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AUGMENTED LEARNING ENVIRONMENT FOR WOUND CARE SIMULATION

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Introduction

Emerging technologies for teaching and learning have made it possible to create environments, scenarios and virtual patients that simulate clinical practices in order to promote the development of skills and knowledge in healthcare education (Lewis et al., 2005; Hogan, Sabri, & Kapralos, 2007). These simulations are seen as educational techniques that bring interactivity and immersion into the learning process, allowing the recreation of clinical experiences without the risk of causing harm to patients (Maran & Glavin, 2003). Other known advantage is the possibility learners have to practice an unlimited number of times a procedure or technique until correct realization, before applying it in real-world scenarios (Rey et al., 2006).

Virtual reality (VR) and Augmented reality (AR) are examples of emerging technologies for teaching and learning that allow the creation of digitally enhanced learning environments. These technologies are expected to have an impact in education, as highlighted by the Horizon report for Higher Education in 2010, 2011, and most recently in 2016 (Johnson et al., 2010, 2011, 2016). Regarding healthcare education, several studies indicate the positive effect of AR and VR in developing decision making skills and practical procedures using virtual simulators, with a higher impact on non-experienced participants (Zhu et al., 2014).

However, using VR in healthcare education can be a debatable approach since it immerses learners in a synthetic environment, enabling them to see the surrounding real-world. Acting in a different environment from which learners will have to act in real life scenarios is another concern to take into account. According to Ellaway (2010; p.791):

> *"(…) in medicine and medical education aspects of virtual reality have found their way into the mainstream through the use of 3D animations, digital imaging tools that can make 3D models (…) and more interactively through the use of synthetic worlds such as Second Life and haptic simulators for technical procedures such as laparoscopic surgery.*
>
> *A key limitation however for virtual reality in medical education is that it requires participants to step away from the environment in which the practice*

> *for which they are preparing takes place. Virtual reality is therefore essentially divergent from real world practice and the embodied experiences within it."*

In AR environments digital objects are added to the real-world, enhancing it and not replacing it. AR is a technology that allows the integration of virtual objects into the physical real-world. It supplements the real world with virtual objects in a way that they seem to coexist in the same space (Zhou, Duh, & Billinghurst, 2008). The combination of real with virtual, real time interactivity and three dimensional (3D) virtual content are the three commonly accepted characteristics of AR systems provided by Azuma (1997). In this way, AR plays an important role in education, as the 2011 Horizon report states:

> *"Augmented reality has strong potential to provide both powerful contextual, in situ learning experiences and serendipitous exploration and discovery of the connected nature of information in the real world." (Johnson et al., 2011; p.22)*

This paper describes part of a doctoral study where the effect of AR in nursing student's decision making skills was investigated, by comparing the usage of a virtual simulator in wound care diagnosis and treatment, with and without the support of AR to visualize the wounds.

A literature review was conducted to identify, select and critically analyse the effectiveness of AR in medical education. Web of Science (https://www.webofknowledge.com) was used to retrieve all studies until 29 July 2015, according to the following query: *augmented reality OR mixed reality AND medical OR healthcare AND training OR education*. In total, 43 studies out of 163 were selected to review, after excluding papers that focused only on VR, telemedicine, technical equipment, veterinary or exclusively related to medical practices and not educational.

According to this literature review, AR is used in several disciplines of medical education, with a higher incidence of studies related to the training of laparoscopic surgery (Botden et al., 2008; Feifer, Delisle & Anidjar, 2008; Oostema, Abdel & Gould, 2008; LeBlanc et al., 2010, Brinkman et al., 2012; Nugent et al., 2013; Vera et al., 2014), surgical puncture (Vikal et al., 2010; Yeo et al., 2011; Ungi et al., 2012; Moult et al., 2013; Nugent et al., 2013; Sutherland et al., 2013) and neurosurgery (Luciano et al., 2011; Alaraj et al., 2013; Mitha et al., 2013; Abhari et al., 2015). In general, AR has shown to be an effective tool to develop clinical skills when compared with other methods, with a greater impact on inexperienced learners, and its transfer to real world scenarios. AR in medical education is seen as a safe simulation method to practice unlimitedly clinical procedures, without the risk of harming real patients.

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Materials and Methods

Equipment

A web based learning simulator (e-Fer, requires an account to access and is available online at http://e-fer.ipleiria.pt) that holds several virtual cases of patients with chronic wounds was developed by Monguet et al. (2009) to improve wound care training. The clinical cases were developed by healthcare specialists and include a detailed description with pictorial (real picture of wounds) and non-pictorial information. The e-Fer simulator allows users to simulate decision-making when treating wounds, providing immediate feedback to the answers submitted (Figure 1). The main goal is to promote the healing of the patient's wound by selecting the best diagnosis and treatment solution, in this order.

The effectiveness of e-Fer was demonstrated by Costa (2010), showing that students developed their skills in all assessment parameters – infection, type of wound, type of tissue, wound cleaning, wound-dressing material and complementary procedure – except for the wound depth. The e-Fer simulator saves all participants data in a file that can easily be extracted for further analyse of performance.

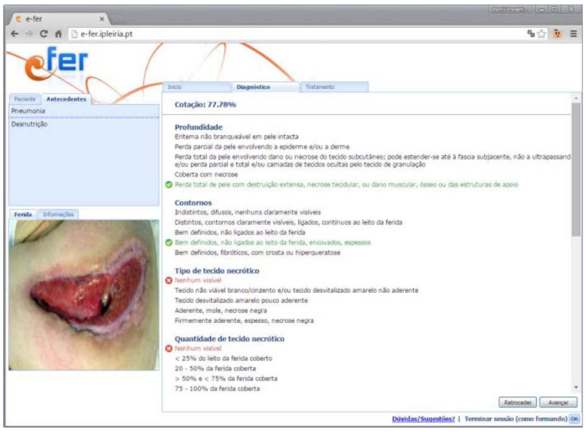

Figure 1. View of a clinical case in the e-Fer web based simulator that shows feedback given after answer submission

The AR component was created using user-friendly technology, both for the production of the 3D objects and its implementation in an AR mobile application. For this study 6 clinical cases were created and added to e-Fer.

The objects for these new cases were produced using Autodesk® 123D® Catch (http://www.123dapp.com/catch), a software that generates 3D objects based on several pictures taken from different angles, as shown in Figure 2.

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Figure 2. Creating a 3D wound with Autodesk® 123D® Catch

After producing the objects the files were uploaded to ViewAR, a software that uses printed markers to show the 3D objects in AR, when detected by an iPad with the application installed (http://viewar.com). At the moment this software is only available for commercial use. Alternatives to create AR experiences: Aurasma https://www.aurasma.com (free); Augment http://www.augment.com (30 day trial version).

Sample

In total, 54 participants completed the 4 week training period on wound care using the e-Fer simulator. All participants were Nursing students in their first year of study with no previous clinical wound care experience. Informed consent was given by all participants, who voluntarily participated in this study.

Procedure

A quasi experimental study with pre and post test was conducted with 54 participants that started the activity by solving clinical cases on e-Fer during 2 weeks. After this period participants were split into control group (n = 24) and experimental group (n = 30) for the second part of the activity. The control group kept solving clinical cases as they were used to in the e-Fer simulator. The experimental group also solved the clinical cases using e-Fer, but observed and analysed the wounds with AR (Figure 3).

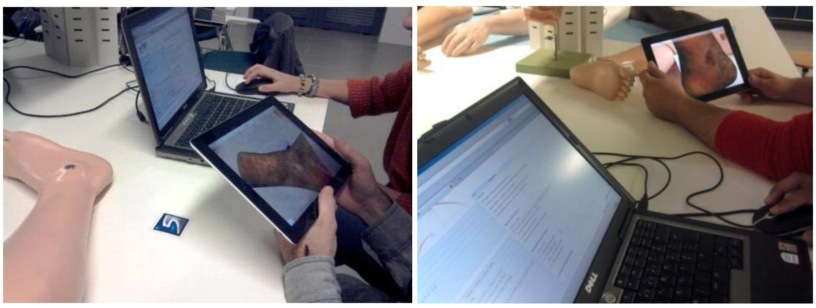

Figure 3. Students from the experimental group solving clinical cases with e-Fer while using AR to observe the chronical wounds

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Since the e-Fer simulator is web based, participants could solve the clinical cases at their own time and pace. However, due to technical reasons, a room with 4 laptops and 2 iPads was arranged in order to facilitate participants from the experimental group to carry out the activity. After 4 weeks the data with the participants' performance was extracted from e-Fer. All data from the 4 week period of training was extracted only in the end, since it could easily be split into pre test and post test data by dates. In this way, the data from the pre test corresponded to the first 2 weeks, whereas the data from the post test corresponded to the last 2 weeks.

Data analysis

All data was extracted from the e-Fer simulator, processed and analysed anonymously using Statistical Package for the Social Sciences 20.0 for Windows (SPSS Inc., Chicago, IL). The Mann–Whitney U test and Wilcoxon signed-rank test were used to compare and analyse the differences in performance, between and within groups respectively. A P value < 0.05 was considered statistically significant.

Results and discussion

The results after statistical treatment of the data extracted from e-Fer are based on the correct number of answers per clinical case given by students. The Mann-Whitney U test was used to compare groups. As shown in Table 1, no statistically significant differences were found between the two groups in the pre test, which validates the homogeneity of the groups before manipulating the independent variable, when both groups were using the traditional e-Fer without AR.

Table 1: Parameters of both groups (n = 54) in the diagnosis and comparison (Mann-Whitney U test) in the pre test

Parameters	Control (n = 24)		Experimental (n = 30)		Mann-Whitney U test
	M	SD	M	SD	P value
Depth	2,47	1,49	2,37	1,14	0,924
Edges	2,08	1,07	2,01	0,87	0,828
Type of necrotic tissue	2,20	1,14	2,15	0,98	1,000
Amount of necrotic tissue	2,24	1,11	2,09	1,04	0,531
Color of surrounding tissue	2,04	0,89	1,89	0,73	0,554
Granulation tissue	2,15	1,05	2,08	0,83	0,979
Epithelial tissue	2,41	1,09	2,32	0,92	0,958
Wound type	2,79	1,65	2,64	1,42	0,754
Infection	2,86	1,66	2,74	1,47	0,774
Diagnosis (total)	21,23	10,87	20,28	9,14	0,889

In the second moment, when the experimental group used e-Fer with AR, statistically significant differences where revealed in all parameters, except for the Type of necrotic tissue, as shown in Table 2. The means (M) obtained by the experimental group raised significantly in the second moment, while the control group had a similar performance.

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Table 2: Parameters of both groups (n = 54) in the diagnosis and comparison (Mann-Whitney U test) in the post test

Parameters	Control (n = 24)		Experimental (n = 30)		Mann-Whitney U Test
	M	SD	M	SD	P value
Depth	2.03	0.99	4.28	2.18	0.000
Edges	1.86	0.79	3.72	1.56	0.000
Type of necrotic tissue	1.92	0.93	2.29	1.10	0.182
Amount of necrotic tissue	1.85	0.89	2.85	0.80	0.000
Color of surrounding tissue	1.83	0.91	3.52	1.31	0.000
Granulation tissue	1.78	0.96	2.48	0.97	0.002
Epithelial tissue	2.27	1.35	4.14	1.20	0.000
Wound type	2.38	1.47	4.69	1.58	0.000
Infection	2.43	1.51	5.13	1.91	0.000
Diagnosis (total)	18.35	8.92	33.10	11.05	0.000

In the treatment phase no statistically significant differences where revealed in all parameters, after applying the same statistical tests to the extracted data. In fact, it's in the diagnosis phase that observing the wound is critical for a correct decision. In the treatment step, observation takes a secondary role, since it depends on the correct diagnosis previously realized.

In this way, observing the wound with AR proved to have a positive effect in the overall diagnosis phase on the experimental group, with highly statistically significant differences ($P < 0.001$).

Conclusion

The e-Fer is an online clinical decision-making simulator used in the initial training of nurses, allowing to simulate the diagnosis and treatment of virtual clinical cases of chronic wounds. In this study an AR component was added, with new clinical cases, creating an augmented learning environment where students could observe the 3D chronical wounds in a more realistic and natural way, simulating real practice.

The goal of this investigation was to verify if AR enhances the development of clinical decision-making skills in wound diagnosis and treatment. The results showed that AR enhanced students' performance in wound diagnostic parameters, with highly statistically significant differences ($P < 0.001$) in the Mann-Whitney U and Wilcoxon tests.

As for many studies of AR in medical education that were found in the literature review, we are aware that the size and convenience of the sample limits the generalization of these results. However, we believe that this study may represent another step in creating augmented learning environments, closer to what students will encounter in real-world scenarios, and that the intelligent use of technologies like AR is making possible.

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