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Application of a low-cost web-based simulation to improve students' practical skills in medical education

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ABSTRACT

Background: Practical sessions in undergraduate medical education are often costly and have to face constraints in terms of available laboratory time and practice materials (e.g. blood samples from animals). This makes it difficult to increase the time each student spends at the laboratory. We consider that it would be possible to improve the effectiveness of the laboratory time by providing the students with computer-based simulations for prior rehearsal. However, this approach still presents issues in terms of development costs and distribution to the students.

Objective: This study investigates the employment of low-cost simulation to allow medical students to rehearse practical exercises through a web-based e-learning environment. The aim is to maximize the efficiency of laboratory time and resources allocated by letting students become familiarized with the equipment and the procedures before they attend a laboratory session, but without requiring large-scale investment. Moreover, students can access the simulation via the Internet and rehearse at their own pace. We have studied the effects of such a simulation in terms of impact on the laboratory session, learning outcomes and student satisfaction.

Methods: We created a simulation that covers the steps of a practical exercise in a Physiology course (measuring hematocrit in a blood sample). An experimental group (EG, $n = 66$) played the simulation 1 week before the laboratory session. A control group (CG, $n = 77$) attended the laboratory session without playing the simulation. After the session, all students completed a survey about their perception of the difficulty of the exercise on a scale of 1–10 and the HCT final value that they obtained. The students in the EG also completed a survey about their satisfaction with the experience.

Results: After the laboratory session, the perceived difficulty of the procedure was lower on average in the EG compared to the CG (3.52 vs. 4.39, 95% CI: 0.16–1.57, $P = .016$). There was no significant difference in terms of perceived difficulty using the equipment. The HCT measures reported by the EG group also presented a much lower dispersion, meaning a higher reliability, in determining the HCT value (3.10 vs. 26.94, SD; variances significantly different, $P < .001$, F: 75.25, Dfd: 68.19 for EG and CG). In the satisfaction test, the majority of the students in the EG reported that the experience was positive or very positive (80.7%) and reported that it had helped them to identify and use the equipment (78%) and to perform the exercise (66%).

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The simulation was well received by students in the EG, who felt more comfortable during the laboratory session, and it helped them to perform the exercise better, obtaining more accurate results, which indicates more effective training. EG students perceived the procedure as easier to perform, but did not report an improvement in the perceived difficulty in using the equipment. The increased reliability demonstrates that low-cost simulations are a good complement to the laboratory sessions.

1. Introduction

Public undergraduate medical education tries to provide students with the best possible training at a reasonable operational cost. In this sense, the time and resources devoted to practical training are especially critical. In order to properly develop their skills and improve their practical scores, students should be able to repeat laboratory sessions and rehearse clinical procedures as many times as they need to. However, this requires more intensive use of laboratories and/or operating rooms, an extra charge for practice materials, and a higher number of teachers involved (increasing the amount of teacher hours per student).

This extra practice could be structured upon computer-based simulations (also known as immersive learning simulations, game-like simulations or serious games) or virtual 3D environments, which are becoming an increasingly recognized tool in medical education [1–6]. Even though there are multiple forms of simulations in medical training [7], computer-based simulations provide students with interactive, safe test environments, which can be accessed at any time without requiring specialized equipment (other than a computer). Computer simulations can, in turn, range from simple multimedia learning contents to complex simulations providing physical feedback through haptic technologies [8]. In addition, computer simulations can include game elements in order to engage students and enhance their motivation towards learning. Some authors argue that a proper balance between the realism of a simulation model, the engagement of game elements and a proper pedagogical model can be the key to maximizing the effectiveness of learning [9–13].

Nonetheless, simulations still present some inconveniences. Probably the most relevant is that complex simulations can be very expensive. The cost of most of the simulations developed in 2008 fell within the range between $20,000 and $100,000 (70.27%), with a median cost per learner of $102.08 and an average cost per learner of $281.51 [14]. Although in some cases such cost can be justified for ethical reasons (for example when health sciences students have to hone their skills with live patients [15]), some authors argue that whether these investments compensate in terms of learning outcomes is still an open research question [16]. In addition, setting up the space, equipment, and the time required to interact with the simulations can also hinder their application [17]. All these barriers can be troublesome, especially if we take into account that having a simulation does not always imply better training [18,19].

In this work we present a case study in the context of a Physiology course in the School of Medicine at the *Complutense University of Madrid*. The course is given during the second year of medical studies as a combination of theoretical and practical sessions. Laboratory training is distributed through the entire year with a single final practical exam. Students are required to achieve and demonstrate the skills to perform certain processes and must acquire the knowledge to relate biological processes to theoretical concepts, a fundamental aspect of a Physiology course [20,21].

In this pilot we have focused on the practical exercises related to Hematology for several reasons. Firstly, these exercises are performed using blood samples obtained from controlled laboratory rats sacrificed for the session. Secondly, Hematology is the first topic covered in the course, 8 months before the final practical exam. Due to the cost and ethical issues raised by the sacrifice of animals, these are also the only exercises that students cannot reproduce in the open laboratory sessions provided at the end of the course as a reinforcement for the practical exam. In this non-critical context, having a reinforcement simulation would be desirable, but it would be difficult to afford such a huge investment, which motivates the exploration of a low-cost approach.

We have developed a low-cost game-like simulation that covers the steps for the determination of hematocrit (HCT) through centrifugation of blood samples (both pure and in different osmolarity solutions). The simulation was developed using the <e-Adventure> platform [22], which facilitates the creation of game-like simulations by using photos of the real working place without compromising the cost [23]. Using an authoring tool such as <e-Adventure> allowed Medicine instructors to participate directly in the development process, which makes the development process much more dynamic and facilitates the maintenance of the content produced [24]. The web-oriented characteristics of the platform [25] made it possible to distribute the simulation to the students through an e-learning environment following a blended-learning approach. The use of these e-learning platforms (e.g. *Moodle*™, *Sakai*™, or *WebCT-Blackboard*™) as a complement to traditional education has become very popular in the academic field, especially among universities [26,27], where it is an ideal medium to distribute content to students. In this case we used the Virtual Campus of Complutense University (based on WebCT) to distribute the simulation to the students, which allowed them to use it at their own pace by using a web browser, either from the computer laboratories available at the university or from their own homes.