Comparing Serious Games and Video-based Instructional Methods in Medical Education: a Randomized Controlled Trial

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***Abstract*—Purpose: To compare the level of knowledge retention between two different instructional strategies (one combined face-to-face and serious game and the other a combined face-to-face and video) on undergraduate medical students. Methods: The comparison was achieve by conducting a randomized controlled trial. This trial involved 42 undergraduate medical students. First they participated in a conventional class of 45 minutes about "the recommendation for the transportation of the critically ill patients", followed by a pre-test. Students were assigned at random to the control, video, and game groups, where they either watched instructive videos or played a serious game. After four weeks of exposure, a retention-test, containing the same questions of the pre-test, was administer to the video and game groups. The students also performed a survey eliciting students' perceptions, expectations and satisfaction regarding serious games. Knowledge test scores were analysed by the Wilcoxon signed-ranks test and Kruskal–Wallis test. The survey was descriptively analyzed. Results: The retention-test results showed that both instructional strategies (game and video) have achieved a slightly higher level of knowledge retention than the control group and in particular in the group that watched the video. Nevertheless, doing a between group analysis, no statistically significant difference ($p=0.5$) was observed for groups when comparing results obtained in the two points of assessment and teaching method. However, within-group comparison showed that there is a statistical significance when comparing the difference between pre/retention-test results for the instructional strategies (game and video, with $p=0.001$ and $p=0.002$, respectively), while this was not verified for the conventional class ($p>0.06$). Conclusion: Results indicate improvement in students' previous knowledge for both instructional strategies, in particular in the group that combined face-to-face and video class.**

***Index Terms*—Serious Games, Instructional Strategies, Randomized Controlled Trial, Knowledge Retention, Medical Education**

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I. Introduction

Both qualitatively and statistically, medical knowledge is growing. Consequently, professionals begin their journey through medical education with a lifetime challenge. Numerous of these professionals require real-world experience without putting themselves or others in danger. This rule applies to a variety of medical disciplines, including clinical decision-making, behavioral training, and other dynamism- and complexity-intensive fields. The teaching paradigm in medical schools and residencies is currently changing. It is challenging for medical education to maintain its curriculum given the growing body of medical knowledge and research. To address these issues, educators have changed curricula, created small group sessions, and promoted independent research and self-directed learning. Nevertheless, is generally accepted that medical students have not been appropriately prepared for their jobs.

In addition to their well-known deficits in a variety of skills, there have been complaints of stress brought on by their lack of proper role preparation. These skill gaps have emerged as a result of changes in the way healthcare is delivered, which have had a substantial impact on students' clinical experiences. Due to working time restrictions, concerns have been raised concerning a more streamlined, shorter period of higher professional training and the quantity of direct clinical experience that may be provided.

Globalization is pervasive, and the evolution of the Internet has changed how people connect and communicate. According to Prensky [1], younger generations prefer visuals and animation over text, are active rather than passive, see technology as an integral part of the way of life, and see work as play and play as work. As a result, medical education must adapt. It has now been established that traditional medical education, which is mostly teacher-centered and dependent on reading, listening, or watching, is ineffective for teaching either technical skills or soft skills to adults.

In a field where safety is crucial, like medicine, there is also growing awareness of the significance of simulating real-world situations and immersing learners in them. Universities must develop adaptable courses that are synchronized with the international medical community. Environments for learning and teaching must change.

In truth, simulations have been used in medical teaching for decades. Low-fidelity and high-fidelity simulation are used to teach various skill levels and as a tool for identifying knowledge gaps. Use of serious games is another trend in medical education [2], [3]. Nevertheless, the majority of these games are aimed at patients and general audiences [4].

In this paper we present a randomized controlled trial that assesses and compares the knowledge retention of undergraduate medical students when exposed to two different instructional strategies (one combined face-to-face and serious game and the other a combined face-to-face and video). Our aim was to understand the viability of introduction serious games as a learning tool in medical formal education.

The remaining sections of this paper are organized as follows: Section II presents the relevant studies done in the context of the presented study. Section III provides a detailed overview of how the randomized controlled trial was conducted. In Section IV the results are described, including the in-game log analysis and perceptions and satisfaction questionnaire. Section V presents our findings and the relationship to previous studies. Finally, section VI presents the main conclusions of our study.

II. Background

Although medical education is still mostly lecture-based and teacher-centered, medical schools are beginning to transition to a paradigm that is focused on the student. To be more precise, according to Rendas [5], medical schools are ”changing their educational programs and teaching strategies to ensure that students have active responsibility for their learning process and are prepared for life-long, self-directed learning”. Many medical schools are already implementing Problem-based Learning (PBL) methodologies to put the student at the center of the learning environment [6], such as the School of Medicine at MacMaster University in Canada. It is steadily becoming recognized as the pedagogical foundation for a real-world teaching strategy at medical faculties [7]. PBL is a problem-centered technique that may integrate many knowledge domains while enhancing student abilities and promoting problem-solving. The majority of postgraduate training, including specialization, is completed ”on the job” while also reading medical journals and textbooks, going to conferences, and taking practical courses—mostly on a volunteer basis. Concrete learning objectives, thoughtful activity design, and result evaluation are typically overlooked, with the exception of the latter. Simulator labs are one of the newer educational tools that are growing increasingly popular. As an illustration, consider the Advanced Life Support [8] courses offered by the European Resuscitation Council[1]. Under the supervision of instructors, small groups of trainees role-play resuscitating cardiac arrest patients using mannequin simulations. Clearly, receiving a medical education involves much more than just learning. It must show students how to solve problems quickly, engage with patients and families, deal with failure and mistakes, and deal with risk and uncertainty. In order for physicians to properly carry out their duties, it must enable them to learn and adopt proper behaviour. It is still unclear how these difficulties might be handled due to limitations like time and energy [9]. Foreman [10] states, ”It is amazing to me that in the modern age, when we have technologies like the Internet and the hand-held and the computers and the computer games, we are still teaching inside four walls, where all the information is coming from within those walls and where all students, regardless of the amount of preparation they have, are sitting together”. Following this pattern, serious game developers have started to target healthcare workers, particularly doctors and medical students. These games seem to have a variety of traits that address the aforementioned contemporary issues. [2]–[4]. Since they can easily be accessed at virtually any time from virtually any location and are capable of creating lifelike simulation environments, serious games have the potential to be highly effective training tools. Since the players can practice at their own pace and receive feedback, serious games can be incorporated into a learning curriculum or a crediting system. The current state of serious games in medical education is thoroughly examined in [2]–[4].

A number of recent studies have demonstrated that serious games can be effective in promoting engagement and improving learning outcomes in medical education. Tsopra et al. [11] discussed the design and assessment of a serious game intended to instruct medical students on proper antibiotic use. The game, called AntibioGame, consists of a series of scenarios that present different clinical cases, each of which requires the player to make decisions about antibiotic use based on the patient’s symptoms, medical history, and other relevant factors. The results of a user evaluation suggest that the game is effective in improving the students’ knowledge about appropriate antibiotic use, as well as their confidence in making decisions about antibiotic treatment. In a similar work, Diehl et al. [12] presented the results of a study to test the effectiveness of a game-based approach to medical education on insulin therapy. The study involved primary care physicians who were randomly assigned to either the intervention group, which received training on insulin therapy through a game called InsuOnline, or the control group, which got conventional training based on lectures. Compared to the conventional lecture-based training technique, the results showed that the game was well received and effective for

[1] https://www.erc.edu

medical education on insulin therapy.

Recently, serious games have been compared to traditional teaching methods for a variety of subjects related to medical education. Hu et al. [13] examined the efficiency of a serious game and online lectures for teaching about COVID-19 to medical students. In their study, a group of medical students was divided into two groups at random: one received online lectures, the other received serious games. The serious game group played a game that presented different scenarios related to COVID-19, and required them to make decisions based on their knowledge of the disease. The online lectures group watched recorded lectures on the same topics. The results of the study showed that the serious game group had significantly higher levels of knowledge about COVID-19 compared to the online lectures group. In addition, the serious game group reported higher levels of engagement and motivation compared to the online lectures group. A similar approach is explored by Mansoory et al. [14], who presented a study that compares the efficiency of conventional lecture-based and virtual reality-based serious gaming to instruct medical students about coma. The results of the study showed that the serious game approach was more effective in improving students' learning outcomes compared to the lecture approach. The serious game group had significantly higher scores on knowledge retention and comprehension compared to the lecture group. The study suggests that virtual reality-based serious games can be an effective approach for teaching medical students complex concepts. The study also highlights that student's readiness and acceptance of the instruction method plays a fundamental role in the learning process.

III. Methods and Materials

This randomized controlled trial was reported according to the CONSORT statement [15], as outlined in the research flowchart depicted in Figure 1. We also measured the quality of our study using the Modified Medical Education Research Study Quality Instrument (MMERSQI) [16] which gave a total of 88 points.

The subjects in this study were comprised by the entire class of forty-two fourth year medical students currently doing workshop classes and practical work in the Emergency Department (ED) of an academic hospital. Prior to the experiment, instructors and researchers explained the goals of the study and inquire the students their willingness to participate. Those that accepted signed a consent form.

The main goal of the course was to instruct the recommendation for the transportation of the critically ill patients. The content of the course included: (1) the identification of critically ill patients, (2) the initial care that should be provided to these patients, and (3) the initial therapeutic attitudes of the physician in charge of the patient.

The serious game is a video game specifically developed to practice the recommendations for the transport of critically ill patients. It was developed by a multidisciplinary team composed of physicians, researchers, software developers, and a designer. Previous to this study the game was evaluated during formal classes at the academic hospital following a before-and-after study design. The details of both the design considerations and initial evaluation were described in [17].

This study's educational methodology was defined according to what was previously proposed in similar studies [18]–[26]. The intervention and allocation of this study was realized in three different rooms at the academic hospital where students usually have their normal classes. Every subject in our study attended a conventional class of 45 minutes led by an instructor, which was supported by PowerPoint presentations. During the class the students were invited to participate by answering questions and clarifying critical issues about the topic being taught. After the conventional class the students were randomly divided in three groups (see Fig. 1). First, we randomly divided the group into two groups, and subsequently one of the groups was divided in control (n=11) and video-based learning group (n=12). The distribution was done in a manner similar to a coin toss - ”0” was attributed to the control group, and ”1” to the video-based learning group. The unequal size of groups [27] allowed us to collect more data in the game group (n=19) regarding students perceptions, expectations, and satisfaction regarding serious games.

The first group (control group) was dismissed and allowed to go home. The second group stayed in the room and watched a video during 15 minutes. The video showed two game sessions, one of the first clinical case, and another of the second clinical case (see Table I) narrated by one of the responsible physicians responsible for teaching the workshop. The third group was directed to another room where they played the serious game Critical Transport during 15 minutes. During this time interval the students played the first two clinical cases of the serious game (see Table I). The two clinical cases differed in difficulty, referring to patients needing to be transported to different institutions due to their critical conditions.

In addition all the students completed three different questionnaires: (a) prior to the conventional class all groups completed a (i) mandatory pre-test to assess their entry level knowledge and (ii) a questionnaire regarding demographic information; (b) after one month, and without previous notice, the students were administered a mandatory knowledge test (retention-test) at the academic hospital after their morning classes. The two most often employed measurements to evaluate the level of knowledge retention in educational settings are *cued recall* (i.e., open-ended questions) and *recognition* (true-false questions) [28]. Multiple-choice questions (MCQs) frequently rely on both recognition and recall. Following these guidelines the knowledge test, devised by the physicians responsible for administering the conventional class involved in the design of the serious game, contained right/wrong and multiple choice questions regarding the recommendations for the transport of the critically ill patient.

The questionnaire aimed at eliciting students' perceptions, expectations, and satisfaction regarding serious games was composed of three yes/no questions, one multiple choice question, four three-point Likert-scale, and one open question.

Table I
CLINICAL CASE 1 AND 2 DESCRIPTION AND MEDICAL DATA

Clinical Case	*Description*	*Monitoring Parameters*	*Transport Type*
1	• 28 year old man • Fell from a scaffolding from a height of 4 meters: Fractured both lower limbs; Head trauma without loss of consciousness • Cranial CT scan unremarkable • Medical history: unremarkable	• Heart rate: (90/min) • Blood pressure: (110/70mmHg) • Respiratory rate: 17/min • O2 Saturation: 96	B
2	• 65 year old woman • Acute myocardial infarction (onset 6h ago) • Must be taken to the cath lab which is located in another facility in order to get timely coronary re-perfusion • Medical history: Type 2 Diabetes; High blood pressure	• Heart rate: (65/min) • Blood pressure: (130/80mmHg) • Respiratory rate: 17/min • O2 Saturation: 96	C

This questionnaire was filled in by the game group.

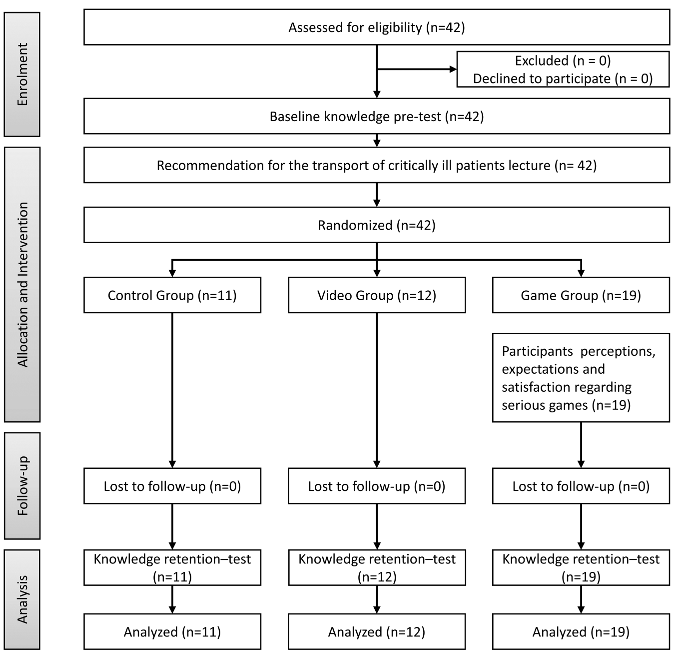

Figure 1. Research flowchart

Statistics

This study used both descriptive and inferential statistics to analyse the data. Regarding inferential statistics the tests either: (a) verified if the difference between the pre-test and retention-test

Both descriptive and inferential statistics were employed in this study to analyze the data. When it comes to inferential statistics, the tests either: (a) verified if the difference between pre-test and retention-test results were correlated using a Wilcoxon signed-ranks test [29]; (b) compared the differences between groups using the Kruskal–Wallis test. These tests were chosen as our sample did not follow a normal distribution. Descriptive and correlation analysis were performed using R Studio. Significance was set at the $p < 0.05$ level.

IV. RESULTS

The group of 42 medical students was composed of 29 women and 13 men with an average age of 23 years. All fourth year medical degree students were from the same university.

Descriptive analysis of the student's scores obtained in the knowledge assessment according to the group and point of assessment are presented in Table II and Figure 2.

Descriptive Statistics					
	Teaching method	N	Mean	Std deviation	Std error mean
Pre-test	conventional	11	4.55	1.21	0.37
	IS (game)	19	4.63	0.90	0.21
	IS (video)	12	4.50	0.80	0.23
Retention-test	conventional	11	5.73	1.27	0.38
	IS (game)	19	5.95	1.03	0.24
	IS (video)	12	6.25	0.75	0.22

Table II
MEAN GRADE OF THE STUDENTS IN THE KNOWLEDGE TESTS

According to pre-test scores we observed that there were no significant differences on students previous knowledge of the recommendations for the transportation of critically ill patients and we have also verified this same conclusion based on a Kruskal-Wallis test of pre-test scores ($p > 0.87$).

Regarding retention-test results, both instructional strategies (game and video) achieved a slightly higher level of knowledge retention, specifically the group that watched the video all scored higher in the retention test than the group in the face-to-face class and face-to-face game session.

Nevertheless, doing a between-group analysis, no statistically significant difference (p = 0.5) was observed for groups when comparing results obtained in the two points of assessment and teaching method (see Table III). However, it was

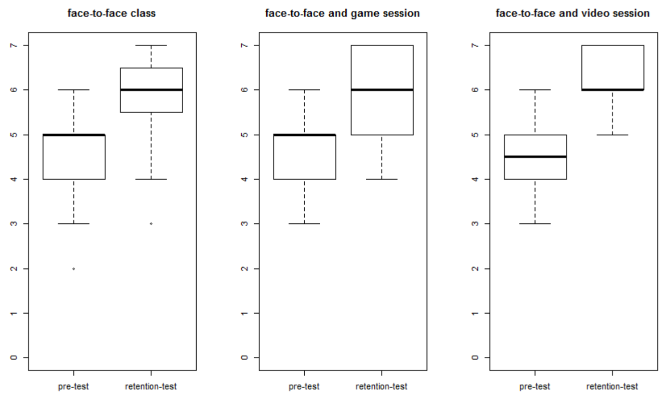

Figure 2. Pre/Retention-test Results

Inferential Statistics			
Kruskal-Wallis test	chi-squared = 1.3478	df = 2	p-value = 0.5097

	Conventional	IS (game)	IS (video)
Wilcoxon signed-rank test	p-value = 0.069	p-value = 0.001	p-value = 0.002

Table III
COMPARISON BETWEEN GROUPS (TEACHING METHOD) AND WITHIN GROUPS (DIFFERENCE BETWEEN PRE/RETENTION-TEST)

also important to analyse the results within-group in order to try to establish a causal relationship between retention-test results and the teaching method. For this purpose the Wilcoxon signed-rank test was used to verify the correlation between knowledge test scores in each of the teaching methods used. The summary of these results is also presented in Table III. These results show that there is a statistical significance when comparing the difference between pre/retention-test results for the instructional strategies (game and video), while this was not verified for the conventional class ($p > 0.06$).

We also analysed the improvement of student's performance per question comparing pre-test and retention-test (Figures. 3, 4, 5). The questions where the students had more difficulties in the pre-test were *Q1*, *Q6* and *Q7*. Regarding the retention-test, in the face-to-face session the students had difficulties with *Q5* and *Q6*, in the face-to-face and video session question *Q6* and *Q7* were a challenge, and in the face-to-face and game session more than half of the class had every question correct. This means that, in general, all the students had difficulties identifying initial medical approach (e.g. ABCDE), knowing the patient evaluation criteria and appropriate transport type. Nevertheless, these group of questions showcased the highest level of improvements specifically regarding the instructional strategies (game and video).

A. In-Game Log Analysis

We were able to assess and evaluate the knowledge acquired with relation to both general and particular questions

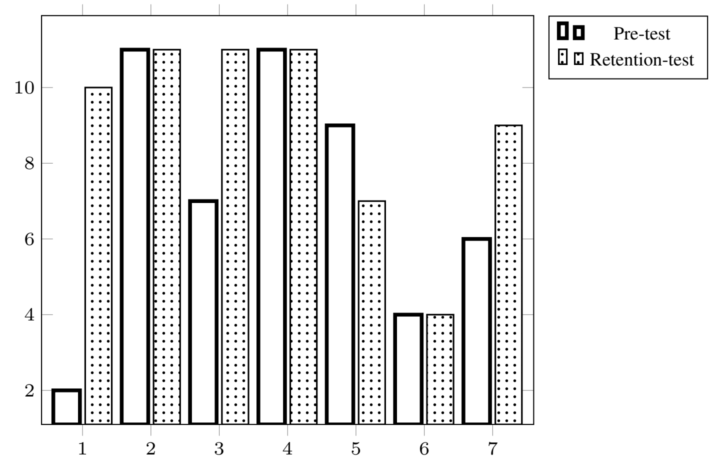

Figure 3. Face to Face: Pre/Retention-Test Results per Question

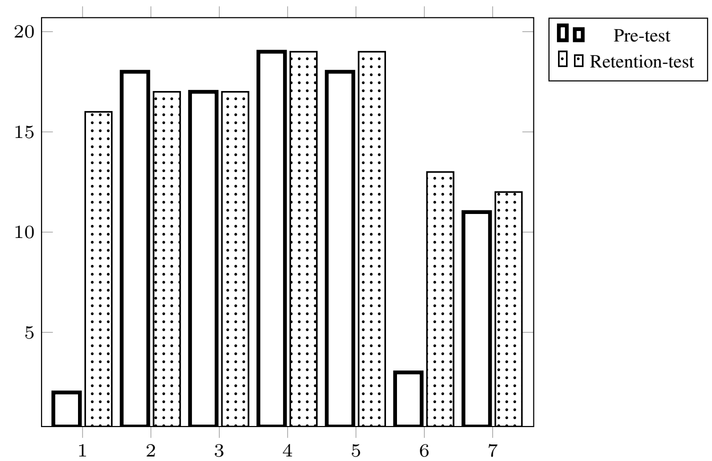

Figure 4. Face to Face Game Session: Pre/Retention-Test Results per Question

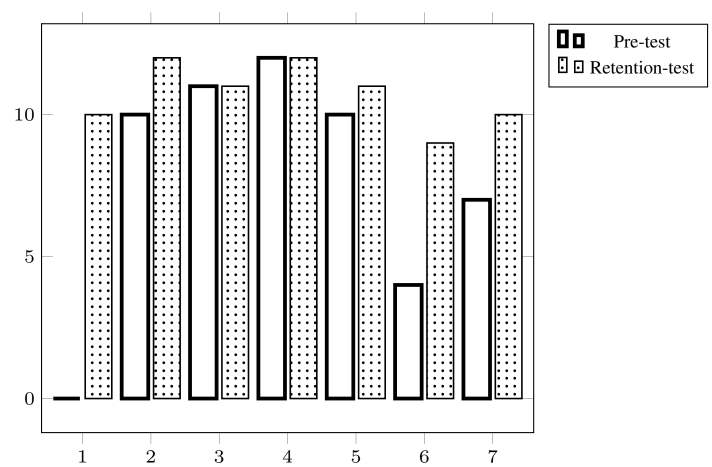

Figure 5. Face to Face Video Session: Pre/Retention-Test Results per Question

linked to the educational material using the pre/retention-test questionnaire. Specific information regarding the suggestions for transporting critically sick patients was gathered through in-game data. The in-game questionnaire, which covered the criteria regarding the patient status, the ambulance team, and the ambulance equipment, was used to aggregate this information into three separate groups. Figure 6 shows data gathered from both the clinical case scenario played by the students and the respective outcomes.

Results from the comparison of the two clinical instances revealed that students' rates of improvement are inconsistent with relation to the issues of team and equipment as well as questions concerning evaluation standards. There have been instances where some students did better than others in the second clinical case. We offer some justifications for the variation in improvement when comparing various question groups in the discussion section.

B. Perceptions and Satisfaction Questionnaire Results

Regarding student game habits and perceptions, 39% of student were regular players, and 39% had prior experience studying through a serious game in a setting other than medical education. 4% of the students had prior training in the subject being studied. In comparison to traditional teaching methods (class, lecture, or reading), serious games were believed to allow for greater knowledge acquisition (64%), an equal amount (24%) and less knowledge acquisition (12%). 76% thought that learning through a serious game would make the information endure longer, 20% thought it would last about the same, and 4% thought it would last less. 92% of respondents said that playing serious games improved skill development.

This questionnaire also included an open question in case students wanted to write a commentary regarding Critical Transport and the experience of using it. What follows is a transcription of some of the commentaries left by the students and were relevant for our study:

> *"Although the discussion of results and errors is very limited, learning with the serious games is more interactive."*
>
> *"Conducting a proper discussion of the clinical cases prior to playing the serious game could help consolidate the knowledge gain."*
>
> *"This teaching method should be applied to other medical areas, involving diverse clinical cases, not just about the recommendation for the transport of the critically ill patient."*
>
> *"Although I know it was a matter of lack of time, I think that it would have been important in terms of learning to have played the four clinical cases available in the game. Therefore, i think that in the future the class should be longer."*

V. Discussion

The results obtained from this study show that although there are no statistically significant differences between groups, both in knowledge assessment test and teaching method, there is a statistically significant correlation for the instructional strategies (game and video) when comparing the difference between pre/retention-test scores. These resulting scores indicate that complementing conventional classes with video watching or serious games have a positive impact on student knowledge retention.

According to previous studies using experiential learning theory, the game group would have better results than the other two groups, but this was not the case. There are a few explanations for this result. A thorough comprehension of the subject matter is referred to as meaningful learning, which entails attending to significant elements of the provided content by cognitively organizing it into a cohesive cognitive framework and integrating it with pertinent prior knowledge. When interacting with a serious game for the first time, the player has to activate cognitive processing to understand and interact with the rules and goals of the game [22]. However, video watching is known to be a passive activity allowing the viewer to dedicate their full attention to hear and observe what is being taught. This finding is corroborated by the results of the study conducted by Ridgway et al. [30] who concluded that surgical students had higher performance results when using web-based aural lectures than non-aural lectures. Similarly, in a study conducted by de Sena et al. [26], the students had superior performance results with video-based lectures compared to using a serious game. Consequently, the learner new to the game requires more cognitive processing abilities when playing a game than when watching a video, resulting in reduced cognitive resources to process the learning content of the game. However, the learner familiar with the game would be more cognitively available to process the pedagogical content whilst playing the game.

The serious game has a higher level of interactivity than watching a video but there is a note worthy difference. During a game session the player explores the virtual environment and attempts to overcome the challenges presented by the game. During a video session the teacher and students can interact, enabling a guided practice in understanding and incorporating the pedagogical content. By complementing the game session with the presence of a facilitator, or integrating an artificial mentor into the game pedagogical advantages could be provided. Nevertheless, both of these approaches have their own set of challenges. Namely, the people responsible for teaching at medical universities and in academic hospitals are medical professionals or medical researchers, who are usually not digitally skilled. Therefore, it would be necessary to prepare them for their role in supporting students learning with serious games.

Another factor that worth analysing is the type of feedback that is provided by both mediums, in this case, the serious game and the video. The video per se does not give any feedback to the viewer since it is a non-interactive experience. On the other hand, feedback is central to the design of games including the design of serious games. Regarding serious games, the importance of such feature is connected

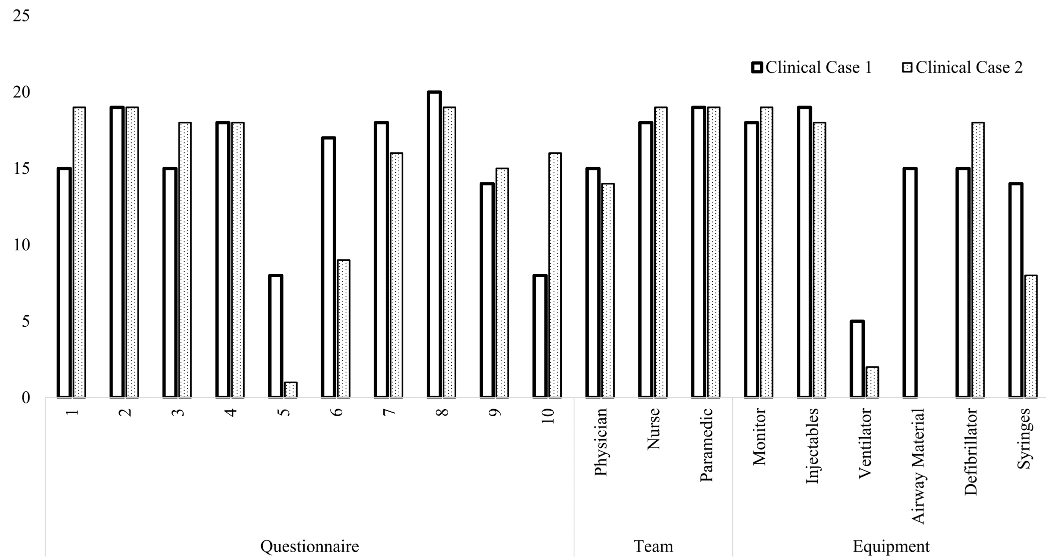

Figure 6. Comparison of In-Game Performance

to the role that feedback plays in pedagogical approaches as described in [31], [32]. Feedback provides the player with information regarding the involvement in the game allowing for improvements in strategies and becoming a better player. In the particular case of Critical Transport, the only feedback provided regards the patient evaluation criteria and its impact on the score related to the ambulance type. Therefore, it has no relation to the choices of the player. Such observation leads us to believe that this type of feedback is insufficient for the player to properly understand and learn from the learning experience provided by the serious game, as it does not provide the player information regarding right, wrong and/or why. However, efficient feedback design in serious games is an open research question. Therefore, further research should be carried out to verify if changing the feedback type would have substantial impact on the levels of knowledge retention. The participants enjoyed playing Critical Transport, providing general opinion that serious games would provide them more effective learning thereby, desiring this kind of medium integrated into their formal studies. This positive insight facilitates enjoyment and engagement in learning has been argued to benefit learning. Knowledge retention recommendations [28] suggest that to mitigate the effects of the ”Ebbinghaus curve”, students should be exposed to the material in different contexts at regular time spans. Serious games can be an effective tool in this case, as games can be played individually, allowing for easy integration of similar or different knowledge in diverse contexts without adhering to a schedule, and no relation to cost regarding repetition.

VI. Conclusions

In this paper we presented a randomized controlled trial study that compared the knowledge retention between two instructional strategies. The retention-test results demonstrated an improvement in students previous knowledge for both instructional strategies (combined face-to-face and serious game and combined face-to-face and video), and in particular in the group that had the face-to-face conventional class and video. Between-group and within-group analysis showed a causal relationship between improvements in previous knowledge and instructional strategies, as well as the individual analysis of pre/retention-test questions. These results could be explained due to the difference in the requirements of cognitive processing between playing a game and watching a video. Another factor that could have had an impact in these results was the presence of a facilitator in the video session, which provided a context that facilitated the integration of the pedagogical content. Another important difference was the type of feedback that is provided by both mediums. These results reinforce the viability of using serious games as a learning tool in medical formal education as a possible solution to mitigate the effects of the ”Ebbinghaus curve”.

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