Serious Games in Formal Medical Education: An Experimental Study

Claudia Ribeiro*, Tiago Antunes*, Micaela Monteiro†, João Pereira*
*INESC-ID, Lisbon, Portugal
Instituto Superior Técnico, Universidade Técnica de Lisboa, Lisbon, Portugal
{claudia.sofia.ribeiro,tiago.c.antunes, joao.madeiras.pereira}@ist.utl.pt
†Serviço de Urgência Geral Centro Hospitalar Lisboa Ocidental, Lisbon, Portugal
mhmonteiro@chlo.min-saude.pt

***Abstract*—Medical knowledge has increased exponentially in the last decades. Healthcare professionals face a life-time challenge in medical education right from the beginning of medical school. They experience serious difficulties to keep updated. Traditional adult education, largely used in medical training, shows little effectiveness. Problem-based-learning has been proposed as a student-centred pedagogy to overcome failure of traditional medical instruction. A more recent trend is related to the use of serious games. Although, there are still few examples of serious games for medical education, the increased interest shown in the latest years shows that this is an important area and with a lot of potential to explore. In this paper we present the serious game Critical Transport, targeted at medical students with the aim to teach and train the recommendations for the transport of critically ill patients. This game was designed and validated with physicians of an academic hospital and tested during a formal class.**

I. Introduction

Healthcare is considered a priority by political decision makers worldwide. Medical knowledge is expanding quantitatively and qualitatively. Therefore professionals face a life-time challenge in medical education right from the beginning of medical school. Many of these professionals need practical experience without endangering themselves and others. This principle holds for many medical areas, such as medical decision making, behavioural training, and other areas involving dynamism and complexity [1].

Medical schools and residencies are currently facing a shift in their teaching paradigm. The increasing amount of medical information and research makes it difficult for medical education to stay current in its curriculum. Educators have faced these challenges by restructuring curricula, developing small-group sessions, and increasing self-directed learning and independent search. Nevertheless, it has been widely recognized that students have been ill-prepared for their roles as young doctors. In addition to their well documented deficiencies in a range of skills, there have been reports of stress resulting from inadequate preparation for their roles. These skill deficiencies have occurred along a changing pattern of health care delivery, which has seen significant changes to the clinical experience of undergraduates. In the postgraduate arena, working time restrictions have raised concerns towards a more streamlined, shorter duration of higher professional training and the amount of direct clinical experience it is possible to provide.

Globalization is almost omnipresent and the Internet and its web 2.0 have changed the way people communicate, interact and perceive the world. As Prensky [2] stated, rising generations are active and not passive, privilege graphics and animation over text, view technology as part of their lives and work as play and play as work. Therefore medical education must not stick. It has to change. Traditional medical education, mainly teacher centred and based on reading, listening or watching, has now proven insufficient in adult education and not adequate for teaching either technical skills or soft skills. There is also increasing consciousness about the importance of approximating the learning environment to real life by simulation and immersive realities, especially in a safety critical area like medicine. Universities have to create flexible curricula, harmonized within the global medical community. Teaching methods and learning environments must adapt. Lifelong learning has become not only an ethical obligation but also a demand of an empowered society in order to guarantee state-of-the art medical assessment and treatment.

The use of simulations in not new in medical education, in fact, it spans the centuries. Low-fidelity and high-fidelity simulation is used across different areas of medical education to teach different levels of skills as an evaluation tool to assess knowledge gaps. Another trend in medical education is the use of serious games. Using serious games for medical education can be considered a relative recent topic. Although there has been a lot effort to develop serious games that address and help overcome some of the difficulties and issues dealt by medicine most of these games are directed to patients and general individuals or groups and not for training medical undergraduates, graduates, or postgraduates. This trend is connected to the idea that prevention can, in many cases, avoid sickness and also promote a better quality of life and longer life span.

In this paper we present a contribution on the use of serious games for formal medical education. Namely, we describe Critical Transport, a serious game designed to teach undergraduate medical students the recommendations for the transport of critically ill patients as described by the Portuguese Society of Intensive Care. This game exploits video game technology to link in a framework computer-based case with e-learning functionalities. Some computer graphics techniques are used to reproduce different clinical cases where these recommendations must be taken into account in order to guarantee a safe transport of critically ill patients. This game was designed together with physicians from a teaching hospital,

978-1-4799-0965-0/13/$31.00 ©2013 IEEE

and tested with medical students during a formal class.

The remaining sections of this paper are organized as follows: Section II presents the state-of-the-art of serious games for health and for medical education. In section III is described the Critical Transport game architecture and its main characteristics. Section IV presents the Evaluation and how the game was validated with real users. Finally, section V presents the conclusions and future work.

II. Serious Games for Medical Education

Patient safety concerns call for the need to train medical personnel in simulated settings to reduce cost and patient morbidity [3]. The advances of technology has allowed to improve medical education through virtual reality simulations and e-learning applications. Recently attention has been given to how games could also play a role in medical education. Games have a number of characteristics to answer current challenges in adult education such as the need to shift from passive to active learning, adapt to individual needs and to attend to the important cognitive style changes of the new generation of trainees, the so called "digital natives" [1]. Video games potentially are powerful tools for training, as they are able to create immersive simulation environments and can easily be accessed at almost any time from almost any place. The player can train at his/ her own rhythm and can be evaluated as well, which makes it possible to integrate the games into a learning curriculum or a crediting system.

Entertainment video games, such as Super Monkey Ball 2, Star Wars Race Revenge and Silent Scope have been use to train surgeons to improve crucial skills in performing surgery (e.g. visual spatial performance, eye-hand coordination, fine motor control, and reaction time) [4]. Several studies were conducted to verified if the use of such games had an impact on learning outcomes and different studies have concluded that physicians that play video games or are skilful at playing games make fewer errors in performing laparoscopy [5], are faster at achieving proficiency on certain tasks in a laparoscopic simulator [6], and are more efficient in screening and faster in examining during simulated gastroscopy [7].

Serious games, which are games that have other purposes other than entertainment, have also been developed for medical education. In this context games such as the Haemophilia Planning Game and the Blood Money [8] have been developed. The Haemophilia Planning Game is targeted at medical personnel and policy makers working in haemophilia care. The goal of the game is to work as a vehicle to aid in the more effective integration of individuals looking at and working on haemophilia care from different perspectives: care, education and training, and payment sectors. The Blood Money game is targeted at the general public, policy makers, physicians and nurses in training or practice. The focus of this game is to provide a highly interactive gaming simulation of the social psychological world of the haemophiliac and general issues in health care delivery. More recent examples include serious games for training medical professional about insulin management for treatment of diabetes mellitus [9], Magnetic Resonance Imaging (MRI) [10] and advance life support training [11].

There are also examples of serious games in medical education that confer CME credits. Recently The Stanford School of Medicine edited an on-line accessed video game called "Septris" [1]. It trains the management of patients with suspected Sepsis, a prevalent infectious condition with a high mortality. It is based on international practice guidelines. Doctors/Players who successfully conclude the game will get CME credits. "Burn Centre" [2] is a video game that creates a simulation environment where healthcare professionals are trained in mass-scale casualty burn treatment. It also awards correct accomplishment with CME and Continuous Nursing Education (CNE) credits. On its website "The American Association of Medical Colleges" draws attention to the fact that "medical schools around the country are creating video games with the expressed goal of improving medical education". It makes reference to "3DiTeams", a project of Duke University, which creates a "game environment for training healthcare team coordination skills". This game recreates very realistic scenarios. The Florida State University Medical College, on the other hand, developed a video game that teaches geriatric concepts to medical students immerging them into a fantasy adventure world like Zelda or Alice in Wonderland [3]. The Imperial College of London Medical School created a virtual hospital in "Second Life", an on-line virtual world where users can interact with each other through avatars. It designs "game-based learning activities for the delivery of virtual patients that can drive experiential, diagnostic, and role-play learning activities supporting patients' diagnosis, investigation and treatment." These activities can be played at home or in the very classroom, oriented by teachers/tutors complementing other education techniques within a learning curriculum.

III. Critical Transport

The transport of critically ill patients is potentially harmful. These patients' condition may deteriorate by being mobilized or they may need sophisticated treatment such as advanced life support during transportation. Therefore there must be an important reason for their transport, i.e. a clinically relevant necessity/ advantage as for instance a heart catheter in a patient with an acute myocardial infarction. The clinical risk of transportation must be quantified and qualified so that a decision can be made regarding what kind of resources - material and human - are needed for a safe intra- or inter-hospital transport. The Portuguese Society of Intensive Care (Sociedade Portuguesa de Cuidados Intensivos) and the Portuguese Medical Board (Ordem dos Médicos) released recommendations for the transport of critically ill patients in 2008 [12]. These recommendations establish objective criteria, such as respiratory rate or degree of consciousness, for the evaluation of the patient that lead to a "risk and needs score". Three categories of material and human resources are defined and should be available while transport to each patient according to his/her individual score (Table I). With this clinical decision tool the responsible physician has an important support for the clinical management of the patient who needs transportation.

[1] http://cme.stanford.edu/septris/

[2] https://www.burncentertraining.com/

[3] http://www.youtube.com/watch?v=YertjfCoWhg

Score	Level	Vehicle	Team	Monitoring	Equipment
0-2 (only with O2 and iv line)	A	Normal Ambulance	Paramedic	None	AMS standard
3-6 (without any item that scores 2)	B	Normal Ambulance	• Paramedic • Nurse	• Pulsoximetry • ECG • Non-invasive blood pressure	The above + Monitor Iv medication and fluids
>7 or <7 if any item sores 2	C	Ambulance with advanced equipment	• Paramedic • Nurse • Physician	• Pulsoximetry • ECG • Non-invasive blood pressure • Capnography if needed	The above + defibrillator with external pacemaker, ventilator; material for tracheal intubation; perfusion pumps

TABLE I. CORRESPONDENCE BETWEEN PATIENT EVALUATION SCORE AND TEAM, MONITORING AND EQUIPMENT

In the next sub-sections it is described how these recommendations were translated into game mechanics and an experience that promotes learning this topic. Also, the graphical user interface (GUI), clinical case structure and information, and implementation details are described.

A. Gameplay

The gameplay is all the doing, thinking, and decision making that makes a game either fun, or not [13]. It includes the game's rules, the various player choices, and how easy, gradual or hard the road to success is. There isn't any magical formula to make a game fun and motivating for the intended players. This is very much dependent on a great number of factors, such as context, characteristics of the players (such as age, non-gamers vs. gamers, etc), among others. This is both true for serious games as well as entertainment games. In order to try overcome this difficulty or minimize its impacts, the gameplay of the Critical Transport was designed together with physicians during several sessions of informal interviews. In these sessions it was decided the phases of the game as well as the content and look-and-feel of each phase. Before deciding to move to the next phase a prototype was developed in order to validate and confront the work done with the expectations of the physicians involved.

At the end of this process it was decided that Critical Transport would be divided into five phases: Introduction and pedagogical goals; Briefing; Game experience (which consists in two sub-phases: Patient evaluation and Team and equipment choice); and Debriefing.

The first phase consists in a reference to the recommendations and explaining the game's pedagogical goals. This is presented in the form of a dialogue between two 3D avatars impersonating a doctor and nurse (Figure 1) in a hospital room. The content of the dialogue was provided by the physicians and is according to the information in [12].

The second phase is a very critical and important phase of the game. It consists in the clinical case briefing, where the information regarding the patient that is in need of transportation is described. This information includes the patient's name, age, medical history, cause of current hospitalization and the reason to be transported to another hospital. This information is presented by a 3D avatar impersonating a doctor (2). In order to increase the level of involvement of the player, the doctor addresses the player by her/his name (given in the start screen),

Fig. 1. Pedagogical goals

Fig. 2. Clinical Case Briefing

and describes the clinical case as a challenge that she/he must overcome to finish the game successfully.

The third phase consists in the evaluation of the patient's condition. This involves evaluating the following criteria: Artificial air way; Respiratory rate; Respiratory support; Venous access; Hemodynamic state; ECG monitoring; Arrhythmia risk; Pacemaker; Consciousness; and Technical and pharmacological support. Deciding how to evaluate each criterion is not a straightforward decision. In some of the cases, the player must collect information from various sources such as the ECG monitor and the perfusion pump to do a proper evaluation of the hemodynamic state. For this task, a 3D environment is provided which allows matching the in-game experience with a real medical environment, in this case a hospital room with all the necessary equipment. This 3D environment is composed of 3D avatars (one impersonating a patient and one impersonating a nurse) and all the components that the player needs to evaluate the patient's medical condition, such

Fig. 3. Patient's Evaluation

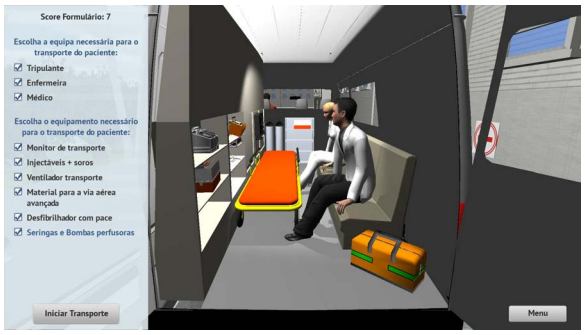

Fig. 4. Team and Equipment Choice

Fig. 5. Debriefing

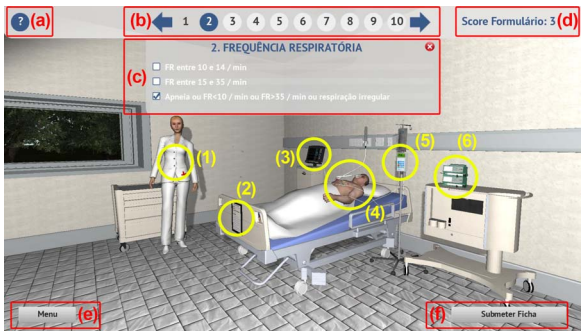

Fig. 6. Evaluation Phase User Interface

as, an ECG monitor, an infusion pump with drug information, respiratory supports, among others. (Figure 3)

In the fourth phase the player must choose the right ambulance type to transport the patient. Specifically, she/he needs to choose, the team and the equipment that should be on the ambulance for the transport (Figure 4). Usually, a hospital uses ambulances with different configurations which are used according to the current clinical condition of the patient that will be transported. Hence, a more critical patient will probably need more equipment and support to guarantee that her/his current condition doesn't deteriorate during the transport. These ambulances are a critical resource because there is a limited number available for each hospital. Therefore, choosing the right equipment and transport team is very important. Making a critically ill patient wait because the necessary transport is not available could have serious negative impacts on patient's quality care. The sum of the answers' values given in the form (Table I), results in the evaluation score. Through this score it is possible to know which transportation level the patient needs.

In the fifth and last phase is when the debriefing is presented to the player. All the answers given by the player during the patient's evaluation phase are analysed and corrected. Also in the debriefing, the chosen team and equipment is analysed in order to give feedback to the player about his choices, pointing out the right and the wrong choices. Additionally, it is attributed a score to the player based on his achievements during the complete clinical case. This score allows comparing the performance between players and single player performance evolution. (Figure 5)

At the end, it is possible to play another clinical case, starting again with a new briefing, or to exit the game.

B. Clinical Cases

A hospital is a complex system with a high level of uncertainty, where the doctors must be prepared to deal with different situations. In order to create such an environment several clinical cases are provided. This allows the players to deal with different scenarios, with different levels of difficulty, as in a real hospital.

Each clinical case is composed by a set of elements that describe the patient and its current condition. These include attributes, such as name, age, clinical history, current patient status, reason for the transportation, current heart rate, blood pressure, respiratory rate, oxygen saturation, drugs administration, and IV lines.

All this information is structured and stored in a XML file (Listing 1), unique for each clinical case/patient. In this manner, we ease the ability to extend the game with different clinical cases/patient. Also, if the recommendations are revised and enhanced, adapting each clinical case is a matter of just adding new attributes to the corresponding XML file. Finally, using an XML notation also allows to translate the clinical cases in different languages. Moreover, since XML is a notation easily understandable by everyone, Critical Transport can be extended by healthcare professionals without the need of a software programmer intervention.

Listing 1. XML Clinical case example

```
<clinical_case id="cc01">
      <patient>
            <name>Dolores Jesus</name>
            <genre>Female</genre>
            <age>65</age>
            <clinical_history> Diabetes Mellitus
            type 2 and Hypertension
            </clinical_history>
            <current_status> Suffered an acute
            myocardial infarction 6 hours ago
             </current_status>
            <transport_reason> Must be
            urgently transported to
            the Catheterization Room that is
            in another hospital to make a PTCA
            </transport_reason>
            <glasgow>Lucid and oriented</glasgow>
            <heart_rate>65/min</heart_rate>
            <blood_pressure>
            130/80 mmHg
            </blood_pressure>
            <respiratory_rate>
            17/min
            </respiratory_rate>
            <o2_saturation>96%</o2_saturation>
            <iv_lines>
                  <drug type="peripheral">
                  Isosorbide dinitrate at 6cc/h
                  </drug>
                  <saline type="peripheral">
                  20 cc/h
                  </saline>
            </iv_lines>
            <3d_model>AvatarPatient01</3d_model>
      </patient>
      <formAnswers>
            <one>0</one>
            <two>0</two>
            <three>0</three>
            <four>1</four>
            <five>0</five>
            <six>1</six>
            <seven>2</seven>
            <eight>0</eight>
            <nine>0</nine>
            <ten>2</ten>
      </formAnswers>
</clinical_case>
```

C. User Interface

The Critical Transport is targeted at medical students which may not be 'gamers' in general. Therefore, the interface was created with the goal of making the player's interaction as simple and efficient as possible. With this purpose we have used a navigation based on point-and-click. This greatly facilitates the navigation inside the virtual world for players that are not used to playing games or navigating inside 3D environments. For the remainder of the user interface, the standard style of interaction such as buttons, boxes and windows were used.

Every string used to label buttons, message boxes, form item, etc, is defined in XML files in order to ease the game translation and to improve its extensibility. Also, this further prevents the game from being obsolete in case the recommendations change and a different form must be filled out during patient evaluation. There are two main views where the user interface is more relevant, which correspond to the third and fourth phase described in Section III-A.

Figure 6 refers to the third phase, evaluation of the patient's condition, where the user interface is composed of an help button (a) which will display the help screen (Figure 7), buttons to open the form's questions (b), the interface to answer the form's questions (c), the form's score (d), a menu button (e), and the submit button (f) which can only be used when the form is completed. Moreover, in Figure 6, the yellow circled areas are clickable interaction spots, namely, a nurse which informs the player about the patient's neurological status (help regarding Glasgow comma analysis) (1), zoom to patient's chart (2), zoom to vital signs monitor (3), zoom to patient (check IV lines and intubation/ventilation) (4), perfusion pump (5), and drugs infusion pump (6). Implementing the interaction as point-and-click facilitates the navigation in the 3D environment since the player doesn't need to move.

Figure 8 refers to the fourth phase, team and equipment choice. This user interface is composed by the form's score (a) to support the user's choices, check-boxes to choose the team (b), the equipment

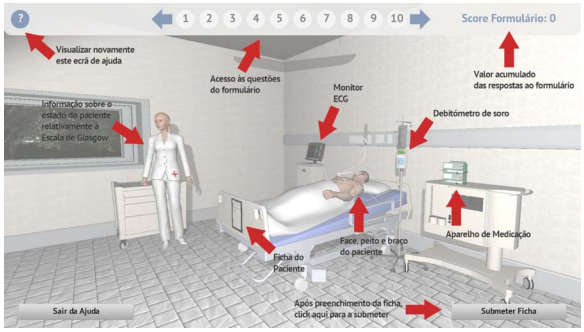

Fig. 7. Help Screen

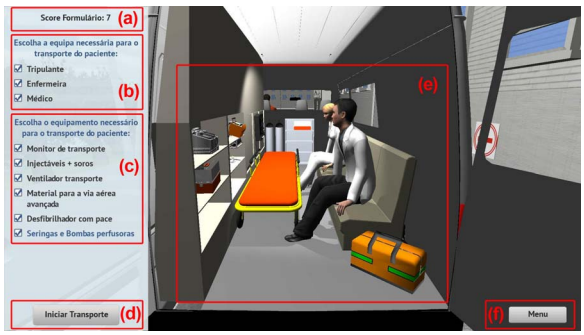

Fig. 8. Team and Equipment Choice User Interface

(c), a button to submit the choices and start the patient's transport, an ambulance 3D scenario where the selected items will appear (e), and a menu button (f).

D. Implementation Details

In Figure 9 a class diagram of Critical Transport is represented. Critical Transport is composed of five main class, a repository and web server. The Game Manager is the main class responsible for managing everything related to the game. The 3D World Manager deals with the 3D game objects creating the 3D world where the game takes place. Every clinical case has its own 3D models that fits in the general 3D hospital environment, which is managed by the 3D World Manager. The GUI Manager is responsible for all the user interface related components. It uses an XML file that contains all the user interface's strings in the game in order to facilitate the game's extensibility to other languages. The Clinical Cases is a class responsible for managing the data related to a clinical case described in III-B. It uses a repository where all the clinical cases available in the game are stored. This repository facilitates managing (adding, deleting, editing) clinical cases. The Data Logger class allows gathering the answers given by the players for further analysis. To facilitate the data gathering a web server was used. This web server receives all the form's answers and team and equipment choices given each time a player runs a clinical case. This collected data can be used to know if the medical students are failing in some specific questions or other relevant topic. This game was developed using Unity3D [4] game engine and every game script was writen in C# programming language.

IV. Evalutation

One important differentiating factor between serious games and entertainment games is the importance of assessment. Measuring, discussing and reasoning about the game play effectiveness is very

[4] http://unity3d.com/

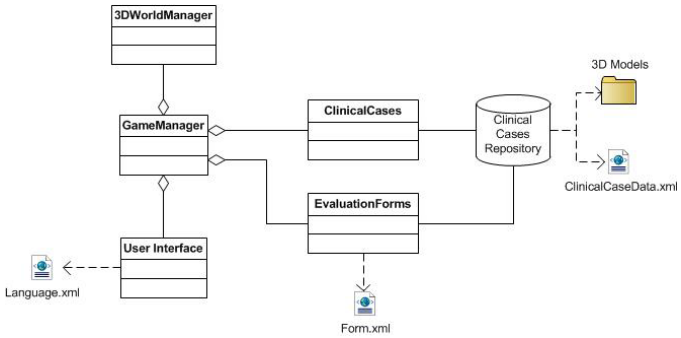

Fig. 9. Class Diagram

important in this domain. This can lead to reflection and therefore improved learning [14]. Chen and Michael have identified some of the main challenges that assessment in serious games is facing, namely effecting and improving player experience. The authors suggest that log information and teachers/instructors knowledge should be fully explored and, in some way, incorporated back in the game, to guide its course [15].

Pamela Kato [16] has also argued that the few research studies published on the validity and efficacy of health games are often poorly designed and that their conclusions cannot be considered valid evidence to support or refute efficacy. In this respect, she has suggested a set of guidelines for conducting high quality efficacy studies on games for health. These guidelines include grounding the game design in well defined theories, conducting randomized trials that included adequate control groups and number of participants, and also incorporating standardized measures to facilitate comparisons across studies.

The authors agree with the recommendations provided by the previous cited authors and they have been considered both during the development of the game as well as when designing and planning the evaluation of game play effectiveness. During game design, experts and medical students were involved in defined check-points to validate that both the pedagogical goals as well as the user interactions were according to the expectations of the end-users. Also, the inclusion of pedagogical content in the game took into account previous studies of similar games and approaches such as design patterns [17].

The goal of evaluating the game was two fold. First, it was important to try to validate that the game actually taught what it had been designed to teach. This was the main hypothesis of our study. In order to confirm or discard this hypothesis, we designed a qualitative study based on pre-experimental design research method [18], which includes three specific moments: briefing, where the player is introduced to the pedagogical goals of the game; a pre-test, where the user responds to the questionnaire; game experience, where the user plays different game scenarios, which in this case meant playing different clinical cases; and, a post-test where the player responds to the questionnaire. The pre-test and post-test questionnaires are one and the same, and consist of a set of questions related to the recommendations for the transport of critically ill patients as described in section III. Secondly, it was important to understand the general impression of the students regarding the use of serious games in the classroom. For this purpose, a focus group method was used.

In the remainder of this section, we detail the study, the achieved results and also provide more information about how the focus group was conducted.

A. Pre-test and post-test

Before each game experience each player was asked to answer the questionnaire in order to have feedback about their knowledge of the recommendations for the transport of critical ill patients. The main goal of the pre-test was to evaluate the previous knowledge of the user. The questionnaire was composed of five questions all related to the content in the recommendations for the transport of critically ill patients [12] and were devised by healthcare professionals. After playing, each player was asked to answer the questionnaire again in order to evaluate the knowledge the player had acquired during the game session. The post-test was exactly like the pre-test. After all the participants were evaluated, the data collected were analysed and the results of the pre and post-test were compared.

B. Pre-test Feedback

The pre-test results are presented in Figure 10. In the first

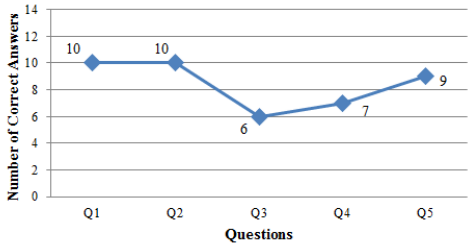

Fig. 10. User's Pre-Test Results.

two questions most of the students answered correctly while in the remaining three only more or less half of the students answered correctly. This result lead us to believe that in general the participants had some knowledge regarding the transport of critically ill patients.

C. Post-test Feedback

During the game experience, the player was allowed to play the first two clinical cases, each with a duration of approximately 15 minutes. After playing the game, each player was asked to answer the questionnaire, for which the results are presented in Figure 11.

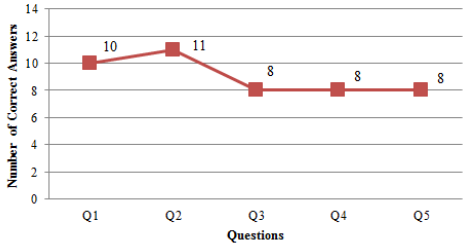

Fig. 11. User's Post-Test Results.

The results were positive in general, in the sense that there was an increase on the number of right answers on the questions were there were more wrong answers in the pre-test. In terms of numbers, the improvement weren't very significative since there was only five questions and the population was composed of 12 (25 no total, 13 raparigas e 3 rapazes (so 2 e 3 aula)) medical students. To scientifically confirm or discard our hypothesis it is necessary to enhance the questionnaire as well as the number of participants. This has been planned and is part of the future work of this ongoing project.

D. Focus Group

Focus groups are a form of group interview that capitalises on communication between research participants in order to generate data. Although group interviews are often used simply as a quick and convenient way to collect data from several people simultaneously, focus groups explicitly use group interaction as part of the method. This method is particularly useful for exploring people's knowledge and experiences and can be used to examine not only what people think but how they think and why they think that way [19].

In the context of this work, this was the idea of using the focus groups method. To examine what people think, how they think and why they think that way. Specifically, when using serious games as a pedagogical tool it is very important to promote reflection on the experience provided by the game in order to guarantee that whatever was meant to be learned was in fact learned. Therefore, explicitly conducting a focus group after the game section helps to enrich the reflection phase and hopefully improve the efficacy and efficiency of the game. Also, since this was a pioneer experience it was very important to perceive the opinion of the students about the use of serious games in the classroom. Using a focus group method in this context seemed appropriate since it was a homogeneous group (all 4th year medical students), they all knew the teachers and had interacted with them before in other classes. Also, it was an informal environment and they were informed about the goal of the discussion beforehand.

In our particular case, the focus group was conducted by the teachers of the class and consisted in going through every question of the questionnaire (Section IV-A) and transforming it into a debate between the students and the teachers. During this debate the students were asked questions and the whole class was invited to justify if a particular answer was correct, why, and if not, which would be the correct answer. After all the questions were reviewed and all the doubts were debated and clarified, some questions were made relating to the game. These questions involved general impressions related to the gameplay and also what were the students' impressions about the role of this tool in their education. Meaning, if they thought it had been useful, if they took it seriously, if it was a proper medium to express content such as medical procedures, protocols and algorithms, among others.

V. Discussion

Comparing the results of the pre-test with the post-test, we obtain better results in most of the questions in the post-test. This positive trend may show that the serious game has some impact in the user's knowledge, as presented in Figure 12. Nevertheless, in order to conclude that the game had an impact on the students knowledge more in-depth statistical analysis needs to be conducted. Specifically, it is necessary to have a bigger and more diverse population, which includes students from other universities. Also, having a control group, which would be exposed to the same topic using different mediums (e.g. tradition classroom, e-learning) would help to better understand the impacts of the game on students prior knowledge. Moreover, doing a retention test (e.g a month after the experience with the game), would also help to understand if the game was promoting route learning or meaningful learning.

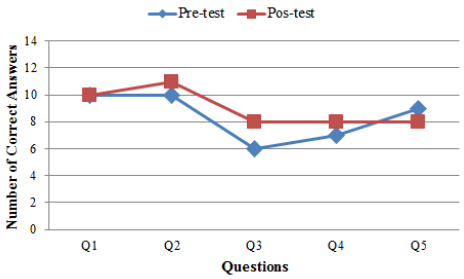

Fig. 12. Comparison between Pre-test and Post-test.

Therefore, with this study we do not intent to prove that the game clearly teaches what it was designed to teach but instead to give us confidence related to the potential of the game. The game will be used with other students during the current semester where more data will be collected which will allow us to do a proper experimental study. Also, showing some initial results, in particular good results, is helping us to address the decision makers in adopting these kind of medium in formal classes at the teaching hospital where the study was conducted.

The information collected during the focus group, allowed us to understand other important characteristics and impacts of the game on student impressions and learning. Namely, as explained some of the criteria that need to be evaluated by the player weren't straightforward. The students in general all agreed that playing the Critical Transport game allowed them to relate knowledge that had been previously learned in different lectures regarding different topics and apply it in a practical case. Also, it was stated that interacting with such a realistic environment could help to improve the integration of medical student in a real hospital environment. In this particular case, it helps improving knowing how a hospital room is organized, to know and better understand the information given by different medical equipment and also get in touch with other medical material such as Guedel tubes, among others.

Finally, some other important difficulties in introducing games on formal education should be mentioned. In general, physicians, are not part of what has been termed "digital natives". Therefore, their previous experiences with games is very limited. So, in order for them to understand and fully take advantage of using games in a classroom it would be necessary to first establish a familiarity of physicians with game technology and in particular with serious games as a tool for learning. Also, developing a game requires resources that are not always readily available, such as financial, human and material resources. For example, to guarantee that the game is running properly, it is necessary that the technical staff provides support to the teachers. Also, some games run online, so internet availability would be another important factor. Another aspect that is sometimes disregarded, is that not all students have the same competence in using games. For some it will take more time to get used to or understand how to use the game. All this things should be factored in when deciding to use games as complementary tool for learning.

VI. Limitations

Serious games have already been use successfully in areas such as military [20] and even for patient health management and prevention [21]. Nevertheless, this is not the case for medical education. Kato [4] has reviewed a set of video games and tailor-made games both for patient health management and prevention and well as medical education and she concluded that more research studies need to be conducted in order to clearly outline a causal link between playing video games and learning outcomes. Also, in recent articles, kato [16] and Graafland et al. [3] have discussed and described the process of validating a serious game. Although they use different terms both authors agree that validating a game involves conducting formal tests that crosses several game dimensions. Graafland et al. [3] has specifically focused on serious games for medical education for which he specified the following dimensions:

- Content validity: the degree to which the game content adequately converts the dimensions of the medical construct it aims to educate (or is associated with).

- Face validity: Degree of resemblance between medical constructs featured in game play and in reality, as assessed by novices (trainees) and experts (referents).
- Construct validity: Inherent difference in outcome of experts and novices on game play outcome parameters.
- Concurrent validity: Concordance of study results using a concept instrument (e.g. game) and study results on an established instrument or method, believed to measure the same medical theoretical construct.
- Predictive validity: The degree of concordance of a concept instrument (e.g. game) outcome and task performance in reality, based on a validated scoring system.

The authors agree that this is the way to go if we want to clearly prove that serious games could help tackle the challenges that healthcare professionals are currently facing. Therefore, in this article we describe but one step of many steps that are already planned in order to validate that Critical Transport is suited to be integrated in formal medical education.

VII. Conclusion

In this paper the serious game Critical Transport has been described. This game was design to teach the recommendations for the transport of critically ill patients. Critical Transport has been developed in collaboration with healthcare professionals, that participated both in validating the pedagogical content of the game as well as the correct translation of the recommendations into game mechanics. An XML structure was devised to represent the clinical cases where the recommendations should be applied. This representation also allowed us to set up different clinical cases each with a different level of difficulty. A study based on pre-experimental design was also conducted in order to assess if Critical Transport fulfil its pedagogical goals. For that purpose a questionnaire was devised in collaboration with healthcare professionals. This questionnaire was used to evaluate both the previous and prior knowledge regarding the recommendations for the transport of critically ill patients. In between answering the questionnaire the participant played two clinical case. This study involved 12 participants and the analysis and comparison of the results was presented in section IV. The number of correct answers marginally increased after the participants played the game which provided us with some confidence that the game could be used as a tools to teach or refresh the recommendations for the transport of critically ill patients. Nevertheless, as future work, this study needs to be extended to a bigger and more diverse audience in order to provide enough data to do a statistical significance test. Also, further developments are being included in the current version of the game with the goal of integrating it as a learning tool in the teaching hospital were the study took place.

Acknowledgment

This work was supported by FCT (INESC-ID multiannual funding) under the project PEst-OE/EEI/LA0021/2013. The authors also would like to acknowledge to the European funded Project Games and Learning Alliance (FP7 258169) the Network of Excellence (NoE) on Serious Games.

References

[1] C. Ribeiro, M. Monteiro, J. Fernandes, S. Corredoura, F. Candeias, and J. Pereira, *Games in Higher Education: Opportunities, Expectations, Challenges and Results in Medical Education*. New Pedagogical Approaches in Game Enhanced Learning – Curriculum Integration, IGI Global, 2012.

[2] P. Prensky, *Digital game-based learning*. McGraw-Hill, 2001.

[3] M. Graafland, J. M. Schraagen, and M. P. Schijven, "Systematic review of serious games for medical education and surgical skills training," *British Journal of Surgery*, vol. 99, no. 10, pp. 1322–1330, 2012. [Online]. Available: http://dx.doi.org/10.1002/bjs.8819

[4] M. P. Kato, "Video games in health care: Closing the gap," *Review of General Psychology*, vol. 14, no. 2, pp. 113–121, 2010.

[5] T. P. Grantcharov, L. Bardram, P. Funch-Jensen, and J. Rosenberg, "Impact of hand dominance, gender, and experience with computer games on performance in virtual reality laparoscopy," *Surgical Endoscopy And Other Interventional Techniques*, vol. 17, no. 7, pp. 1082–1085, 2003. [Online]. Available: http://dx.doi.org/10.1007/s00464-002-9176-0

[6] M. Shane, B. Pettitt, C. Morgenthal, and C. Smith, "Should surgical novices trade their retractors for joysticks? videogame experience decreases the time needed to acquire surgical skills," *Surgical Endoscopy*, vol. 22, no. 5, pp. 1294–1297, 2008. [Online]. Available: http://dx.doi.org/10.1007/s00464-007-9614-0

[7] L. Enochsson, B. Isaksson, R. Tour, A. Kjellin, L. Hedman, T. Wredmark, and L. Tsai-Felländer, "Visuospatial skills and computer game experience influence the performance of virtual endoscopy," *Journal of Gastrointestinal Surgery*, vol. 8, no. 7, pp. 874 – 880, 2004. [Online]. Available: http://www.sciencedirect.com/science/article/pii/S1091255X04002550

[8] C. Greenblat, "The design and redesign of gaming simulations on health care issues," *Simulation & Gaming*, vol. 32, no. 3, pp. 315–330, Sep. 2001.

[9] L. Diehl, E. Lehmann, R. Souza, J. Alves, R. Esteves, and P. Gordan, "A serious game prototype for education of medical doctors and students on insulin management for treatment of diabetes mellitus," in *Serious Games and Applications for Health (SeGAH), 2011 IEEE 1st International Conference on*, nov. 2011, pp. 1 –4.

[10] J. Valente, V. Kozlova, and C. Lima, "Virtual tutor in mri learning," in *Serious Games and Applications for Health (SeGAH), 2011 IEEE 1st International Conference on*, nov. 2011, pp. 37–41.

[11] M. Monteiro, A. Corredoura, M. Candeias, P. Morais, and J. Diniz, "Central hospital: Master of resuscitation: An immersive learning approach," in *Serious Games and Applications for Health (SeGAH), 2011 IEEE 1st International Conference on*, nov. 2011, pp. 1 –4.

[12] S. P. de Cuidados Intensivos and O. dos Médicos, "Transporte de doentes críticos - recomendações," 2008. [Online]. Available: (accessed Novembro 2012) $http://www.spci.pt/Docs/GuiaTransporte/9764_miolo.pdf$

[13] M. Prensky, "The Motivation of Gameplay: or, the REAL 21st century learning revolution," *On the Horizon*, vol. 10, no. 1, 2002.

[14] R. Lopes and R. Bidarra, "Adaptivity challenges in games and simulations: a survey," *Computer Intelligence and AI in Games, IEEE Transactions on*, pp. 85–99, 2011.

[15] S. Chen and D. Michael, "Proof of learning: assessment in serious games," 2005. [Online]. Available: (accessed Novembro 2012) http://www.gamasutra.com/view/feature/2433/proof_of_ learning_assessment_in_.php

[16] M. P. Kato, "Evaluating efficacy and validating health games." *Games for Health Journal*, vol. 1, no. 1, pp. 74–76, 2012.

[17] S. Björk and J. Holopainen, *Patterns in Game Design*. Charles River Media, 2005.

[18] W. J. Creswell, *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches*. Sage Publications, Inc, 2008.

[19] J. Kitzinger, "Qualitative research: Introducing focus groups," *BMJ*, vol. 311, no. 7000, pp. 299–302, 7 1995.

[20] D. Michael and S. Chen, *Serious games: games that educate, train and inform*. Thomson Course Technology, 2006. [Online]. Available: http://books.google.com/books?id=49kTAQAAIAAJ

[21] M. P. Kato, W. S. Cole, S. A. Bradlyn, and H. B. Pollock, "A video game improves behavioral outcomes in adolescents and young adults with cancer: A randomized trial," *Pediatrics*, vol. 122, no. 2, pp. 305–317, 2008.