

Online Learning and Clinical Procedures: Rapid Development and Effective Deployment of Game-Like Interactive Simulations

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Abstract. Traditionally, medical education has used live patients to teach medical procedures. This carries a significant risk to patients. As learning technology advances, the early integration of computer-aided medical simulations into medical training before patient contact is becoming an ethical imperative, yet development costs are constraining. In this paper, we describe the use of a gaming engine to create rapidly a game-like interactive simulation for medical training at a low cost. Our process model, driven by the simulation storyboard provided by the instructors, allows for easy simulation refinements and permits an early evaluation of the educational outcome. We also describe its initial integration into the existing matrix of low-tech simulation (procedures practiced on mannequins) and an educational platform (e-learning system) used to support and track novice physicians within a large academic training center.

Keywords: game-like simulations, game-based learning, development process model, development costs, virtual learning environments, learning management systems, clinical procedures, e-Adventure, IMS Learning Design, LRN.

1 Introduction

Over thousands of years, medical education has relied on a master-apprentice system where patients are the primary learning tool for first-time medical procedures. This has created an ethical tension between the need to hone the skills of health professionals on live patients while insuring patient safety and well-being [1]. The emergence of high-powered computing, which allows real-time virtual interaction with haptics, is putting us in a position where we can mitigate this ethical tension by developing healthcare workers' skills early on by using realistic patient simulators without putting patients at risk. While this kind of advanced simulation technology may allay this tension, it also introduces a new problem: the development cost of highly advanced computer-driven simulators and their integration into existing educational infrastructure.

Presently, visual and tactile realism in immersive simulations can only be achieved with significant investment. However, when dealing with specific procedures of limited application, lower-cost computer-based educational games and game-like simulations can still offer advantages over other forms of training (e.g., practice exercises using mannequins or live patients), allowing a broader range of experimentation, feedback and reflection on mistakes. Game-like simulations can be played by the trainees at home, as many times as desired, and at their own pace. They are free to explore, to try different approaches, without fear of breaking the equipment (or harming the patient) and, potentially, with the guidance and feedback provided by the simulation itself.

These products cannot match state-of-the-art simulations in terms of the development of motor skills, but those skills are often only a small part of what needs to be honed when learning to do a procedure. Most procedures require a combination of motor skills and the memorization of a large number of steps required before, during, and after the procedure. Learning with game-like simulations can provide important prior knowledge, so that motor-skill training and face-to-face exchange can be the focus when practicing the procedure in the presence of a clinical educator. This can reduce the total face-to-face time needed, increase the value of the teaching encounter, and ultimately reduce the risk involved in training on live patients.

Additionally, in order to coexist with the modern Technology-Enhanced Learning (TEL) settings, educational games and game-like simulations cannot be independent artifacts, but must be integrated with co-existing courses and training modules. Take, for example, The Hub, a community-driven learning and knowledge management system used by physicians and staff at Harvard Medical School's teaching hospitals. The Hub is built on top of the opensource .LRN e-learning platform [2], with several training courses already deployed there. The community value and the results achieved through The Hub encourage us to seek new applications of these technologies and the educational games and simulations used in training should not be disconnected from these environments. On the one hand, it should be possible to launch the games from within the online training environment, just as if they were a document or a streamed video. On the other hand, the game should monitor automatically the performance of the student, measuring the time required to complete each task, committed errors and level of completion. Finally, the data gathered from the monitoring of the student should be available as a report for the instructors as well as an automatically generated grade to be stored with the student's profile and achievements.

This work describes a design and implementation methodology for medical simulations that avoids the high development costs of VR-like simulations, and successfully addresses the integration requirements with the existing e-learning platforms (in particular, those identified in the context of The Hub, although the results apply for other training platforms). For this purpose we conceive simulations as game-based modules and we use <e-Adventure>, an educational game engine created at Complutense University of Madrid for their implementation.

The work is therefore organized as follows: in section 2 we present the design and implementation methodology. In section 3, we illustrate the methodology with a case study. In section 4 we discuss the conclusions derived from the development of the case study and in section 5 we summarize our conclusions and discuss future work.

2 The Design and Implementation Methodology

Clinical procedures do not only require motor skills or tactile tasks, but also the memorization of a large number of related steps required before, during, and after the procedure. For this purpose, we propose a blended-learning approach, where a simulation can be used to get an overview of complex procedures and the additional skills required can later be exercised in focused practical sessions. In our approach, simulations are conceived as point-and-click adventure videogames. Adventure videogames have been already identified as a suitable game genre for education [3-5], especially when it comes to learning complex procedures that involve sequences of steps. We have defined a process model to create these adventure-like simulations from already established clinical procedures, following a number of steps (see Fig. 1). The following subsections detail each of these steps.

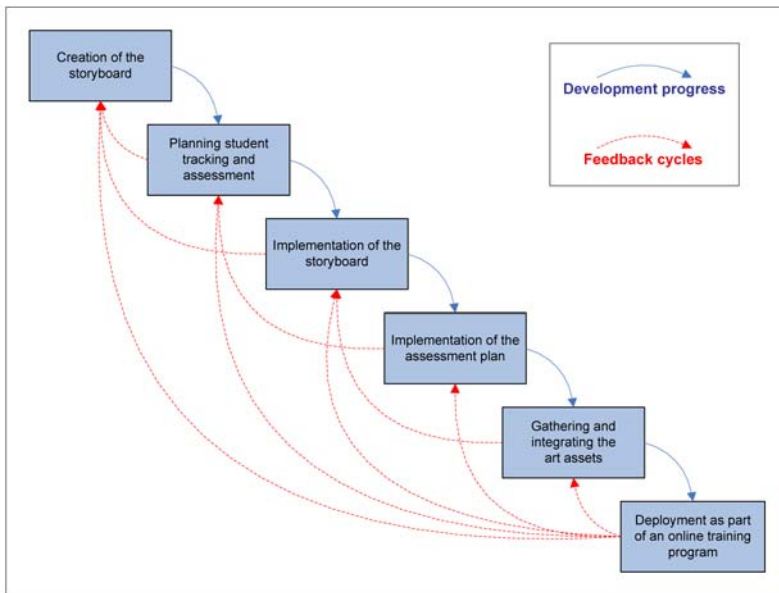


Fig. 1. Outline of the complete process. The red arrows indicate expected feedback cycles, although the process is flexible and can be iterated as a spiral development model.

2.1 Creation of the Storyboard

When creating a clinical procedure simulation, the initial storyboard is created with the physicians responsible for the face-to-face training. Typically, clinical procedures take place in a number of locations: a procedure could involve, for example, some activities in the patient's room, a visit to the lab to get some results, and checking with the nursing station for updates. The storyboard should include descriptions of all these locations or *scenes*.

Additionally, other participants in the procedure (patients, nurses, etc.) populate the diverse locations. In the adventure game jargon, those participants are described as

characters that the trainee can interact with during the execution. In addition, the procedures involve interacting with objects, which can be described in the storyboard as *items*.

Finally, as described in [6], a network of scenarios that can simply be navigated and where every object and character always exhibits the same behavior does not create a meaningful game. Clinical procedures have steps and possible branches depending on certain conditions (e.g., “Is the patient conscious? “What are the test results?”). That is to say, the simulation must include a notion of state, and performing a specific activity within the simulation usually requires having performed some other activities first. Thus, the storyboard should contemplate sequenced steps, and include branches that may have an effect on what should be done next.

2.2 Planning Student Tracking and Assessment

One of the most important requirements identified in our experiences with Technology-Enhanced Learning is the need to monitor and assess the performance of the learners who interact with the different learning artifacts. Indeed, we identify it as a primary requirement for integrating simulations in the context of The Hub, as described in section 1, and we consider that it deserves a distinctive phase in our methodology. For this purpose, once the storyboard is ready, the instructor also prepares documentation describing the evaluation profiles. Since we want to monitor the performance of the student, it is necessary to identify what constitutes “good performance”.

The assessment plan should cover the objectives that the formalized procedures try to accomplish. Questions that should be answered include “which steps are critical in the procedure?”, “which branching decisions are correct?”, and “what final states in the procedure are considered a success?” With this assessment plan, it should be possible to define rules that will transform the path followed by the trainee into a final grade and a written report with grading and self-evaluation purposes.

2.3 Implementation of the Storyboard

Once a detailed storyboard is available, the next step is to choose an appropriate technology for its implementation, with special attention to cost-effectiveness. Since these game-like simulations are only used to support part of the training (i.e., they do not substitute for the rest of the training program) the cost is definitely an issue.

The opensource <e-Adventure> platform was originally developed for the creation and execution of educational adventure games with modest technical requirements at a low cost. We found that the adventure game engine included in the platform covered most of the requisites outlined in the previous section, such as efficient involvement of the instructor physicians, while the cost-efficiency of the development process provided by the platform was ideal.

<e-Adventure> uses an XML (eXtensible Markup Language) notation [7] to describe the games that are interpreted by the engine and offers an authoring approach that facilitates the transition from the storyboard to a running game [8]. This helps us guarantee that no vital information is lost in the process of implementing the script. As described in [9], the center of the entire implementation process is the actual storyboard. The platform also includes a simplified graphical editor that facilitates the entire authoring process (Fig. 2).

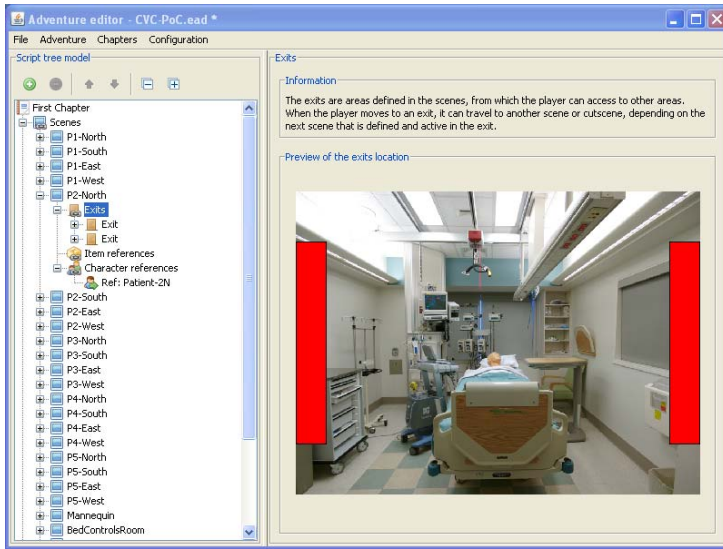


Fig. 2. The <e-Adventure> graphical editor being used to define a scene with exits on the sides that lead to other scenes

2.4 Implementation of the Assessment Plan

To track and assess the performance of the trainee during the simulation, <e-Adventure> uses a built-in assessment mechanism that supports the objectives related to monitoring and reporting the activity of the learner [10].

The configuration of this mechanism can be performed using the supplied graphical editor to define the so-called *assessment rules* (Fig. 3). These rules identify specific internal states of the simulation as relevant from a pedagogical perspective and describe the actions that should be performed if the rule is activated during the execution of the simulation. The payload of these rules can include generating a human readable entry in a report, measuring the time elapsed between two states and computing the grade that will be assigned to the student [11]. With this approach, implementing the assessment plan is a straightforward process that requires transforming the questions outlined during the “Planning Student Monitorization and Assessment” activity into <e-Adventure> assessment rules.

2.5 Gathering and Integrating the Art Assets

Often one of the most costly aspects of game and simulation development is obtaining the art assets that will be included with the game, as well as integrating these assets in the final videogame. Again, we focused on developing a sustainable methodology with a low cost.

Given that these procedures are being taught in the context of a healthcare institution, we used actual photographs of the environment in which the procedures take place and the items employed. In other words, we found that one of the cheapest and most effective ways of modeling a patient’s room was to take a photo of that room.

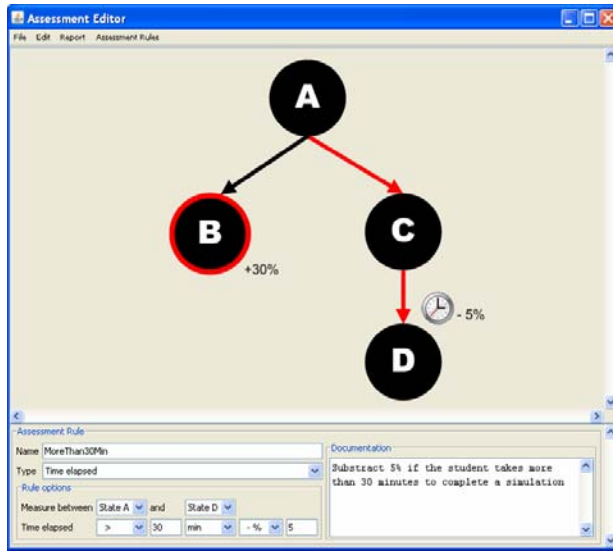


Fig. 3. Using the <e-Adventure> editor to create an assessment rule that measures the time elapsed between two states of the game and computes part of the student's grade

We hope the use of photorealistic environment will help familiarize trainees (often recently arrived residents) with their workplace. If the simulation requires going to the nursing station to check some information and this action is performed by navigating a series of pictures of the actual hallways, the trainee will find it easier to find the station when working on the medical wards depicted.

The <e-Adventure> platform clearly separates the treatment of the script from the treatment of the art assets, which facilitates both processes. It is possible to implement the script while the assets are gathered and then it is a straightforward process to include the assets in the simulation by using the supplied editor.

2.6 Deployment as Part of a Training Program

Finally, <e-Adventure> was designed with the objective of integrating the educational games with online learning environments compliant to the IMS Learning Design (IMSLD) specification [12, 13]. This specification allows the formalization of complex instructional designs including collaborative activities, branching and adaptive learning [14] and is currently considered the reference specification for educational modeling [15]. The .LRN platform supports this specification [16].

The <e-Adventure> platform includes plug-ins that enable the communication between the game engine and different IMSLD-compliant environments, .LRN included. This compatibility means that the simulations can be launched from a web environment and then, the assessment mechanism built into the engine, sends the grades and reports to the learning environment as the trainee executes the simulation [17].

The latest scores achieved by each trainee are stored in the environment along with their results from other tests of their training program. In addition to the final score, the engine also generates human-readable reports explaining all the criteria included

in the final score. These documents are shown to the trainees so that they receive feedback about the mistakes made and are also available for the instructors so that they can see where the trainees are failing and act accordingly.

3 Case Study: Implementing a Simulation of the CVC Insertion Protocol

In the Blake-7 Medical Intensive Care Unit of the Massachusetts General Hospital (MGH), there is an ongoing effort to reduce the number of cases of central line infection. For this purpose, there is a formalized 98-step protocol for the Insertion Procedure of Central Venous Catheters (CVC) [18]. This type of catheterization is a delicate procedure, involving the insertion of 20 to 30 cm of wire into the patient's chest, in order to drive the tip of the catheter right to the junction of the Superior Vena Cava and the heart's right atrium, accessed via either the Jugular vein or the Subclavian vein.

The protocol's main aim is to improve the quality of the sterile technique during the procedure. Since central line infections are potentially fatal, following this protocol closely is a necessary requirement. However, the residents being trained at the Medical Intensive Care Unit (ICU) find it hard to remember all the steps, especially when working under the additional pressure they experience the first few times that they perform this aggressive procedure.

For this reason, there are ongoing training sessions using specially designed mannequins. These mannequins have the corresponding anatomical landmarks that allow the localization of the targeted landmarks and emulate the texture and anatomy of real tissue. During these sessions, one or two residents start the CVC protocol guided by an experienced physician (the clinical educator), who takes notes on trainee performance.

However, these sessions take longer than they should, making it hard to find enough time to perform them as frequently as desirable. Additionally, the feedback gathered from the residents after the training sessions suggests that the procedure itself is not as difficult for them as following all the preparatory steps required by the protocol. Thus, we decided to create a game-like simulation in which the trainees could go through all the steps of the protocol. The game-like elements were provided by adding a time pressure and by introducing competition by comparing and publishing individual results.

It must be noted that having a simulation of this procedure cannot substitute the training sessions with mannequins (let alone with live patients) due to the lack of tactile feedback and the fact that the trainee is not really practicing the landmark localization and the actual movements during the procedure. However, having a simulation of this 98-step protocol helps the trainee practice and memorize the required steps so that they are well prepared for sessions with an instructor.

This approach should save on-site instruction time and increase the confidence of the residents when performing the procedure with live patients. Next, we describe how our design and implementation approach has been applied in the development of this game-like simulation.

3.1 Creation of the Storyboard: Description of the CVC Game

The game storyboard reflects all the steps indicated in the 98-step protocol for CVC insertions applied at the Massachusetts General Hospital. The game starts with the



Fig. 4. During parts of the procedure, the bed should be in Trendelenberg (head down) position in order to facilitate vessel engorgement and optimize conditions for the procedure. The controls for the bed are the same controls the trainees will find on the beds at the Blake-7 Medical ICU.



Fig. 5. During the simulation, the trainees get familiarized with the actual line kits used at the Hospital, including descriptions of all the components and their use

trainee standing in the corridor of the Blake-7 Medical ICU at the MGH. From here, the first step is to proceed to the actual location of the supply room to gather the supplies required for the procedure (except for those already available in the patient's room).

Then, the trainee enters the room and begins the initial stages of the procedure, including bed positioning (Fig. 4), identification of anatomical landmarks, and the use of the Ultrasound probe to locate the vessel. Other general aspects which are occasionally ignored are encouraged and monitored, such as proper use of disinfectant gel, good communication with the patient (if conscious), and redundant identification of the patient.

The second (and critical) stage of the simulation deals with the deployment of the sterile field and proper manipulation of the equipment. Indeed, most of the steps of the protocol deal with effective creation and maintenance of the sterile field, which includes proper use of sterile equipment, proper opening of the line kit, preparation of the Ultrasound probe, identification of the components in the line kit (Fig. 5), and final preparation of the line kit to begin the procedure.

After completing all these steps, the trainee is led through the steps of the insertion procedure itself, with the simulation showing a perspective of the patient with the sterile field deployed and the line kit prepared. This part of the simulation focuses on helping the trainee memorize the sequence of steps, but cannot substitute practicing the procedure using the actual components of the line kit and a mannequin.

3.2 Planning Student Tracking and Assessment

As mentioned previously, an instructor monitors and assesses trainee performance during training sessions for the CVC Insertion. During the session, the instructor completes a checklist as the trainees follow the procedure. Some of the items on the checklist deal with bad practices (e.g., not maintaining good communication with the patient - Fig. 6-, improper confirmation of identity, etc.), others are related to the procedure

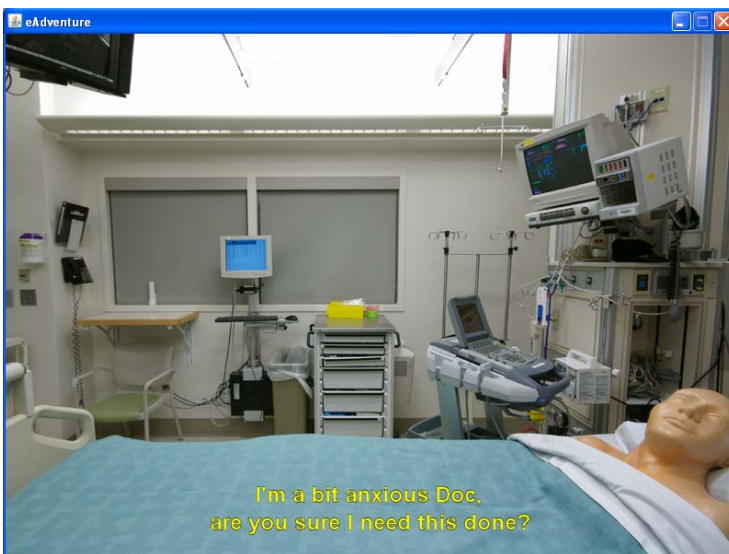


Fig. 6. Proper communication with the patient is not always mentioned in the materials explaining this procedure, an essential component that can get sidelined while the trainee is focusing on the task at hand. The simulation integrates patient communication reminders into the virtual encounter so it is less likely to be forgotten during the real encounter.

itself (e.g., correct sterile technique), and general safety practices (e.g., correct disposal of sharps or contaminated materials).

Every omission of an item from that checklist is a mistake made by the trainee. Therefore, each mistake results in a reduction of the score of the procedure. A simulation completed in a timely manner and without any mistakes represents a score of 100%. Each omission results in a deduction, with some omissions being considered more grave than others. Using excessive time to complete the simulation also results in a deduction (Table 1 summarizes some of the aspects included in the final calculated score). The final score is thus an estimation of how familiar the trainee is with the protocol, and can be used as an indicator of whether the trainee is ready to move on to training sessions with mannequins or even live patients. The score is accompanied by a full report with feedback explaining all the deductions. The trainees can consult the report in order to see on which steps they failed.

Table 1. A partial list of score deductions for different concepts. Grades below 80% mean a failed procedure.

Checklist Item	Grade	Checklist Item	Grade
Calstat used prior to entering room	-10%	Patient told to expect needle stick prior to injecting lidocaine	-5%
Bed adjusted to proper height, patient brought to head of bed	-2%	Lidocaine used at insertion site with ultrasound in real time	-5%
Patient in Trendelenberg position when examining vessels with ultrasound	-5%	Appropriate technique to reduce risk of air embolism (finger over needle hub)	-10%
Patient returned to supine position after ultrasound to avoid vessel collapse	-5%	Pressure tubing (if available) used to assess that needle is in vein	-5%
Landmarks appropriately identified	-5%	Guidewire always kept in hand and under control	-10%
Time out with nursing noted	-5%	Sharps returned to needle holder and scalpel retracted after use	-5%
Chlorhexidine properly applied w/ sterile gloves	-10%	After insertion, flushed air, flushed w/ saline, & clamped to keep closed system	-5%
Gown, gloves, and goggles/face-shield used; gowned w/ hands inside sleeves	-10%	CVC left 3 cm out and sutured in with soft clamp and box clamp	-5%
Sterile sheet from line kit used to cover field; opening matted down on patient	-5%	More than 30 minutes to complete the simulation	-5%
Tray and items set up completely prior to use including loading of suture	-5%	More than 45 minutes to complete the simulation	-10%
Line flushed and clamps placed prior to removing syringe when flushing	-5%	More than 60 minutes to complete the simulation	-20%

3.3 Implementation of the Storyboard

The implementation of the storyboard with <e-Adventure> started with an initial effort focused on the adaptation and evolution of the <e-Adventure> platform to this new domain. This evolution essentially supposed passing from a second-person perspective to a first-person one, more suitable for game-like clinical simulations.

However, even with this side-effort, the global implementation effort was reasonable (see Table 2 in the next section for a summary of the resources invested on each stage of the development). Once the tools had been adapted, the implementation simply required using the <e-Adventure> editor to turn the storyboard into a game.

3.4 Implementation of the Tracking and Assessment Plan

The implementation of the tracking and assessment plan was performed using the assessment features of <e-Adventure>. The process consisted on turning all the potential errors (most of them are described in Table 1) into <e-Adventure> assessment rules. Most of the rules followed the same pattern:

1. Identify the simulation state that indicates that the student failed to comply with the indications and express it in terms of game flags.
2. Add a *computation* payload to the rule, indicating the percentage that should be deducted automatically from the grade.
3. Add a *description* payload to the rule, with the texts from Table 1, in order to generate text reports indicating all the steps in which the student was penalized.

The exceptions to this pattern were the last three rules, related to measuring the time required to complete the entire procedure. These rules were created as *time measurement rules* (see Fig. 3), which require identifying two states and also carry a payload. In this case, the two states were the initial state of the game and the final step of the procedure, while the payload was similar to the rest of the rules (a score deduction and descriptive feedback).

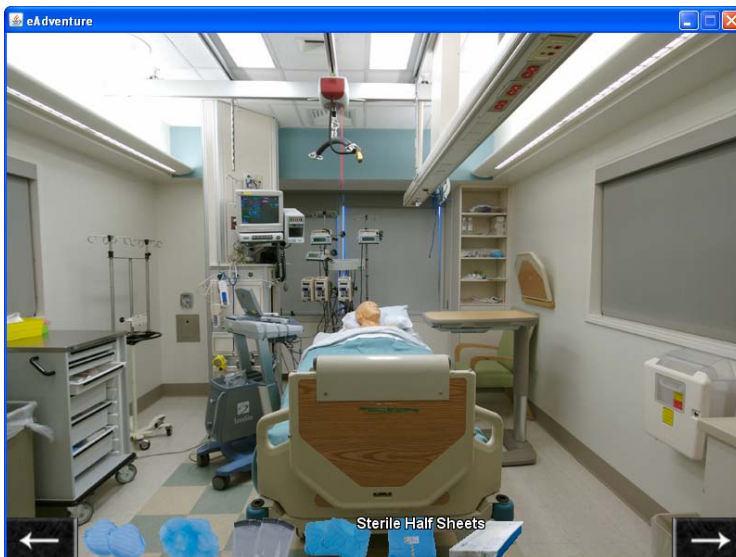


Fig. 7. All of the scenarios and objects displayed during the simulation are photographs of the actual rooms and equipment used in the Blake-7 Medical

3.5 Gathering and Integrating the Art Assets

The graphics for the simulation were obtained in three photo sessions. In the first session, we visited the Medical Intensive Care Unit at the Massachusetts General Hospital and photographed one of the rooms where this procedure is usually performed. The second session included taking close-up photographs of all the materials used in the procedure (Fig. 7). The third and final session simply provided additional assets for those materials that were identified as required during the testing and improvement stage.

3.6 Deployment as Part of the Training Program

The integration between <e-Adventure> and the .LRN platform described in section 2.6 gives busy residents access to the CVC training at any of the hundreds of clinical workstations available in the hospital and allows its integration into the existing e-learning infrastructure (The Hub) where individual trainee's progress is tracked and evaluated. This can be exemplified in the following hybrid-learning scenario (combining *e-learning* tools with other approaches), which can be fully supported using <e-Adventure> and .LRN:

Dr. X is scheduled to start his first rotation on the intensive care unit (ICU) on Monday. On Friday, relevant learning materials show up in his portal page in The Hub, because the administration has made the CVC game-like simulation part of the ICU curriculum. Dr. X knows it is also a requirement to take part in the face-to-face CVC skills training so he takes it until he exceeds 80% in the game. His progress is reported to The Hub, is added to his e-Portfolio, and results in him being scheduled for a CVC skills training session on a mannequin with a clinical educator (Dr. C) on Wednesday. He does well. On Friday a patient comes in that requires a CVC and 30 minutes before the procedure is planned Dr. C calls Dr. X to get ready to test what he has learned. Dr. X quickly reviews the steps required in the CVC game using the computer downstairs. After a successful unproblematic placement of the CVC, Dr. C fills out the evaluation form on The Hub for Dr. X. Later that night, Dr. X adds the successful procedure to his procedure log. Afterwards the administration can show that they have fulfilled their mission (and ethical obligation).

4 Discussion

The development methodology supported by the <e-Adventure> platform suggests in this work could be potentially used to develop low-cost instructional content that improves training outcomes. The prototype developed from the case study shows some promising results as discussed in this section.

4.1 Development Costs

The work in [19] presents the results of a survey made during a session on serious games at the 2005 edition of the Game Developers Conference (<http://www.gdconf.com/>). The survey included questions about the costs of the initiatives that were being

developed at the time, and most answers (26,23%) fit into the \$100.000-\$500.000 range (with also a significant 14,75% in the \$1,000,000-\$10,000,000 range). Similarly, the results introduced in [20] estimate costs for the development of a “next-generation simulation” on the 15-30 person-years range. These figures are far beyond the typical budgets available for learning specific procedures at individual institutions. Even if it were possible to generalize such simulations and apply them in different hospitals, it would be difficult to recoup such enormous development costs. One of the causes of this excessive cost is that developing even the simplest 3D simulation environment has a high cost.

In most application scenarios, the investment needs to be several orders of magnitude lower in order to be aligned with the educational budgets of most institutions, even if it means sacrificing part of the benefits. The simulation described in this work replaces pure interactive 3D environments with virtual spaces consisting of navigable series of photographs. This simplification is the key element in the reduction of development costs, although it sacrifices realism, interactivity and depth, taking a leap back from the current state of commercial videogames. The total effort for the development of this case study, as described in Table 2, took about 410 hours or roughly 2.5 person-months, which is a figure much more aligned with realistic budgets for a learning module focused on a single procedure at a specific institution. However, there is a concern in whether this approach really retains the educational value and the attractiveness that game-like simulations should provide, as discussed in the next section.

Table 2. Approximate number of man-hours required for each of the stages of the project and the profiles of the personnel involved (I = Instructors, SD = Software Developers, A = Artists, T = Trainees)

Concept	Cost	Profiles
Modification of the <e-Adventure> engine	50 hours	SD
Conception of the storyboard / Creation of the initial XML script	80 hours	I
Monitoring and Assessment Planning / Creation of assessment and grading profiles	50 hours	SD, I
Creation of the art assets	150 hours	A, I, SD
Deployment, testing and improvement	80 hours	I, SD, T
Total:	410 hours	

Additionally, it must be noted that there may be training scenarios where a higher level of interactivity (with its associated cost) is required. Even in those cases, this simplified methodology can have an impact. In those developments, it is usually difficult to appreciate the potential usefulness of a simulation project before it is completed. When dealing with complex and costly projects, an often-feared scenario is the

possibility of the resulting product failing to deliver the expected educational results. In these cases, the approach presented here is still worthy as a prototyping methodology. This low cost-low risk approach can deliver a functioning product to demonstrate how the completed simulation would work. Indeed, these simplified games would act as interactive storyboards of the completed product.

4.2 Educational Value

As several academic authors defend, the use of videogames and simulations can improve the learning process [21-25]. This is partially a result of a closed game cycle, where the actions result in immediate feedback [26]. However, this feedback does not only provide the grounding for the acquisition of knowledge. In fact, this cycle also engages the player in wanting to interact more with the environment. Games are motivational and engaging, and motivated or engaged students learn better and retain more information [27-30].

When this approach is examined in terms of educational value and engagement, the concessions to interactivity and pacing made for the sake of reducing the development costs can raise concerns about their effectiveness. The resulting products are not nearly as interactive and fast-paced as modern commercial videogames or training simulations. In fact, moving back a few years, these games behave much more similarly to the originally best-selling series *Myst*TM. However, these games have lost their impact in the commercial videogame scene, suggesting that current players prefer more intense action. Can this be an issue in terms of motivation? To prevent trainees from disengaging, we introduce game-like elements such as a time pressure and the publication of rankings and results. With this, we add objectives, performance measurement and an established rule-set, which are the basic ingredients for any form of game.

Additionally, there is a concern that the lower interactivity (when compared with a fully-featured 3D environment) may have an impact on the educational value. Training sessions performed with either mannequins or live patients with the close guidance of an experienced instructor can not be replaced by the approach proposed in this work or a fully interactive 3D emersion. However, as it has already been stated, the residents are not actually overwhelmed with the delicacy of the procedure itself, but with the requirements of the strict protocol devised to reduce the risk of infections. In these terms, the performance of this simplified game when it comes to memorizing the 98-step protocol is similar to the potential results of a more complex 3D simulation.

Additionally, the <e-Adventure> platform offers some other pedagogical advantages, such as the built-in assessment mechanism provided by <e-Adventure> can be employed to automatically compute the score of the player, a task that in other game-based approaches is usually performed by an instructor during the play sessions. The trainees can perform the procedure as many times as they want and get an instant report on how well they followed the protocol and whether they are ready for a practice session with an actual instructor that will not result in a waste of time.

4.3 Integration with the Existing E-Learning Infrastructure

Given that the <e-Adventure> platform can be integrated with .LRN, we can use it to deploy and serve the games as any other kind of instructional content delivered

through the platform. When the games are launched they establish a communication with the server, allowing scenarios as the one described in section 3.6 to occur. The assessment mechanism is connected to .LRN through this link, and can interact with the rest of the modules on the course through the server's implementation of the IMS LD specification described in [16].

When the execution is completed, the calculated score can be sent back to the IMS LD engine, which, in turn, stores that information for further executions of the game and can publish the score along with the completion time to the student's profile. This publication of the score, apart from leveraging the competitive nature of students, serves a clear educational purpose. The instructors can check the grades of all the residents and decide which of them are ready to start participating in the instructor-guided practical sessions.

It should also be noted that the use of existing e-learning standards such as the IMS LD specification does not limit this kind of integration with the e-learning infrastructure used at this specific site, but allows it to be deployed wherever standards compliant e-learning tools are used.

5 Final Remarks

Although there is broad agreement in the need of improving medical training that precedes the interaction with live patients in order to maximize safety, the realities of daily life at a major hospital constrain the opportunities for training experiences. The current use of low-technology mannequins is a good approach for training before proceeding to live patients, but finding time for these guided training sessions is almost impossible.

The use of advanced forms of simulation would deliver an improved experience, but their costs are far beyond the training budgets of specific units such as the MGH Medical ICU. The use of educational adventure games, however, can reduce the time associated with guided sessions and offers the trainees a way to focus on learning complex procedures that consist of a number of steps and branching decisions beforehand, so that the steps do not subtract face-to-face time needed for practicing the necessary motor skills.

The genre of adventure games has proved efficient for acquiring this type of knowledge [3]. Even without featuring amazing graphics and sophisticated interaction, they can provide an engaging experience. The experiences with portable consoles like the Nintendo DS suggest the existence of a market for engaging titles without last generation graphics or interactions (like the specifically educational *Brain Training™* or the simple but engaging gameplay of *Phoenix Wright: Ace Attorney™*, both on the Nintendo DS console). Therefore, there is room for lower budget educational adventure games, provided that the contents engage the players.

If we are willing to accept the reduction of interactivity and eye-candy and use specific educational game engines, there is a potential rapid development process that incurs higher costs than traditional teaching materials for clinical procedures, but is still within the boundaries of most training budgets.

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