Game-like Simulations for Online Adaptive Learning: A Case Study

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Abstract. Serious games are becoming a powerful tool in education. However, there are still open issues needing further research to generalize the use of videogames and game-like simulations in the educational system. On the one hand, how to take advantage of the videogames' inherent adaptation behaviour in order to maximize the effectiveness of the learning experiences is still a world worth to be explored. On the other, there is still a need to develop mechanisms to track and evaluate the performance of the students when they use these learning tools. Finally, it is necessary to elaborate further game-based learning architectures that facilitate the delivery and distribution of the games to the students. In this paper we propose how to deal with all these issues taking also into account other relevant aspects such as development cost and instructor implication. This is exemplified with the HCT game, produced in cooperation with professors of the Complutense University School of Medicine at Madrid.

Keywords: Game-based learning; game-like simulation; assessment; adaptation; learning management system.

1 Introduction

The videogame industry has already become one of the most relevant entertainment industries, with computer and videogame sales growing almost every year. Along with the growth and evolution of the industry, there is in an ongoing discussion about the educational potential of videogames [1-3]. Among the potential benefits of this approach, two have been identified as especially relevant. On the one hand, game-based learning can be used to enhance students' motivation towards learning [4]. On the other hand, videogames can be developed in the form of game-like simulations, providing highly interactive and safe test environments, very adequate for learning complex topics, and which can be accessed at any time without requiring specialized equipment (other than a computer) [5]. Consequently it seems that this interest in the use of game-based learning, although not new (it virtually dates back to the very first steps of the videogame industry [6]), is beginning to represent a real alternative, both from commercial and academic perspectives [7]. As the *e-Learning Guild* report reveals ([8]), the number of productions of serious games is growing every year,

along with the number of organizations adopting this kind of learning for their staff training programs.

However, there are still some open issues requiring further research and discussion. Educational videogames have their own needs, which do not always converge with the requirements of classic videogame development methodologies [9].

First, videogames are not always easy to distribute and deploy. In educational contexts this can be a real burden for instructors when games have to be distributed to many students, and the results of the game experiences must be collected and processed manually. Besides, game-based learning needs to track the performance of the students to check whether the learning goals are achieved or not [10], a feature that is not very common in commercial videogames.

In addition, educational videogames and game-like simulations need to adapt their behaviour according to the profile of the player (i.e. student) in order to cater for the special needs of each student [11]. Commercial videogames are inherently adaptive, but there are still few initiatives trying to ease the design and integration of adaptive behaviour in educational videogames. Finally there are other issues, such as development cost and the difficulties of involving instructors and content experts in the development process.

In this paper we exemplify through a case study how the <e-Adventure> educational game platform [12] addresses these issues, describing the development of a low-cost, adaptive and assessable game-like simulation in the field of Medicine education. The game covers the procedure to measure Hematocrit levels on a blood sample, and was developed with the participation of professors from the School of Medicine at the Complutense University of Madrid.

The paper is structured as follows: in section 2 we discuss some issues related to adaptation, development and deployment of educational videogames. In section 3, a brief description of the <e-Adventure> platform is given. In section 4 we provide a full description of the case study. In section 5 we present a direct experience with students and some evaluation of the results, and in section 6 we present some conclusions and future lines of work.

2 Games and education: challenges and issues

In this section we discuss two aspects that are tightly related to the work we are presenting. First we introduce adaptive learning and how this can be achieved through videogames. Then, we describe some of the issues that must be addressed when developing educational games and game-like simulations.

2.1 Adaptation in Learning and Videogames

During the last years, there is a steadily growing trend towards adaptive learning, especially focused in online learning systems [13, 14]. The idea is to personalize the content and flow of the learning experience for each student, taking into account their individual context to maximize the effectiveness of the learning experience. This adaptation can consider different aspects, such as user preferences, different levels of

prior knowledge, cultural conditions, and even learning styles (e.g. exploratory vs. guided).

In this context educational videogames can be very helpful as games are inherently adaptive. Commercial pressure pushes videogame developers to personalize the game experiences as much as possible, in order to widen the spectrum of potential customers and maximize their engagement when playing the games. Therefore it is very usual to see videogames catering for different gaming styles and skills, offering for instance diverse difficulty settings. In addition, unlike other content videogames are extremely interactive. The interaction between user and videogame can be used to gauge the game behaviour. For instance, it can be detected transparently if the user is stuck trying to solve a puzzle, and then give a clue or lessen the difficulty of the task slightly [15]. In short, adaptation mechanisms in videogames are now much more fine-grained than a simple difficulty level choice.

There are interesting works identifying the characteristics of videogames that are better for implementing adaptive behaviours and how to design adaptive videogames [16]. Nonetheless it is difficult to see authoring tools and learning models supporting the modelling and implementation of adaptive behaviours in videogames [17].

2.2 Videogame Development and Deployment

During the last years, several development tools have appeared trying to ease the production of videogames, including game engines, IDEs (Integrated Development Environment), and user-friendly authoring tools. The range of possibilities is massive, going from very simple open source projects to complex professional tools.

A great example is the *Torque*™ game engine, published by *GarageGames*™ which allows users to produce top-tier computer games for different platforms. Another good example is *Microsoft*™'s *XNA*™ development environment, which is being used in the development of numerous videogames for both PC and *XBOX*™ platforms. Besides, there are lots of authoring tools aiming to encapsulate the most complex aspects of videogame development, facilitating the production of videogames by people with no technical skills. Some good examples are the tools developed by *The Game Creators*, *Unity3D*™ or *GameMaker*™.

In spite of all these initiatives there are still open issues which have not been completely addressed yet, especially for educational gaming. On the one hand videogames are not easy to distribute and deploy in educational settings. On the other hand, these platforms do not cope with the specific needs of the educational gaming field, such as the need of tracking and evaluation of the progress of the student or adaptation to the student special requirements.

These inconveniences can be lessened by integrating the educational videogames and game-like simulations in the widely extended e-Learning environments (the so called Virtual Campus, Learning Management Systems or LMS) [18]. These environments allow instructors (i.e. teachers and professors) to organize courses and lessons for students, and are becoming a common tool not only for distance learning programmes but also as a complement in traditional classes. Besides, modern LMS do not only store content for remote students, as they are complex web applications that allow instructors to track the activity of the students and manage their learning

experiences. These systems usually offer facilities to evaluate the students and to store information about their activity. This process is usually performed following standards and specifications that allow the content interoperability between the different competing platforms [14]. Therefore the content must be developed and packaged in compliance with these standards and specifications to be deployed in a LMS. These standardized content packages are usually known as Learning Objects. Unfortunately, most game development tools lack the proper mechanisms to support the encapsulation of the games as Learning Objects.

3 The <e-Adventure> Platform

<e-Adventure> is an authoring platform for the production of point-and-click educational adventures, which has been used in the development of diverse educational games and low-cost game-based simulations in multiple contexts, as for instance, the medical education field [19]. Besides, <e-Adventure> present some additional features especially oriented to education.

Point-and-click adventure games are quite cheap to produce in comparison to other, more sophisticated game genres. This makes the production of <e-Adventure> games affordable even with small educational budgets. In addition, the <e-Adventure> platform was designed with instructors in mind, providing a friendly authoring environment [12] and an instructor-centered development process model [20]. The main advantage of this approach is that instructors can be directly involved in the production of the games.

<e-Adventure> also provides education-specific features that are not typically found in commercial games or game development tools. One of these features is the possibility to define assessment rules in the games that are triggered when a set of conditions on the "state" of the games are satisfied. The effect will be that the grade of the student is changed according to the definition provided by the author of the game (i.e. the grade is set to a value, incremented or decremented). When the game is completed an assessment report is generated with all this information. Besides, <e-Adventure> games can take advantage of the high interactivity in the games to adapt their behaviour according to a set of rules defined by the author of the game [11].

Finally, the games produced with <e-Adventure> can be packaged as Learning Objects, easing the delivery of the games to the end users. When an <e-Adventure> game is delivered through a standards-compliant LMS, the assessment and adaptation mechanisms described above can be linked to the central server. The tracking reports and the computed grades can be sent to the LMS for automatic processing; then instructors can access the results via web. Alternatively, the information can be displayed to the students as feedback. Similarly, the adaptation mechanism can be used as input for the adaptation decisions stored in the student's profile at the LMS side

4 Case Study: The HCT Blood Test Game

For a long time teachers of Human Physiology, a module taught in the second year of the Degree in Medicine at Complutense University of Madrid, have identified diverse difficulties that students usually have when working in practical lab sessions, especially the first time they have to use the equipment. In this module students must complete various practical lab sessions where they test multiple properties of the Hematocrit (HCT) and learn to measure HCT levels through a classic HCT Blood Test. The attendance to these practical sessions is compulsory for all the students, although the results are not directly considered for the final grade of the module, which lessens the students' motivation.

In addition, in order to prevent potential infections and according to current Spanish health regulations, the blood used in these practical exercises must be drawn from laboratory rats that must be sacrificed. This means that, for ethical reasons, blood samples are scarce, while the number of students enrolled in this module every year is rather high (around 400 students). As a consequence the lab time is scant and must be administrated carefully.

We considered that creating a game-like simulation of these exercises would increase the motivation of the students. Moreover, a game-like simulation would help the students to use their limited time at the laboratory more effectively. In addition, these sessions are usually the first contact students have with the equipment and materials required for the HCT test, and the game would also provide a first contact with the equipment before the actual laboratory session.

This case study also demanded a simple delivery and deployment mechanism to provide students with free access to the game during the year, so they could use it to improve their long-term retention of the procedure and lessen the inconveniences of the limited working hours in the lab. Besides, the limited budget available for this experience restricted the range of development options.

4.1 Design, Implementation and General Description of the HCT Game

To meet all these requirements the <e-Adventure> platform was chosen for the development of the game-like simulation. During the development process, the experts of the field (in this case the teachers from the School of Medicine) were actively involved, providing advice and feedback. Additionally we profited from the instructor-oriented condition of the <e-Adventure> platform, as experts could directly open and modify the game with the <e-Adventure> editor without requiring technical background. This simplified a lot the refinement of the videogames when the situation required a high level of preciseness either of the vocabulary or the concepts.

We also used the features provided by <e-Adventure> to integrate the game in a standards-compliant LMS, which provided an easy game delivery mechanism through the Virtual Campus of the Complutense University, as well as the server-driven adaptation and assessment mechanisms provided by <e-Adventure>.

The general view of the game-like simulation produced is quite simple. It is basically a *point-and-click* navigational environment which recreates a laboratory station where the student must perform the HCT Blood Test. A good balance between

cost and realism is obtained with this approach as the student is visualizing all the time the real working place but without needing costly 3D environments.

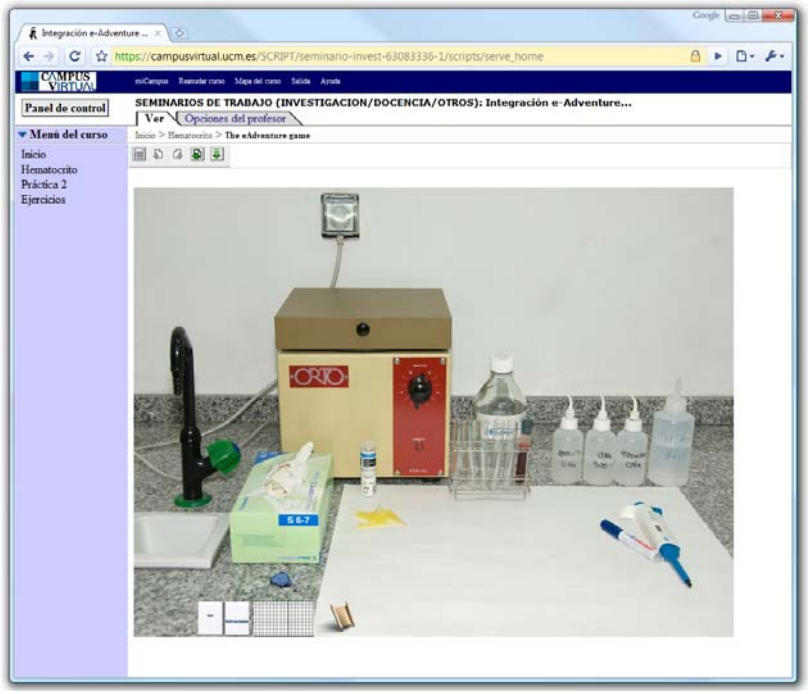

Fig. 1. The HCT Blood Test videogame deployed in the online Virtual Campus of the Complutense University.

In this scenario, the students find the objects (equipment and material) they need to accomplish the game. To complete the steps of the procedure and progress in the game, students need to use or combine the right objects in the right order. Additionally, to complete some steps of the procedure, students must answer some questions about how to do it. This is special relevant to explore how just small incorrect variations of the procedure can affect the results. Besides, the preciseness of the simulation is improved with real videos of the more complex tasks.

In this manner the whole HCT blood test is simulated achieving a high level of accuracy but without compromising the cost. Besides, the attractiveness of the experience profits from a game-based approach. For instance, the consequences of some negligent acts are slightly exaggerated to capture students' attention and reinforce the redefinition of wrong suppositions.

4.3 Feedback & Assessment

In addition the game includes further interaction mechanisms for those steps of the procedure that require a more fine-grained simulation, as they cannot be properly

simulated by a simple combination of objects. When it is important to tinge details about how the combination of elements must be performed, the student is prompted with a multiple-choice question with diverse options. The consequences of this choice depend on the correctness of the answer. Basically three different things can happen:

- The answer is completely right: the student can carry on with the simulation and no feedback is provided.
- The answer is partially wrong, but the mistake is not critical: the game provides feedback to the student and the error is written onto the assessment report.
- The answer is critically wrong: feedback is provided in any case, but if the negative effects are not immediate, the feedback is postponed to the end of the game (e.g. the effects of a wrong action might imply no visual consequences but influence the final determination of the HCT level). Besides, the grave error is written onto the assessment report.

In this manner, interaction is tracked and used from a pedagogical point of view. On the one hand the activity of the student is recorded for later evaluation. The successes and failures of the student are written onto the assessment report which is sent to the Virtual Campus server, which stores it to be taken into account for later executions of the game. On the other hand this activity can be used to provide feedback to the students. However, not all the actions in the game provide feedback immediately. Following instructors' recommendations, when the student fails to perform a critical step of the procedure feedback is delayed to the end of the game. In this manner students can check the real consequences of their acts, even when those are not produced immediately.

4.4 Adaptation

Another key aspect of the game is that it can be adapted according to the profile of the student in a process which is driven by the LMS. In the real HCT Blood Test some occasional events rarely occur, and most students do not have the opportunity to see them when they are in the lab. A game-like simulation like this is a perfect place to simulate these situations.

For instance, when a capillary tube is filled with blood, sometimes a blood coagulum blocks it, spoiling the whole tube. Then students must throw the tube away and start again the procedure. In our game, those rare events occur randomly, but with a much higher probability. The assessment report notifies the LMS about whether these situations have already happened so that it can keep a record of the students who have already experienced the abnormal situation in previous executions of the game. The next time those students play the game the LMS triggers a simple adaptation process which forces the normal situation. This is essential to avoid frustration in students who can see these abnormal situations as unjustified punishments [21]. Thanks to the adaptation mechanism, students will experience the effect of a coagulum with a much higher probability, but only once, which is enough illustrative but not frustrating.

In addition, there is a small adaptation layer taking account prior knowledge of the students based on the results of previous executions of the game. Students are roughly categorized in two groups: novice and intermediate. The idea is to skip some easy

tasks for skilled students so that the game does not become boring. Besides reference documents, like a hints book, are only available in the game for novice users.

When the game starts it receives from the LMS the group the student belongs to; then the game is adapted accordingly. Once the game is completed the assessment report is sent to the LMS, which re-categorizes the student. Initially all students are novice until they achieve at least a 60% of performance playing the game (then they become intermediate students).

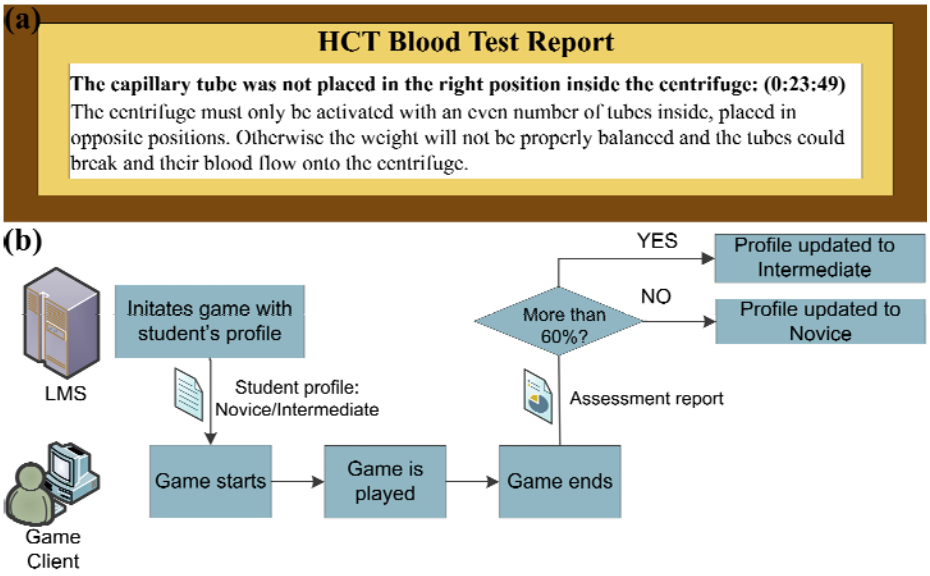

Fig. 2. (a): Fragment of an assessment report of the HCT game. (b): Full adaptive cycle implemented in the HCT game.

5 Preliminary Evaluation of the HCT Case Study

To check the effectiveness of the HCT Blood Test game-like simulation, we carried out a pilot experience with a class group of second-year students from the School of Medicine at Complutense University. The idea was to measure the effectiveness of the HCT videogame in terms of motivation towards learning and improvement of the effectiveness of the lab sessions.

The experiment was carried out with part of the students enrolled in the Physiology course (n=98). One of the laboratory groups was selected as the Experimental Group (EG, n=21) and the rest of the groups were taken as a unified Control Group (CG, n=77). The EG had the chance to play the game for 30 minutes with no guidance from their teachers beyond a brief description of the purpose of the exercise. The students from the CG attended the lab session without additional support. The objective was to test, after the real lab session, if there were any difference between the students who played and who did not play the game before going to the lab, in the following terms:

- Were students who played the game more motivated?
- Did the students who played the game understand the procedure better?
- Did the students who played the game have any advantage when using the equipment in the laboratory?

5.1 Student satisfaction

In order to assess the subjective perception of the students, the participants from the EG completed a satisfaction survey after the practical lab session. In this survey they were asked four questions about their perception of how the game did help them in some concerns:

- Q1: Do you think the HCT game has helped you to recognize the equipment needed?
- Q2: Do you think the HCT game eased the practical session for you?
- Q3: Would you like to use more games like this in this module?
- Q4: Would you like to have at your disposal the game during the practical session as a reference material?

The answers were in multiple-choice Likert-scale format, where 1 meant "strongly disagree" and 5 "strongly agree".

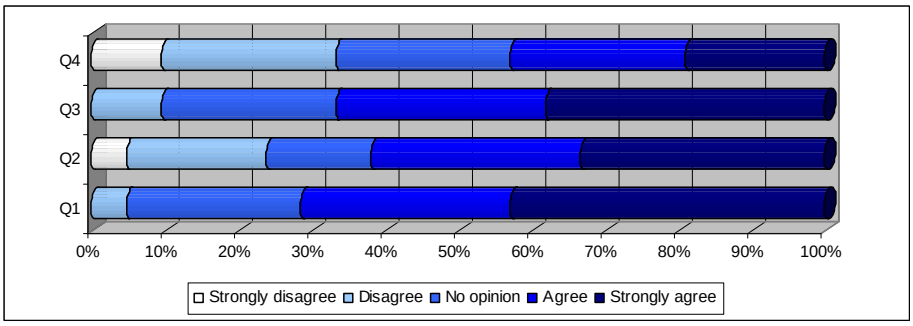

Fig. 3. Accumulative results of the satisfaction survey for students who played the game.

The results are certainly positive. As figure 3 depicts, more than 70% of the students (71,43%) "agree" or "strongly agree" with the idea that the game helped them to recognize the equipment. More than 60% of the students "agree" or "strongly agree" (61,90%) with the idea that the game helped them to complete the practical session. In the same line, more than 60% of the students "agree" or "strongly agree" with having more games like this for the module (66,67%). Finally the results for question 4 are less meaningful, as over a 40% of the students (42,86%) "agree" or "strongly agree" with having the game available in the lab.

5.2 Learning Outcomes

A basic analysis of the learning outcomes was based on a second multiple-choice questionnaire that all the students (both control and example groups) had to answer about the difficulty of the practical session. .

Table 1. Student perception of the difficulty of the practical exercise and the difficulty of using the equipment

	Difficulty performing the exercise			**Difficulty using the equipment**		
	Easy	Normal	Difficult	Easy	Normal	Difficult
EG	85.71%	14.29%	0%	80.95%	9,52%	9,52%
CG	72.73%	23.38%	3.9%	77.92%	16.88%	5,19%

As the table above depicts, the results suggest that students who played the game found the session slightly easier. On the one hand, more students in the EG perceived the exercise as "easy" (85.71% in EG against 72.73% in CG) and less students perceived the exercise as "difficult" (0% in EG against 3.9% in CG). On the other hand, the results are similar when analyzing the students' perception of the difficulty of using the equipment. (85.95% of the students found it "easy" in EG against 77.92% in CG), although the results here are less significant when comparing the number of students who found the use of the equipment "difficult". This could be justified because the limited interactivity provided by the game can help students to recognize the equipment, but not how to actually use it.

6 Conclusions

As discussed in this paper, there is a growing interest of both the academic and the industry worlds on the educational gaming field. However, the integration of educational gaming (in all trends) in the educational system will not be complete until diverse issues are addressed.

These issues include development cost aspects, how to track and evaluate the performance of the students and how to use this evaluation to produce adaptive learning experiences. There are also practical issues, such as how to effectively deliver and deploy the games in educational environments, and even development models allowing the active involvement of experts in the production of the games.

In this paper we have presented the HCT Blood test game-like simulation, developed with the <e-Adventure> platform taking into account all these issues. A group of experts (teachers of the school of medicine) were actively involved in the project in order to ensure the correctness of the concepts transmitted by the videogame. Besides the game includes a full adaptation and assessment cycle which allows adapting the videogame according to the student's profile (profile which can be modified taking into account the results of the game). The game can be easily deployed and distributed through the online Virtual Campus of the Complutense University. Thus all the students can access it via a web browser as many times as

desired, solving in this manner the inconveniences of the little time students can spend practicing in the real lab.

The primary analysis of the results of the game-play session suggests that the use of the videogame can have a great impact in the motivation of the students. The satisfaction survey reveals a great acceptance of the initiative and a good predisposition to use the game to improve their skills. However this may turn to be only an illusion once the novelty is gone. Further research about the usage trends for the games will provide additional insight.

Regarding the learning outcomes of the experience, the results suggest that the use of the game facilitates the first contact with the equipment and the successful accomplishment of the HCT measurement procedure. This can be interpreted as a sign of the positive effects that this kind of approaches can have not only on the motivation of the students, but also on the effectiveness of the learning experience. Our results suggest that students who played the game learnt the procedure more easily than those who did not play the game.

Coming back to the problem of the lab availability, this also suggests that students who had the chance to play the game could use their lab time more effectively. It must be noted that the objective of this work is not to provide an alternative to the lab time. The embodiment of the full experience, where students can physically interact with the equipment in a real setting cannot be substituted by simulations (not even expensive and complex 3D simulations). Instead, the objective is to try to help the students to get more profit from their limited lab time.

From our initial results we can hypothesize that students are in fact profiting more from their lab time, because they are finding the exercise easier (and are thus focusing more on performing the task). However, it must be noted that these results are based on subjective appreciations from the students. Further work and experimentation will be required to draw more solid conclusions.

Acknowledgments. The Spanish Committee of Science and Technology (projects TIN2005-08788-C04-01, TSI-020301-2008-19 and TIN2007-68125-C02-01) has partially supported this work, as well as the Complutense University of Madrid (research group 921340) and the EU Alfa project CID (II-0511-A). Special thanks to María Dolores Comas, Julián Bustamante and Carmen Fernández for their interest in the <e-Adventure> platform and their active. Thanks to Enrique López-Mañas, Ismael Salgado and the technical staff of the computer labs of the School of Medicine for their generous help before and during the game-play session with the students.

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