

# Using Low-cost computer-based simulations in the Spanish National Transplant Procedures

Blanca Borro Escribano

Itziar Martinez Alpuente

Ángel del Blanco

Beatriz Dominguez-Gil

Baltasar Fernandez Manjon

Rafael Matesanz

Department of Software Engineering and Artificial  
Intelligence  
Complutense University of Madrid  
Madrid, Spain

Spanish National Transplant Organization  
Madrid, Spain

**Abstract**—Spain holds a worldwide privileged position with extraordinary rates of organ deceased donation resulting from an organizational approach known as the “Spanish Model”. The Spanish National Transplant Organization (ONT) is making a continuous effort to improve its teaching methods and to share its knowledge with other countries.

This study describes the use of low-cost computer-based simulations covering two key procedures of the organ deceased donation process managed by the ONT central office. The goal of these simulations is to increase the awareness of other health care professionals involved in the process and to support the ONT instructional approach.

After ONT experts’ validation, these simulations were used by 90 trainees for practicing after a short theoretical presentation of the procedures. Students gave their opinions in a short survey where they confirmed that the simulations helped them establish a better comprehension of the processes. These simulations are now part of the ONT instructional material.

**Keywords**—*Computer-based software simulation; transplant procedures; training; learning by doing*

## I. INTRODUCTION

Spain has reached the highest rate of organ deceased donation in the world on a nation-state basis, namely 33–35 donors per million population (pmp) during recent years. The excellent deceased donation rates achieved are the result of the so-called Spanish Model on Organ Donation and Transplantation[1]. This is an organizational approach to guarantee that opportunities for organ deceased donation are properly identified and that potential organ donors are converted into actual donors. One of the key elements of this model is its continuous professional training targeted to all professionals involved directly or indirectly in the process of organ donation through dedicated courses focused on the procedural steps of the said process. These necessarily include steps mainly dependent on the Spanish National Transplant Organization (ONT). As a worldwide leader, ONT is making

an effort to share this knowledge with other countries and institutions around the world, which further increases the training demand on the limited number of ONT staff.

Computer-based simulations are becoming recognized as an adequate medium for teaching and training in general [2]. The use of computer-based simulations yields multiple benefits [3–5]: a) Simulation and game-like simulations promote active learning [6] and learning-by-doing, which make them an adequate learning tool in medical education [7–10]; b) Because this training is computer-simulated, it is risk-free in terms of human life [11], [12]; c) It addresses the need to minimize costs [13]; d) It is less constrained by the availability of medical facilities and reduces the pressure on the expert trainers; and e) It provides the learner with an objective assessment and immediate feedback [14]. The effectiveness of computer simulations in the area of medical teaching and learning has been demonstrated in different areas [15–18].

In an attempt to reinforce and systematize its instructional approach, ONT developed two computer-based simulations on the management of organ deceased donation. The aim of this paper is to describe the development of these computer-based simulations. Additionally, to analyze users’ perception of these simulations, they were tested on a group of 90 trainees who then gave their opinions on the contribution of these simulations, their interaction while playing, and the kind of improvements that could be made.

## II. MATERIAL AND METHODS

Simulations were developed using the eAdventure platform [19], a trainer-oriented game development platform that facilitates game and simulation development and their integration into the learning process while at the same time reducing technical and cost constraints [20, 21]. This platform is an authoring tool for creating point-and-click adventure games or game-like simulations, where the player has to

interact with different objects within the scenes to make progress while playing. A content centric development process [22] was followed as the development methodology. The eAdventure platform and the proposed development process have been previously used successfully to create game-like simulations in the medical domain [23].

#### A. Creating the simulations

Using as a baseline the documents describing ONT procedures, an initial simulation script to drive the game-like simulation development was created. Two different stakeholders took part in the creation of this script: the domain experts, corresponding to ONT nursing personnel; and the programmers of the simulations, corresponding to developers of the Department of Software Engineering and Artificial Intelligence of the Complutense University of Madrid.

Simulations were based on teaching cases selected by ONT nurses among all potential donors notified to ONT, so as to select the most representative ones [24]. Ten teaching cases were selected from real potential donor cases, covering what ONT expert nurses considered to be more than 70% of the most common situations. In order to keep anonymity as defined by law, personal data was anonymized and some additional information modified to avoid traceability, but without altering the logic of the case and that of the process.

After the creation of this script, an early prototype of the simulations was produced. First versions were simply executable mockups to ensure that the information had been properly acquired and that these educational games represented what was expected. Hence, ONT's expert nurses played the simulations. They were then modified based on the mistakes detected and validated again until they were believed to closely replicate real life cases [25].

Game elements like timers and other types of distractions that indeed are commonplace in the daily work life of the ONT were also included in an effort to make the simulation as true to real life as possible. At the end of each simulation, the player obtains a self-evaluation report showing player performance (including details about the errors made) and a final mark. This evaluation report can also be sent to the trainers for review.

#### B. Analyzing user opinion

To analyze user opinion, simulations were used by ONT in a dedicated workshop at a training course for transplant coordinators, the Transplant Procurement Management Course in Barcelona, in February 2013, with trainees divided into several small groups.

Each group went through a complete simulation with one predetermined donor case following the instructions of the trainer. Each group simultaneously received the theoretical explanation of the processes for the first time while performing the simulations.

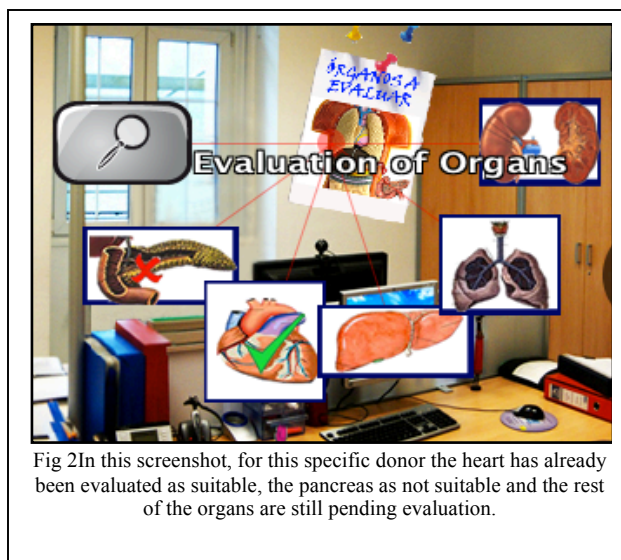
Afterwards, the students used the simulations again, this time without guidance and with different donor cases, in order to assess whether they had properly understood the processes.

Trainees completed a short survey after the workshop with three open questions.

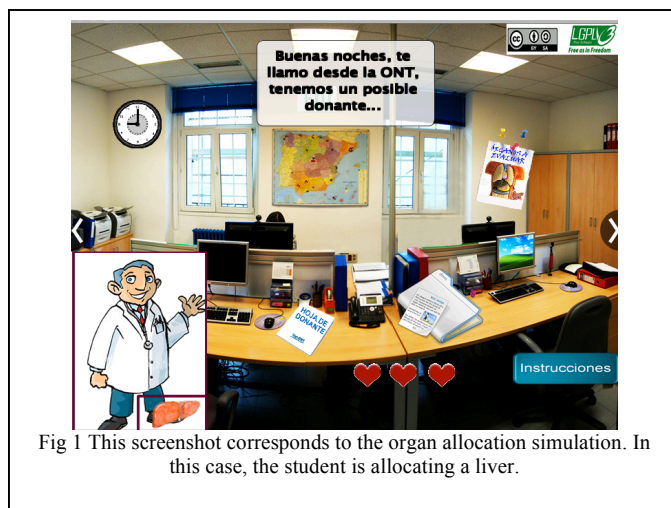
### III. RESULTS

#### A. Simulations

The first simulation represents the process of organ and donor evaluation. The student is asked to analyze an incoming donor case and determine whether or not each organ is suitable for transplantation. To do so, the student has to identify which information is relevant for the evaluation of donor and organ suitability. During the simulation, any missing data can block the evaluation of one or more organs. Fig 1 shows how the user would evaluate each organ in the simulation.



The second simulation represents the phase of organ allocation. The trainee is asked to allocate the liver, heart and lungs to the corresponding hospital, taking into account the complex national allocation criteria. The student must demonstrate that he/she can oversee this allocation process by identifying the information that needs to be verified and then offering the organs to the proper hospital. Fig 2 corresponds to the organ allocation simulation.



### B. Testing the simulations

Simulations were tested at the Procurement Management Course in Barcelona in February 2013 with a group of 90 trainees, 33 men and 57 women, including 73MDs and 17 nurses. Although all trainees were health-care professionals, they were novice in the donation and transplantation processes. Therefore, playing with these simulations while receiving the proper explanation of the logic of the process is how they were intended to learn (learning by doing) [26]. As a way to promote reflection and group discussion, simulations were played in groups of 5 persons that needed to agree on the decision and actions to be carried out in the simulation.

After playing with the simulations, trainees were expected to understand properly the following concepts:

1. What information on the donor case reported to ONT is essential and cannot be missing?
2. What information on the donor case reported to ONT is relevant, but not essential?
3. What kind of errors can lead to an incorrect evaluation of an organ?
4. What are the possible causes of unsuitability of an organ?
5. What information needs to be checked in order to properly allocate an organ?
6. How does one properly select the criteria when allocating an organ?
7. How do time constraints affect these processes?

An evaluation was carried out in this workshop. Trainees completed an evaluation form with three open text questions:

1. Give your opinion on the contribution of the simulations to the learning of the organ deceased donation process.
  - 67% of the participants agreed that the simulations had contributed to helping students learn and better understand the donation and transplantation processes.
  - Among the rest of the answers, it is important to note that 3% of participants stated that simulations had helped them in the systematization of their concepts.
2. Tell us what would you change or improve to make the simulations more useful or engaging.
  - 42% of the trainees requested more visual and remarkable game elements; for example, they asked for a louder sound when the phone rings or for the warnings of the simulation to be more colorful.
  - 14% of the trainees requested a third simulation representing the logistics of transportation.
  - 9% of the participants said that they would like to have more levels of difficulty and another 9% suggested that they needed more time to learn or to be able to finish the simulation properly.
  - Among the rest of the answers, each one representing 2%, the most remarkable were the request of the translation of this game so it can be exportable to other countries and also the request of

the inclusion of random calls at the middle of the game to add more stress.

3. Describe your interaction with the simulations. How did you make the decisions? Did you need any guidance?
  - 76% of the trainees said that they made the decisions with full consensus from the rest of the group playing.
  - 90% of the trainees needed help to finish the simulation while playing without supervision, most of them because they got lost and did not know how to advance.

### IV. DISCUSSION

These simulations have given the ONT the opportunity to represent its procedures with low-cost computer-based simulations as a way to reinforce and systematize its instructional approach.

Developing healthcare simulations is always a challenge because it is necessary to involve different domain experts (medical personnel, developers) and communication is usually problematic. However, involving these different experts in the simulation development process ensures the educational value and the validity of the content.

Learning some of the steps of the complex process of deceased donation with game-like simulations allows trainees to practice as many times as they want without risking the lives of the recipients and without interrupting the effectiveness and transparency of the process [27], [28]. Moreover, the feedback provided automatically to the trainees by these simulations allows them to learn from their own mistakes and to increase gradually their level of knowledge.

To understand the importance of these simulations, we now focus on the particular case of a new nurse in the ONT Central Office working a typical day. Imagine that he or she makes a clinical mistake when analyzing the donor information page or an allocation mistake and offers a heart to a hospital when there is a high priority recipient compatible in another hospital. Immediately after realizing the error, he or she will experience strong feelings of regret that will probably be very instructive for the next instance. He or she will likely remember this mistake forever, but in that exact moment there will quite certainly be feelings of anxiety and frustration, as well as some other negative consequences. These simulations replicate some of these common errors in a risk-free environment, allowing this nurse to experience the consequences of this kind of mistake without risking efficacy and the lives of the recipients.

With reference to user opinion, we can conclude that most of the participants in the course agreed that the simulation helped them to establish a better understanding of the donation and transplantation process. We need to focus on improving the simulations to make them easier to follow and finish, as most of the students needed guidance while playing on their own. In reference to the improvements suggested by the trainees, we must work to make game elements easier to find and more noteworthy, as this what requested and will

help users avoid getting lost while playing. More levels of difficulty may be included in future versions. The amount of time provided, however, will not be increased, though it was requested, as one of the objectives of the simulations is to show how pressing time is in these kind of processes. In fact, the fact that users requested more time demonstrates that they felt the pressure of time while playing.

Finally, the resulting simulations are editable by using the eAdventure platform, not only by the programmers but also by the medical experts, as no programming is needed. So, if simulations were to be exported other countries, it could be done with some modifications such as replacing the screenshots of the ONT central office or modifying the logic of the allocation criteria simulation if needed.

## V. CONCLUSION

ONT has created two simulations to support and improve its educational program. They provide an educational environment in which learning occurs while doing. These interactive simulations have allowed students to learn the demanding process of donation and transplantation while interacting with a simulation of the real environment based on real pictures and videos. This way, players understand complex concepts not easily acquired by simply studying textual procedure descriptions. These simulations provide an active, realistic environment where learning can advance from simple knowledge acquisition towards skill development to evaluate a potential donor and allocate organs [29].

These simulations represent two of the steps in the donation and transplantation process and open the door to more simulations depending on the success of the ones already developed. After internal ONT evaluation and validation by ONT expert nurses, these simulations were used in a workshop in February 2013 in Barcelona for the first time. Trainees used these simulations and subsequently completed an evaluation form expressing their opinions. The results indicate that the simulations helped them to better understand how the ONT works. In addition, several trainees requested the creation of an additional simulation comprising the logistics of organ transportation in order to get a more complete picture of ONT processes.

Subsequent steps in the project include the development of a transport logistics simulation, the aforementioned improvements, and the analysis of how these simulations can be effectively distributed to final users (e.g., integrating the simulations into an e-learning environment such as Moodle or LAMS [30]). In addition, a larger study is being planned that will examine the use of simulations in other courses offered by the ONT in Spain. It is hoped that this study will provide additional data regarding the use and benefits of simulations in actual training settings.

## REFERENCES

- [1] R. Matesanz, R. Marazuela, B. Domínguez-Gil, E. Coll, B. Mahillo, and G. De Rosa, "The 40 Donors Per Million Population Plan : An Action Plan for Improvement of Organ Donation and Transplantation in Spain," *TPS*, vol. 41, no. 8, pp. 3453–3456, 2009.
- [2] J. D. Roberts, A. E. While, and J. M. Fitzpatrick, "The utilization and evaluation of a simulation game in pre-registration nurse education.," *Nurse Education Today*, vol. 12, no. 6, pp. 409–415, 1992.
- [3] J. McCallum, "The debate in favour of using simulation education in pre-registration adult nursing.," *Nurse Education Today*, vol. 27, no. 8, pp. 825–831, 2007.
- [4] K. L. Mcclarty, P. M. Frey, and R. P. Dolan, "A Literature Review of Gaming in Education Research Report," *Pearson Education*, no. June, 2012.
- [5] Y. Okuda, E. O. Bryson, S. DeMaria, L. Jacobson, J. Quinones, B. Shen, and A. I. Levine, "The utility of simulation in medical education: what is the evidence?," *The Mount Sinai journal of medicine, New York*, vol. 76, no. 4, pp. 330–43, Aug. 2009.
- [6] L. Boyle, B. Johnston, E. MacArthur, and B. Fernández-Manjón, "The role of technology and digital gaming in nurse education.," *Nurse Standard*, vol. 27(28), pp. 35–38, 2013.
- [7] E. A. Akl, R. W. Pretorius, K. Sackett, W. S. Erdley, P. S. Bhoopathi, Z. Alfarah, and H. J. Schünemann, "The effect of educational games on medical students' learning outcomes: a systematic review: BEME Guide No 14.," *Medical teacher*, vol. 32, no. 1, pp. 16–27, Jan. 2010.
- [8] D. K. Andersen, "How Can Educators Use Simulation Applications to Teach and Assess Surgical Judgment?," *Academic medicine : journal of the Association of American Medical Colleges*, May 2012.
- [9] I. Dror, P. Schmidt, and L. O'connor, "A cognitive perspective on technology enhanced learning in medical training: great opportunities, pitfalls and challenges.," *Medical teacher*, vol. 33, no. 4, pp. 291–6, Jan. 2011.
- [10] P. M. Kato, "Video games in health care: Closing the gap.," *Review of General Psychology*, vol. 14, no. 2, pp. 113–121, 2010.
- [11] D. A. Cook, "The research we still are not doing: an agenda for the study of computer-based learning.," *Academic medicine : journal of the Association of*

*American Medical Colleges*, vol. 80, no. 6, pp. 541–8, Jun. 2005.

- [12] N. DeKanter, “Gaming redefines interactivity for learning,” *TechTrends*, vol. 49, no. 3, pp. 26–31, 2004.
- [13] R. T. Hays, “The effectiveness of instructional games: a literature review and discussion,” *NAVAL AIR WARFARE CENTER TRAINING SYSTEMS DIV ORLANDO FL.*, 2005.
- [14] E. A. Burrows, “‘Last adventure’--a computer simulation package for use in nurse education.,” *Nurse Education Today*, vol. 9, no. 2, pp. 124–128, 1989.
- [15] J. H. Barsuk, E. R. Cohen, J. Feinglass, W. C. McGaghie, and D. B. Wayne, “Use of simulation-based education to reduce catheter-related bloodstream infections.,” *Archives of internal medicine*, vol. 169, no. 15, pp. 1420–3, Aug. 2009.
- [16] J. H. Barsuk, W. C. McGaghie, E. R. Cohen, K. J. O’Leary, and D. B. Wayne, “Simulation-based mastery learning reduces complications during central venous catheter insertion in a medical intensive care unit\*,” *Critical Care Medicine*, vol. 37, no. 10, pp. 2697–2701, Oct. 2009.
- [17] W. Chan, J. Qin, Y. Chui, and P. Heng, “A Serious Game for Learning Ultrasound-Guided Needle Placement Skills.,” *IEEE transactions on information technology in biomedicine : a publication of the IEEE Engineering in Medicine and Biology Society*, Jun. 2012.
- [18] R. P. Ten Eyck, “Simulation in emergency medicine training.,” *Pediatric emergency care*, vol. 27, no. 4, pp. 333–41; quiz 342–4, Apr. 2011.
- [19] J. Torrente, P. Moreno-ger, B. Fernández-manjón, and J. L. Sierra, “Instructor-oriented Authoring Tools for Educational Videogames,” *IEEE Computer Society*, no. 8th International Conference on Advanced Learning Technologies (ICALT 2008), pp. 516–518, 2008.
- [20] P. Moreno-Ger, J. Torrente, J. Bustamante, C. Fernández-Galaz, B. Fernández-Manjón, and M. D. Comas-Rengifo, “Application of a low-cost web-based simulation to improve students’ practical skills in medical education.,” *International journal of medical informatics*, vol. 79, no. 6, pp. 459–67, Jun. 2010.
- [21] J. Torrente, P. Moreno-Ger, B. Fernández-Manjón, and Á. Del Blanco, “Game-like Simulations for Online Adaptive Learning: A Case Study,” in *Learning by Playing Gamebased Education System Design and Development*, vol. 5670, M. Chang, R. Kuo, Kinshuk, G.-D. Chen, and M. Hirose, Eds. Springer, 2009, pp. 162–173.
- [22] P. Moreno-ger and B. Fernández-manjón, “A Content-Centric Development Process Model,” *IEEE Computer Society*, pp. 24–30, 2008.
- [23] E. J. Marchiori, G. Ferrer, B. Fernández-Manjón, J. Povar-Marco, J. F. Suberviola, and A. Giménez-Valverde, “Instrucción en maniobras de soporte vital básico mediante videojuegos a escolares : comparación de resultados frente a un grupo control,” *Emergencias*, vol. 24, pp. 433–437, 2012.
- [24] J. A. Gordon, N. E. Oriol, and J. B. Cooper, “Bringing Good Teaching Cases ‘To Life’: A Simulator-Based Medical Education Service,” *Academic medicine : journal of the Association of American Medical Colleges*, pp. 3–5, 2004.
- [25] S. B. Issenberg and R. J. Scalese, “Simulation in health care education.,” *Perspectives in biology and medicine*, vol. 51, no. 1, pp. 31–46, Jan. 2008.
- [26] C. Aldrich and I. Clark, “Learning by Doing: A Comprehensive Guide to Simulations, Computer Games and Pedagogy in e-Learning and Other Educational Experiences,” *Educause quaterly*, no. 3, pp. 69–72, 2006.
- [27] S. Dawson, “Procedural Simulation: A Primer,” *Radiology*, vol. 241, no. 1, pp. 17–25, 2006.
- [28] B. Ricketts, “The role of simulation for learning within pre-registration nursing education - a literature review.,” *Nurse education today*, vol. 31, no. 7, pp. 650–4, Oct. 2011.
- [29] W. C. McGaghie, S. B. Issenberg, E. R. Petrusa, and R. J. Scalese, “A critical review of simulation-based medical education research: 2003-2009.,” *Medical education*, vol. 44, no. 1, pp. 50–63, Jan. 2010.
- [30] A. Blanco, J. Torrente, and B. Fernández-Manjón, “Integrating educational video games in LAMS: The< e-Adventure> Experience Proceedings of the 5th International LAMS Conference 2010,” *lams2010sydney.lamsfoundation.*, pp. 83–91, 2009.