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Streamlining Tangible 3D Printed and Intangible XR Content Creation and Evaluation: The ENTICE Experience

Panagiotis ANTONIOU[a] Efstathios SIDIROPOULOS[b,1],
Natalia STATHAKAROU[c], Charalampos CHATZIMALLIS[d],
Evangelos CHONDROKOSTAS[e], Dimas SUMUNAR[c], Tobias KARLSSON[c],
Sofia LACHANOUDI[a], Panagiotis DAVID[b], Konstantinos TAGARAS[b],
Annita VARELLA[a], Alkinoos ATHANASIOU[a], James PICKERING[g],
Andreas TOOULIAS[a], Ion KAROLOS[a], Panagiotis-Marios FILIPPIDIS[d],
Eirini SCHIZA[f], Vassilis VOULGARAKIS[d], Charalambos BRATSAS[e],
Vassilis TSIOUKAS[a], George TSOULFAS[a] and Panagiotis BAMIDIS[a]
[a]*Aristotle University of Thessaloniki, Greece*
[b]*Anaptixiaki Meletitiki Voriou Ellados, Greece*
[c]*Karolinska Institute, Sweden*
[d]*Open Knowledge Greece, Greece*
[e]*VILABS, Greece*
[f]*University of Cyprus, Cyprus*
[g]*University of Leeds, UK*

Abstract. ENTICE aimed to use co-creative methodologies in order to build a solid creation pipeline for medical experiential content. The project has developed and evaluated immersive learning resources and tools aiming to support well-defined learning objectives using tangible and intangible resources (AR/VR/MR, 3D printing) that are highly sought in the fields of anatomy and surgery. In this paper the preliminary results from the evaluation of the learning resources and tools in 3 countries as well as the lessons learnt are presented towards to the improvement of the medical education process.

Keywords. Co-creation, Immersive Learning, Virtual/Augmented reality

1. Introduction

Medical knowledge is crucial and necessitates a strong theoretical foundation in addition to implicit understanding and experience [1]. Currently there is a gap in educationally sound, effective resources for anatomy teaching. In order to achieve this, the need for suitable educational techniques and approaches is constantly emphasized. Immersive experiential technologies flourish in this setting and help to support medical education. Through their enhanced engagement, virtual patients, chatbots, and Virtual, Augmented, or Mixed Reality (VR/AR/MR) in particular have a significant impact on the affective and educational states of healthcare students [1-4]. Additionally, it has been asserted that

[1] Corresponding Author: Efstathios Sidiropoulos, E-mail: stathsid@gmail.com.

students can successfully visualize abstract rules in concrete ways by taking cues from diverse instructional content [5,7, 8]. The sensory immediacy of these technologies leads to an intuitive anchoring of the key knowledge for the learner and facilitates paradigm building, which in turn enables learners to acquire robust and deep knowledge while minimizing the possibility of establishing or maintaining conceptual errors [4]. 3D printing is the latest tool in the arsenal of healthcare practitioners that visualizes tissue damage and assists in therapeutic diagnosis and intervention through detailed localization of it. This technique makes use of 3D digital models created from medical imaging data, offering pre-surgical training or diagnostic visualization with an unheard-of level of immediateness. Participatory Design (PD) emphasizes the value of balance, receptivity, and non-hierarchical relationships [9, 11] by allowing stakeholders to be fully involved in the design and production process [6,12]. The co-creation process makes it possible to identify [10] knowledge distribution as one of the major factors influencing co-creation efficiency. It has been stated that working in a co-design environment with interdisciplinary actors facilitates the production of more original thoughts and ideas [11].
Through integration of learning objectives in the design and implementation pipeline of digital content creation, ENTICE produces increased quality content, thus improving and thus improve the quality and efficiency of education and training by the use of it. Additionally, the co-creative pipeline, which has been formulated for educational-centric digital resources, intrinsically fosters creativity, innovation and promote entrepreneurship. The aim of this paper is to present the participatory process for the development of tangible/intangible educational resources and the preliminary evaluation results in 3 countries. The aim of this paper is to present the holistic methodology and the first results from an integrative participatory approach for development of immersive VR/AR/MR and 3d print resources.

2. Methods

The core innovation of the project is the validation of a systematic, integrative approach for education-centric experiential teaching episodes and resource content creation for 3D printed models, and AR/VR/MR resources. This approach consists of three main aspects: a) Tangible/Intangible integration in immersive educational resource design, b) Learning Objectives-centered development of educational episodes with immersive resources c) Prototyping Knowledge Engineering methodology for education-centric immersive resources.

The fabrication of 3D printed models suitable for medical educational training began with the segmentation and 3D modelling of anonymized DICOM digital images of real patients in order to optimally depict the human anatomy. This modelling was accomplished using separation techniques of each anatomical detail, with gradation in separate layers, for the representation of which various textures and colors were employed. During the digital reproduction of the final 3D-printed models (Fig.1), specially designed fiducial markers placement regions were generated for the purpose of enhancing their appearance using AR mobile applications. In order to preserve anatomical information, these fields were generated on each surface of each human organ. The student can reveal the fiducial markers by using a specialized holder to remove the corresponding region. Magnets are used to keep the regions on the model enabling easy attachment and detachment. Magnet locations were also fabricated in other areas of each model, primarily to facilitate the detachment and fusion of diverse anatomy.

Figure 1. 3d printed models

For the development of the XR resources we used Unity3d and combined it with more technologies depending on the tasks at hand. The result was a multi-user exploratory environment, a virtual anatomy installation where anatomically correct models were digitally augmented by labels and panels describing details (Fig.2). To make the conversion to multiuser we used Photon Engine. Photon is built on top of a globally distributed infrastructure, which means it is able to handle a large number of users and maintain a high level of performance even under heavy load. This is especially important for Unity3D projects that require real-time communication and synchronization, such as multiuser applications. In order to handle the AR part of the project we used Vuforia Engine. Vuforia is a very well optimized AR platform that gave us the opportunity to handle multiple targets at the same time and render overlayed 3D objects on top of our tangible resources.

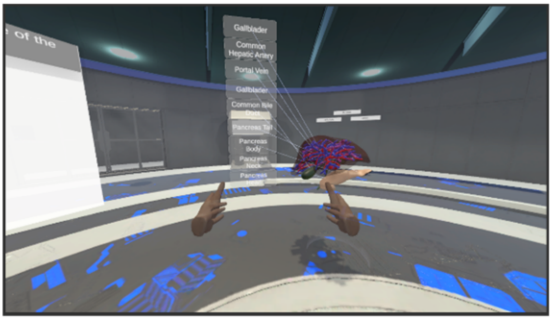

Figure 2. ENTICE VR environment

One of the core innovations of ENTICE was the enrichment of the XR resources using semantic annotations. To accomplish this the first step was to model XR medical resources conceptually and thus a Knowledge Graph (KG) was created by transforming to RDF, medical terms from the UMLS metathesaurus, as well as UX terms for annotating immersive AR/VR/MR content, that were eventually linked and further described using the ENTICE Core Ontology (ECO).

Finally, a qualitative analysis was performed for the initial evaluation of the resources. The qualitative evaluation consists of semi-structured interviews around three main axes: usability, technology acceptance, and perceived usefulness of the resources. Each one of these axes includes more specific topics and sub-topics regarding the questions asked during the interviews. The Unified Theory of Acceptance and Use of Technology (UTAUT) model selected for evaluating the technology acceptance axes [13]. The UTAUT Questionnaire in this evaluation consists of 25 items. Majority of the questions adopted from previously validated research related to VR acceptance. We also aim to evaluate achievements of learning outcomes (LO) of all VR episodes of the study.LO evaluation intends to measure students' knowledge upon completing their VR interaction.

3. Results

While technical and design innovations are well within the methodological purview of this work, the evaluation of the resources are the core results of the holistic approach. The ENTICE pre-pilot was launched to evaluate the virtual reality (VR) resources collecting qualitative data. The developed resources upon first feature complete release were sent for testing in three medical institutions-project partners, in Sweden (Karolinska Institutet), In Cyprus (University of Cyprus) and in Greece (Aristotle University of Thessaloniki). **In Sweden**, eight students participated in a pre-pilot think-aloud session. Preliminary results from the session demonstrated that the visibility of system status should be improved. During the VR interaction, lack of appropriate feedback provoked students pressing similar buttons multiple times. In addition, fostering a sense of freedom and confidence in VR learning are deemed important. Eventually, help and documentation related to VR is necessary. Students felt convenience when having clear instructions on how to interact with the VR. Furthermore, provisioning technical support during the learning episodes is considered valuable by the students. **In Greece**, 4 surgery residence doctors and one general surgeon specialist participated in a pre-pilot facilitated think aloud session. Participants, being already familiar with the material offered feedback on each explained feature as was explained to them. After the experience, semi-structured interviews were conducted to receive even more targeted feedback on the specific evaluation themes. Overall, feedback was positive with all residents expressing the need for curricular integration of these resources, as well as offering expansion ideas for future upgrades of the resources. **In Cyprus**, six medical students (6th grade), one clinical skills teacher and one technician participated in a pre-pilot semi-structured interview. The educational facilitator introduced the participants to the features of the resources as they individually experienced them and asked for feedback regarding educational usefulness and possible changes. Afterwards, the teacher conducted the semi-structured interview to receive more specific feedback of the resource and the overall experience of the students. In general, the feedback was positive and medical students were excited and recommended more features to include in the resource.

4. Discussion and Conclusion

This study confirms the importance of improving the quality and efficiency of learning resources. The work presented here and currently being validated by the ENTICE project pilots is an effort to streamline immersive content creation while maintaining pedagogical focus [1-3]. This process is still an ongoing process. In that context, it is still limited regarding its efficacy validation as the pre-pilots are currently finishing and wider piloting of the resources is still pending in the coming months. Infrastructural results, however, as discussed, are present. Future Lessons learnt from the process and tools proposed and developed during the project will be the essential enablers for further supporting and proliferating this rapid iterative process.

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