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Work-in-Progress—Gamified Experiential Learning of Human Anatomical Structures for Undergraduate Students in eXtended Reality: Experiences, Results and Recommendations

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Abstract. eXtended Reality (XR) environments appear to be a promising approach to learning in educational contexts where knowledge regarding spatial location and orientation in relation to a number of different structures has to be acquired. The aim of the presented work-in-progress is to report on insights and results gathered throughout the user-centered implementation of gamified experiential learning of human anatomical structures for undergraduate students in eXtended Reality. First, we report on the application design itself and certain design decisions we have taken based on input from the target group and related trainers. Second, we report on results from a preliminary study with 96 students (n=96) and feedback from three experts in the field of education and healthcare. Third, we contextualize these results and the feedback with respect to recommendations for improvements within the next iterations of the application.

Keywords: Extended Reality, Training, Immersive Learning, Spatial Memorization, Anatomy, Psychology, Pedagogic.

1 Introduction

Achieving learning objectives in education is one of the key components in healthcare education. Especially anatomical structures are a central subject for any healthcare professional, ranging from nursing students, over physiotherapists and medical students. The learning and understanding of these structures is a didactical process that persists since several centuries in a rather unmodified educational practice: It is mainly based on 2D representation of the anatomical structures and is complemented with (limited) exercises on donated human bodies or simulators. This practice involves ethical problems as well as scalability issues and leads to very limited exercises with realistic 3D representations of these structures. Hence, spatial memorization of these structure is not well achieved [1] by such educational practices.

In that context the opportunities eXtended Reality (XR) technologies open up in education and training are very promising. The utilization of these technologies offers the ability to implement learning theory from experiential [2, 3] and phenomenological learning [4] in a comprehensive fashion. It enables the massive improvement in practical exercises times through XR's abilities of providing 3D environments in a scalable fashion for a large number of students. In addition to this enhancement in exercise and interaction time, recent research results show that virtual representations significantly improve spatial memorization compared to visualization on a 2D screens [5] in general settings but also in the realm of human anatomy learning in medical education [6].

Based on these developments and research results we set out to team-up with experienced trainers in health professional educational settings to revisit potential improvements in their educational practice through the utilization of an XR anatomy learning application (XRALA) that complements existing courses. Based on these exchange we set out to develop a respective XRALA prototype. One of the key components and main reasons why a full virtual environment has a big impact on learning anatomical structures is the ability to have a fully spatial design and to use real size structures to learn bone and muscle structures of the human body. Another aim which was set up for the application was the combination of correct location and interaction between anatomical structures. All those described components are a perfect integration for learning correlations and interactions between these structures. Especially the immersion into the environment is another key factor in achieving the planned out learning objectives. Anatomical structures can be overwhelming and especially for undergraduate students a more or less boring topic, so having a high rate of involvement is essential to succeed. Ambition through the integration of gamification aspects is a well observed and evidence based way to do so. Especially sustainable motivation and usage of fun and integrative interaction between the human and the computer system can be crucial for meeting learning objectives or not. The last, maybe the most important, component of training is systematic and individual feedback. Doing so, learners can achieve magnificent learning achievements, adding this achievement to high score and comparable outcomes for the learner is also important for even more involvement into the application.

The remainder of the paper is structured as follows: In section 2 we report on stakeholder requirements identified and describe the application design based on these requirements. Section 3 presents the study design. whereas Section 4 describes the evaluation study results as well as expert feedback gathered. Finally section 5 draws conclusions and highlights recommendations for improvements of XRALA's.

2 Stakeholder Requirements and Learning Application Design

To understand the needs of the future trainees regarding virtual learning environments for the acquisition of anatomical knowledge we have teamed up with experts in the area of vocational training for undergraduate health professionals. We concentrated especially on the domain of pedicure, massage, care assistance etc. where in depth medical knowledge of anatomical structure is not the educational goal. For these job profiles, the understanding of the spatial location and interplay between different musculoskeletal structures is an important learning objective. The common understanding of the didactical experts was that XRALA based anatomy trainings are mainly targeted towards experienced health care providers. These applications feature a high quantity of details, many of them also including pathologies. From their experiences, such kind of applications are overwhelming and far too complex for the teaching of the muscoskeletal system (MSS). This leads to a mismatch between learning achievements and predefined learning objectives. In order to limit the complexity anatomical learning applications for medical education typically inherit, we decided to therefore define the following non-goals XRALA's for health professionals: No visualisation of injuries, medical conditions, cross-sections and pathologies should be contained. However, bad learning achievements with existing XRALA's is not only based on the content-wise complexity of these applications, but is also rooted in their lack of didactical tools and procedures. Furthermore, the delivered user experience is often very low. Hence, acceptance of such applications as additional learning tool for undergraduate health professionals is limited.

From the trainer perspective it is furthermore important to be able to follow and evaluate the learning behavior and progress of the students throughout the semester and store it in the student records. Information on the learning behavior can be very valuable in identifying potential shortcomings in the accompanying courses and is therefore an important quality assurance knowledge source. Typically, this is achieved by learning management systems (LMS) of the institutions (e.g. canvas, blackboard, moodle) that provide this functionality. However, existing commercially available XR anatomy applications do not provide this functionality.

Based on these insights the following design criteria were defined and followingly implemented: 1) The human anatomy comes with high complexity, detailed naming and also very extensive wording and description. Thus we implemented only the MSS as a first step, to proof the concept of a gamified XRALA. 2) Feedback is important for meeting learning goals, that's why we tried to integrate haptic and also immediate feedback in a very game based manner. User's are able to explore the MSS and receiving instant feedback for wrongly naming or placing structures. 3) intrinsic motivation is important for students to actually start their learning journey. To achieve that, we incorporated a scoring system across devices. Doing so, trainees are able to see each others high scores thereby leading to high intrinsic motivation to perform better. 4) Learning should be a immersive, interesting but also fun experience, using a pedagogically meaningful learning environment which is held in dense colours and relaxing user experience is key to meet learning objectives in each student. 5) Having the ability to monitor students in their learning progress is an important feature for every lecturer and teacher, with the bespoken MSS-trainer it is possible to have a direct learning integration in LMS through an integrated database. 6) Not only the trainer, but also the trainees should have a good experience with new technologies, that’s why we implemented a haptic UX design across the whole system, with the main focus on stand alone usage. Thereby, usage of the application without prior XR experience or extensive tutorials could be achieved.

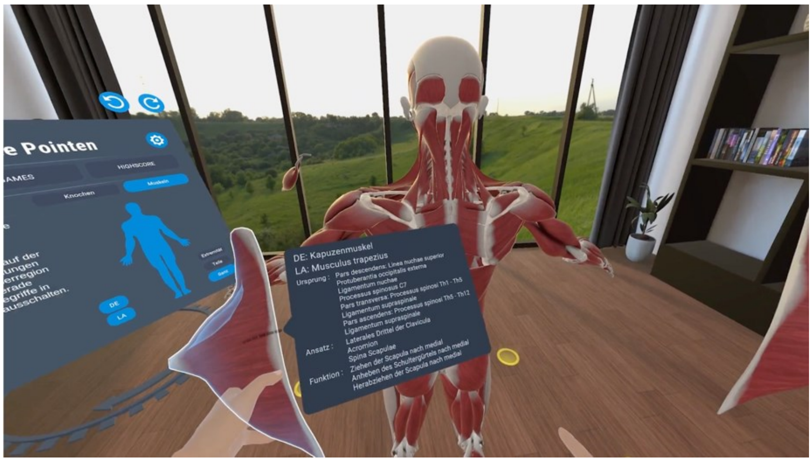

Fig. 1. Screenshot of the application with the mini game control screen on the left and the anatomical information for the selected muscular structure in the middle.

3 Study Description

To empirically investigate the effectiveness as well as potentials and limitations of extended reality based anatomy training in healthcare professionals and especially in undergraduates we conducted a quantitative study with N=96 nursing students in a three year bachelor program. The students were all one week ahead of their main anatomical exam in the first semester. The study took place in November 2022 at the university of applied sciences in St. Poelten. All participants were asked to complete the tutorial as well as minigames inside the application. In total individuals were able to train for a mean total of 15 minutes, varying from 9 to 17 minutes. As a assessment instruments we combined the Virtual Reality Neuroscience Questionnaire [7] and the Quality of Learning Scale [8] and combined that with four (n=4) socio-demographic questions and four (n=4) open questions regarding the future use of the application in order to get more insights with respect to additional features they would demand meaningful.

4 Study Results and Expert Feedback

The demographics of our sample were as follows: 77.1 percent identified as female, 22.9 identified as male and one student identified as non binary. The median age of was 20 years (MEAN=20), with a min. of 17 years and a max. of 43 years. For this WiP paper we did not yet complete a full analysis of the gathered quantitative data so we share the following indicative numbers. Overall 92,7 percent of the students reported that they would like to integrate the application in their future learning process. Also the on the item ”What was the overall experience of the anatomy trainer like?” 85,4 percent of the students reported that their experience was good or very good (with very good being the best rating on a 7-point scale). Besides the quantitative ratings we also wanted to identify features for further development of the app through open questions. 16 of the 96 students reported that they would want organ systems, such as the nervous system, the cardiovascular system or the lymphatic system as additional learning content. Furthermore, 41 students either wanted pathologies inside the environment or nursing specific skills to be reflected in the application, 39 students didn’t give any valid answer. Other highly requested features were learning progress across certain regions as well as the integration of the scores into the universities LMS for comparing scores as well as learning progress with fellow students. Another anecdotal evidence we did gather was a comparison regarding the examination results from the previous year (2021) and this years anatomy examination (which took place one week after the study). Whereas in 2021 the avg. grade = 3,38 (scale with 1 being A and 5 being F in the Austrian grading system), this year’s average score was avg. grade = 2,33. We didn’t conduct an in depth analysis of these examination results (distribution of the scores etc.) yet, hence caution has to be taken regarding the interpretation of these numbers. However, as there have been no changes in the curricular setting between those two years it might be that even the short 3D experiential learning session one week prior to the examination has already had a positive impact on memorization.

Besides the data acquired through the study, we gathered feedback from an eXtended reality specialist, a learning psychologists and an anatomy specialist. All three experts reported that the application has overall a very good user and interaction-experience and outperforms other learning applications on that respect. The psychologist highlighted the calm and pleasant learning environment inside the application. As for the controls and functions, the extended reality specialist claimed that especially the haptics and functions for picking up structures and moving them around was smooth and without any loss of frames and was substantially better than what he has seen up to now in existing XRALA's. Having the opportunity to dive into anatomical structures such as bones and muscles was the highlight for the anatomy specialist. Seeing everything in a three dimensional manner denoted a welcome addition to standardized paper-based learning in his opinion. Also the interaction between muscles and the underlying bone structures with regard to muscle insertions end resulting interrelations was a learning highlight for him. Overall all three experts reported predicted good learning experience, especially the learning games were mentioned as motivational factor for improved student engagement. Features they suggested were the opportunity to add a zoom function one of the inputs, as well as the possibility to have a pullapart functionality to make it easier to look inside e.g. the abdomen. Similar to the students they mentioned additional organ structures as potential add-on, while claiming that the existing application and its limited complexity of anatomical structures was a very good fit for undergraduate health professional students. However, the proper integration into existing curricular settings was mentioned as an important further task in order to ensure optimal usage of the experiential learning options of the application.

5 Conclusion and Recommendations for Improvements

Overall we summarize that for health professionals (HP) existing XRALA's are 1st too complex as they include medical conditions that go beyond the relevant knowledge for HP's and 2nd hand lack interaction fidelity, didactical learning games as well as integration in existing learning management systems. In order to overcome this, we developed a prototypical XR anatomy learning application that was limited to the muscu-loskeletal system (MSS) structures. The quantitative student feedback and the qualitative expert feedback we gathered was beyond our expectations and very positive. In terms of further improvements the following features were mentioned: Tendons, Softbone structures are missing for the full MSS system and certain organ systems would be of interest such as the cardiovascular system, lymphatic and nervous system. From an educator perspective a clear curricular embedding of such XRALA would also be important for optimal learning results.

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