructional Materials Motivation Survey based on the ARCS Model, which evaluates attention, relevance, confidence, and satisfaction. The paper concludes with recommendations for addressing these limitations, incorporating teacher education, and exploring longitudinal studies to evaluate the long-term impact of mAR technology.

Keywords: Mobile Augmented Reality, ARTutor, Anatomy, Occupational Therapy Education.

1 Introduction

Augmented Reality (AR) enhances real-world environments by overlaying computer-generated content, such as graphics, videos, and sound, onto physical settings using technologies like image recognition and geo-positioning. Unlike Virtual Reality (VR), which immerses users in a fully digital environment, AR integrates virtual elements with the real world, often accessed through mobile devices like smartphones and tablets [1]. Mobile AR (mAR) applications, in particular, utilize embedded cameras to create interactive and dynamic learning experiences, making them effective tools for educational purposes [2]. In the context of Occupational Therapy (OT) education, where learning requires interactive, visual, and tactile methods, mAR offers an innovative approach to addressing traditional teaching challenges. Anatomy instruction (which is taught in undergraduate OT programmes) in healthcare education often relies on labor-intensive methods such as dissection labs to teach structure-function relationships and reasoning skills [4–5]. For OT students, who must develop a deep understanding of anatomy and kinesiology to design and apply therapeutic interventions, conventional methods can lack engagement and accessibility [6–7]. Delivering interactive, visualizations of upper limb anatomy and functional grips, mAR facilitates the understanding of how anatomical structures and kinesiological functions integrate during daily activities. This technology fosters active participation and higher-order skills like critical thinking and creativity while overcoming barriers of time and location [4, 8]. Furthermore, mAR has demonstrated effectiveness in improving motivation and comprehension in anatomy education, making it particularly suitable for OT students [9]. This paper focuses on ARTutor, a prototype mAR application tailored to teach OT students the anatomy and biomechanics of the hand. It examines the application's theoretical framework, development process, software and hardware requirements, learning materials, and its specific benefits and limitations for OT education.

2 Methodology

2.1 Prototype ARTutor Architecture

The AR application used for the purposes of this work is ARTutor. This is about a platform that consists of two sections: (i) an AR authoring tool that allows educators to augment existing books (either print or electronic) in an easily and straightforward way without the need of programming knowledge and (ii) a mobile application that is used to access and interact with the educational AR content overlaying the textbooks. Through the use of ARTutor, students are allowed to interact with the augmentations using voice commands, and also to ask questions verbally and receive answers based on the contents of the book. Each augmentation that is enabled can be manipulated from the user under the commands that have been allocated to the authoring tool. The student can use finger gestures to start or stop a video, zoom in or out of a video or image, or rotate a 3D model [2]. Also, ARTutor offers several advantages, such as affordability and easy accessibility through smartphones and tablets, making it more convenient for students compared to tools like Complete 3D Anatomy® and HoloAnatomy®, which require specialized, expensive hardware [10].

2.2 Prototype ARTutor Application

The development of the application is based on the augmentations that will be held in *Functional Anatomy and Biomechanics of the Hand,* which is chapter of the book *Developmental and Degenerative Disorders*. This can be presented in both, electronic or printed way. It includes all anatomical and kinesiological elements of the upper limb. It also describes the functionality of the hand in relation to the grasps made during the performance of activities of daily living.

The augmentations concerning the use of the ARTutor have been made to the pictures of the hand grasps related to the performance of daily activities and include pictures and videos. Through the use of these augmentations, students will become aware of: (i) the way in which the anatomical and kinesiological structures of the hand are combined during the performance of daily activities and (ii) the typical grasps of the hand (see images below).

Fig. 1. Cylindrical and Spherical Grasp.

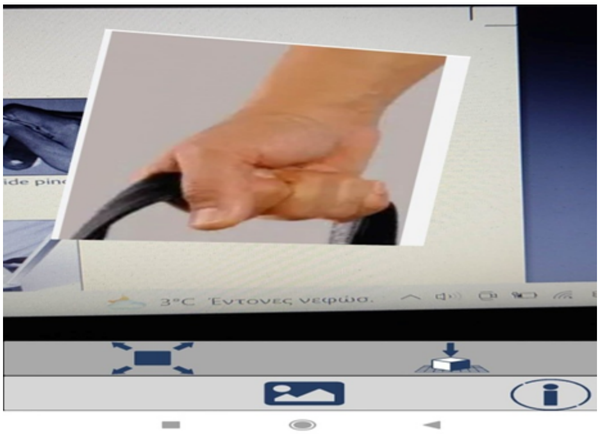

Fig. 2. Hook grasp.

2.3 Learning Approaches

The theoretical background informing the development of the learning activities created for this study stem from the Bloom's taxonomy. This taxonomy is described as a method classification of educational objectives, educational experiences, learning processes and assessment questions and problems. It can be used as a progenitor to contemporary assessment techniques and is linked to other concepts such as creative and critical thinking, problem-solving skills, etc. [11]. The initial taxonomy description, developed by Benjamin Bloom and his collaborators in 1956 and was revised in 2001. The updated version includes the elements of remembering, understanding, applying, analyzing, evaluating and creating [12–13].

2.4 Implementation Process

This course is recommended for the anatomy module for occupational therapy students on a university or college BSc in Occupational Therapy at level 1. It will be held for four weeks, when according to the curriculum, students must learn the anatomy and kinesiology of the upper limbs. In particular, it involves a compromise between different modes of teaching using a comprehensive range of resources including generally: 2 hours formal lecture on anatomy of upper limb ; 1 hour practical laboratory session which includes body painting to better understand the anatomical components ; 1 hour use of ARTutor Functional Anatomy and Biomechanics of the Hand for learning the anatomy and kinesiology of upper limb; 2 hours video projection and practical training on the movements of the upper limb; 2 hours use of ARTutor Functional Anatomy and Biomechanics of the Hand for learning the grips of the hand, for each week. In order to fully evaluate the effectiveness of the AR tool, a control group will be included in the experiment. The control group will have the normal lecture-based learning method, without the use of ARTutor. These will be supplemented with self-directed learning approaches including student-led presentations. In addition to the students' use of ARTutor, it is critical to emphasize teacher education and training on how to effectively utilize the ARTutor platform. Educators must be thoroughly familiar with the tool's features and its integration into the course structure to maximize its potential in enhancing learning outcomes. Before the course begins, teachers will undergo a comprehensive training module focused on understanding the features, functionalities, and pedagogical integration of ARTutor into the anatomy curriculum. More specifically and using the Blooms taxonomy the teaching includes the following (see table 1):

Table 1. Cognitive Processes and Learning Activities for Upper Limb Anatomy and Types of Grasps using Blooms Taxonomy.

Category	Cognitive Process	Upper Limb Anatomy & Types of Grasps Examples
Remembering	Recognizing	Recognize the orientation of the images.
	Recalling	Recall structures: point and label
Understanding	Interpreting	What is this type of grasp?
	Exemplifying	Give examples of bones to distinguish anatomical structure location.
	Classifying	
	Summarizing	Classify the categories the bones and their movements in a upper limb.
	Comparing	
	Explaining	Write a short summary of grasps in a hand.

		Compare atypical to typical grasps Explain for what reason is this grasp required for this object
Applying	Executing	What movements does the upper limb execute while using a cup?
Analyzing	Differentiating Organizing	Distinguish the different parts of structures, structures of elbow and structures of hand Organize the muscles in each part of the upper limb.
Evaluating	Checking Critiquing	Do you remember all the movements of the hand after watching the augmentation with the video? What are the movements of each joint for catching a tennis ball?
Creating	Generating Planning	What could cause a burn in the functional grasps of the hand? What movements of the whole body are required for catching a plate?

2.5 Evaluation

In accordance with the scientifically substantiated assumption that motivation is necessary for students to increase their academic performance [14—16] for the assessment of this course it will be used the Instructional Materials Motivation Survey based on the ARCS Model. The acronym of this model is based on the initials of the words: attention, relevance, confidence, and satisfaction. Based on the ARCS model, the design of the AR technology must attract student attention, it must be relevant to the students, the students must be confident with the technology, and the students must feel satisfied after using the technology [17]. Thus, a comprehensive evaluation framework will be employed, aligning with the ARCS Model of motivational design and incorporating both pre- and post-tests. This method will provide insights into engagement, usability, motivation, and knowledge acquisition. The four elements of the ARCS Model—attention, relevance, confidence, and satisfaction—will be assessed using the Instructional Materials Motivation Survey (IMMS):

- Attention: Questions like "How engaging did you find the AR content compared to traditional methods?" will center on how much pupils are drawn in by ARTutor's interactive and visual elements.
- Relevance: Items such as "Did the AR content directly relate to the anatomy and kinesiology topics you needed to learn?" will assess how well the ARTutor content aligns with the curricular goals.
- Confidence: Questions such as "Did using ARTutor make you more confident in understanding anatomical structures?" will gauge students' proficiency with the application.
- Satisfaction: Overall satisfaction will be assessed with questions such as, "How satisfied are you with ARTutor as a learning tool?" and "Would you recommend ARTutor for other anatomy courses?"

Before using ARTutor, students will take pre-tests to assess their baseline knowledge of upper limb anatomy and functional grasps. After completing ARTutor modules, post-tests will be administered to gauge learning progress. Both recollection (such as naming anatomical features) and application (such as describing the biomechanics of particular grasps in functional settings) will be the main objectives of the test items. Knowledge gains will be measured by comparing the outcomes of the pre- and post-tests. Additionally, using instruments like the System Usability Scale (SUS) or open-ended feedback questionnaires, students will offer input on how usable ARTutor is. Easy navigation, clear directions, accessibility of enriched information, and any technological difficulties like responsiveness, gesture tracking accuracy and the rendering of 3D models encountered are important rating criteria. Finally, for teachers, the SECTIONS framework can be used to assess the platform's alignment with educational goals, interactivity, and ease of use.

2.6 Guide for the Use of ARTutor and Potential Benefits

All the necessary information on the use of the platform and the application, both for teachers and students, can be found on the official website of the application: https://artutor.cs.duth.gr/home/. The user has to register for free in order to use the ARTutor. Also, the application must be downloaded on the mobile of the student. In general, indicating that the inclusion of virtual material in anatomical training may benefit OT student outcome [6, 9] Additionally, the simplicity in the use of ARTutor can help students to learn in an easy and interactive way the elements of anatomy, kinesiology and functionality of the upper limb and promote motivation and autonomy of the students. In recent bibliography, the development of tools promoting self-learning and autonomous work must be seriously considered for anatomical training [18].

3 Conclusion

The integration of mAR technology, such as ARTutor, into anatomy education for OT students presents a promising approach to enhance learning experiences. The platform's ability to merge traditional teaching methods with digital augmentations, including videos and 3D models, enables students to visualize complex anatomical structures and functional grasps, promoting deeper understanding and critical thinking. The combination of formal lectures, hands-on activities, and mAR tools provides a holistic learning experience, addressing various cognitive processes and learning styles. While ARTutor demonstrates significant potential, there are limitations to its implementation. The absence of an assessment tool for evaluating the proficiency of both students and educators in using mAR, along with the restricted application period, limits the generalizability of its effectiveness across the entire anatomy course. Furthermore, ethical considerations, such as data privacy and inclusion, have not been addressed, which should be explored to ensure the equitable and secure use of the platform. It is also recommended to expand its application to other disciplines and technologies, thereby broadening its impact and effectiveness.

Nonetheless, the use of ARTutor as a pilot project indicates that mAR technology could be a valuable addition to traditional anatomy education, fostering greater student autonomy and motivation. To fully realize the potential of ARTutor, future studies should focus on developing assessment tools for both students and educators, and address ethical concerns related to data privacy and inclusion. Additionally, longitudinal studies are essential to measure knowledge retention and the long-term impact of mAR technology on student learning outcomes. As educational technologies continue to evolve, mAR applications like ARTutor have the potential to revolutionize health sciences education by offering more interactive, flexible, and engaging learning environments.

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