Educational Game Development Approach to a Particular Case: The Donor's Evaluation

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ABSTRACT

Background.   Serious games are a current trend nowadays. Almost every sector has used serious games in recent years for different educational purposes. The eLearning research team of the Complutense University of Madrid main focus of research is the development of low-cost serious games. During the past 10 years, we have been working with and developing serious games, paying special attention to those related to healthcare.

Methods.   From all these studies, a methodology was defined—the Educational Game Development Approach (EGDA)—to design, develop, and evaluate game-like simulations or serious games in healthcare. We present the application of the EGDA to a particular case, the development of a serious game representing the donor's evaluation in an intensive care unit from the point of view of a hospital coordinator following the EGDA methodology. In this simulation, we changed the strategy of selection of teaching cases by exponentially increasing the number of teaching cases.

Results.   This kind of educational content provides several benefits to students as they learn while playing; they receive immediate feedback of mistakes and correct moves and an objective assessment. These simulations allow the students to practice in a risk-free environment. Moreover, the addition of game elements increases engagement and promotes the retention of important information.

Conclusions.   A game-like simulation has been developed through the use of this methodology. This simulation represents a complex medical procedure.

THE GROWING prominence of serious games (digital games applied to education) in recent years has consolidated them as a learning approach with great potential to enhance students' motivation and learning outcomes, thus being reinforced in the military, business, industry, and education fields as a training and motivation tool [1].

Serious games have especially gained acceptance in the medical field, in which they have been used to improve patients' healthcare and health professionals' education [2,3].

The development of serious games that are meaningful and effective is not an easy venture. One of the key aspects for successful serious game design is to effectively create synergies between domain experts (ie, healthcare professionals in this case) and serious games experts that enable quick translation of domain experts' knowledge into a working serious game prototype that can be collaboratively refined by the team and the potential end-users. When this is not achieved, there is a significant risk of ending up with a product that does not accomplish the educational objective [4]. Unfortunately, this scenario is common nowadays, resulting in many serious games that have not lived up to expectations [5].

At the eLearning research group of the Complutense University of Madrid, we have proposed the Educational Game Development Approach (EGDA), a methodology for designing and developing serious games that focuses on the effective integration of domain experts in the process [6]. The EGDA is the result of an intensive research and development of serious games for the past 7 years [7–11]. We specialized in developing a type of serious games that we call "low-cost game-like simulations," a formula for

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maximizing the educational value delivered at a minimum cost, which we have applied mainly in the healthcare domain.

Among the simulations developed over the past years, the most relevant ones for this article are those developed for the Spanish National Transplant Organization [12,13], which include some of the steps of the supra-hospital level of the process of deceased donation [14]. These simulations are used nowadays as a support tool in the Spanish National Transplant Organization instructional approach.

The acceptance of these game-like simulations among students attending Spanish National Transplant Organization courses and other professionals has enhanced the development of a new simulation, called the *Donor's Evaluation*, which includes another step of the deceased donation process (belonging to the hospital level). In this work, we describe the application of the EGDA methodology to the design and development and of the *Donor's Evaluation*, in hopes that this case study could help other programmers and designers in the development of cost-effective serious games or simulations in healthcare. This new case study proves the effectiveness of EGDA for eliciting complex procedural knowledge from domain experts in such a complex and risky field as deceased donor transplant evaluation.

METHODS

The development of this game-like simulation was led by an expert in serious game development, working in close collaboration with a physician specialized in the transplantation process, who acted as a domain expert during the entire development process.

We applied the EGDA methodology [6], which is built around these 4 basic principles:

- Procedure-focused approach: the EGDA gives the most importance to capturing the procedural knowledge of the domain, a kind of knowledge that is very difficult to elicit because it is acquired by years of practice in doing the same highly specialized tasks. In the case of the deceased donation process, this type of knowledge is of vital importance. Therefore, once this procedure has been correctly formalized in the simulation, we improve it with game elements to increase engagement and learning value. In this way, we try to help students understand the procedures intuitively.

- Collaboration between experts: The EGDA encourages communication between the different stakeholders (in our case, game developers and the transplantation specialist) to take advantage of both profiles and to maximize the learning outcome.

- Agile development with agile tools: The EGDA is based on the principles of agile software development. It provides rapid response to changes, and it is iterative-based. We achieved a highly educational value with a low production cost. The main tasks involved are (1) analysis; (2) game design; (3) implementation; and (4) quality assurance.

- Low-cost game model: The EGDA is designed to produce low-cost 2-dimensional point-and-click conversational adventures. In our case, we developed the simulation by use of the eAdventure game platform.

To expand the audience of our previous healthcare simulations, we opened this simulation to anyone interested in learning the know-how of the process in general terms.

The next subsections are an explanation of the application of the EGDA methodology to our particular case.

Analysis

The aim of this task is to find a common strategy between the stakeholders of the project to formalize the procedure. In our case, the stakeholders were composed of game developers and one expert, a medical assessor involved in the transplantation process.

Although game developers had already received some knowledge of the deceased donor process from the previous studies of the transplant procedures, the domain expert was involved in complementing that knowledge and fully validating how the procedure was transferred into the game. We have learned that the best way to acquire all the knowledge is by observing the experts perform their daily tasks and procedures. For this reason, we performed several observations for those situations in which we needed to ensure knowledge.

In this task, we also defined a set of teaching cases (representative set of potential donor cases), along with the domain expert. To maximize the number of possible teaching cases and to improve the learning outcome of the simulation, we decided to use data from an actual potential donor and to vary some of the data included to generate different teaching cases. The domain expert selected the data to be modified and defined the different values this data could have (for example, the chest radiograph would have 4 possible values: "normal," "pneumothorax yesterday but today normal," "basal aspirative pneumonia," "bilateral infiltrates"). We then decided that all these values would be loaded dynamically and randomly at the beginning of the game, which substantially enlarged the number of possible teaching cases. By combining all the possibilities, we reached a number of 576 possible teaching cases, varying among very simple cases and very complex ones. Moreover, we could exponentially increase this number easily by adding new values to any of the data selected (chest radiograph, age, diabetes, hypertension, etc). At this stage, we also defined which scenarios to use in the game. We set the simulation in an intensive care unit (ICU), where potential donors are evaluated in the actual process. The definition of the scenario also describes the purpose of possible objects, such as the telephone, the fax, or the trash, used to launch bonus questions, or the use of the donor's page or the blood type page to provide the player with the donor information. The people or other agents who interact during the execution of the procedure are also defined in the analysis stage. In our case, the hospital coordinator and a nurse were the only characters involved.

Game Design

Multiple scenes were designed, based on pictures of the actual environment (ICU as the main scene, the donor page scene, the evaluation scene, etc) linked to set a navigational environment (from the ICU, the donor page scene and the blood group page scene can be accessed; from the evaluation scene, the main scene can be accessed and the donor page scene can be consulted, etc). This way, the physical setting in which the procedures are performed is accurately represented.

In this the game design task, it is important to situate the player to provide him with an experience that fosters immersion. In the simulation, the player acquires the role of a hospital coordinator who must correctly evaluate a potential donor and decide which organs are suitable (this defines the main goal for the game).

Another character also appears in the scene—a nurse, whose role in the game is to guide the player throughout the simulation, to help the
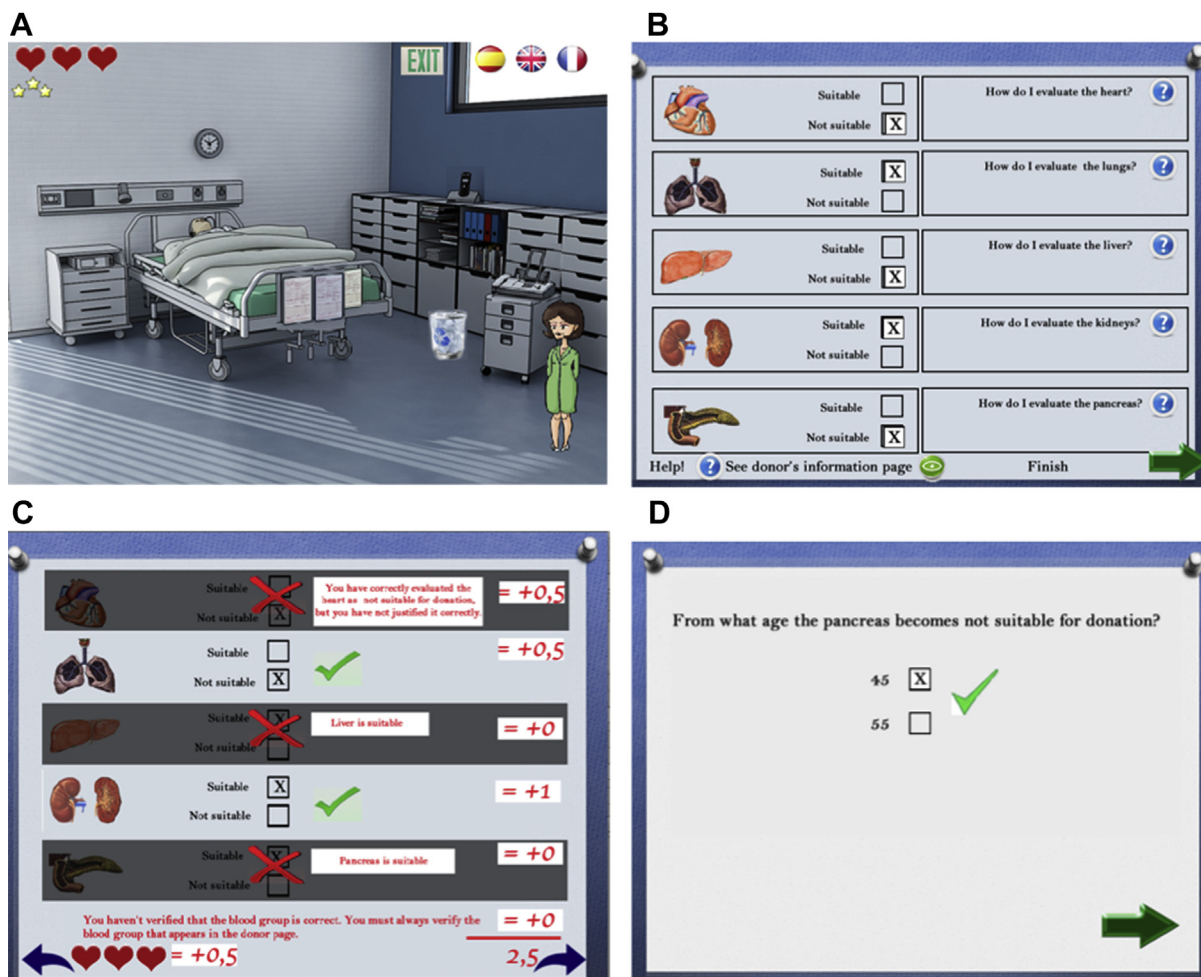
Fig 1. **A**, Main scene of simulation; **B**, organ evaluation scene; **C**, final punctuation scene; **D**, random question to earn rewards.

player when he needs it, and to provide the player with information of the donor when needed.

In this simulation, we needed to reinforce immediate feedback so that the player would learn from his mistakes while playing and would receive an objective assessment [5,15]. To do so, a score system was included and the player's mistakes were shown while he was playing. The correct actions were also shown to motivate the student.

Finally, to improve game engagement, game elements were included. To this end, we analyzed which aspects of the simulation we wanted to highlight so that the player could retain them easily. These aspects were represented through different game elements, such as scoring, lives, and bonus stars. This is called "gamification of the design."

Implementation

In this task, the development began and all the design decisions were placed in the simulation. As in other implementations, we first developed a very simple case and showed it to the expert, which is the easiest way to rapidly validate the knowledge representation, as the expert is seeing and playing with the exact case he usually deals with in his daily job. Game elements, complexity, and more teaching

cases will be added once this first mock-up prototype has been validated.

Game resources were included to make the game appealing. We hired a professional to design a workplace animation of the main scene and of the cover. In contrast with other simulations developed, we did not use authentic photos of the environment, which could lead to loss of realism. Instead, we gained versatility and avoided upsetting players, because including authentic photos would mean including a photo of an actual potential donor in a hospital.

Quality Assurance

We attempted to ensure that the resulting simulation had the following characteristics:

- Reliability: We ensured that the game was stable and free of programming errors. This was achieved by performing tests at different levels: by the developers, the experts, and users not related to the project. Validation of the teaching cases was necessary; as the amount had increased dramatically, the domain expert revised the cases to perform such validation. First, he analyzed the combinations that could never occur or that he thought unlikely to occur (for example, it was decided that if the

Fig 2. Immediate feedback: **A**, beginner's level; **B**, intermediate level.

abdominal ultrasound value charged dynamically, "signs of chronic alcoholism," then the addictions results must show a history of alcoholism, so other combinations were excluded), and he then discarded those cases that were too similar.

- Playful/engaging experience: It was checked that playing the game was enjoyable and immersive as well after adding game elements and attractive art resources.
- Usability: Interaction with the simulation must be pleasant. If playing the game is frustrating, then the player will not repeat the experience. Most of the usability problems are found when testing with users/players not related to the project because they usually click randomly, with no awareness of what they are doing. Usability problems were quickly identified and fixed.
- Educational value: Last but not least, having a clear learning outcome is essential for an educational simulation. The player must know what he is learning and what he must achieve.

RESULTS

Organ and donor evaluation in the ICU simulation has been developed as a result of this project, through the use of EGDA methodology and taking advantage of the previous experience in developing game-like simulations.

We added three levels of difficulty, and language options were included as well. When starting the game, the player will be able to choose between English, French, or Spanish as well as between beginner, medium, or expert level. To help players understand the simulation, we included a tutorial to guide them throughout the game on the first attempt. The tutorial also helps to clarify what the players must do to complete the simulation.

In Fig 1A, the main scene of the simulation is shown, which is common at every level and language selected. Some game elements are included in this scene.

- Time is represented by the use of lives that decrease when the player makes critical mistakes or after a certain period of time (1 life lasts 6 minutes for the beginner, 4½ minutes

for the intermediate level, and 3 minutes for the expert level) (in Fig 1A, the heart is shown in the top left corner).
- A set of 5 rewards (stars) was included. The player earns them throughout the game by performing some extra actions (Fig 1A shows the rewards obtained in the top left corner), such as using the trash or the phone (Fig 1D shows one of the bonus questions that appears when clicking on the trash or the phone). These rewards are also earned when the player performs an action considered as proficient, such as the checking of the blood group and sending it by fax to the corresponding organization.
- We have made a special effort to provide immediate feedback [16–18] by enabling players to learn from their mistakes and to reinforce their correct moves. This is a common feature in games, and it is very useful in educational contexts.

To promote decision-making support and provide the student with an adequate sense of control, the player must study the donor information page and decide whether or not each of the organs is suitable (Fig 1B, evaluation scene). In this scene, the player finds different objects and the different organ options for which he decides the suitability of the organs. If he is not sure about the suitability of one of the organs, he can search for help by clicking on the "question mark" button (see Fig 1B). Once he has finished, he will navigate to the validation scene, where the simulation will let him know which options were correct and which ones were not, and then the simulation will explain to him why (immediate feedback). Finally, the player will obtain a score explained (see Fig 1C).

The beginner level is targeted to students who are novice in the process; this means that when studying the donor information page, they will be able to detect some of the wrong information and decide whether or not one organ is suitable but not always (for example, they can determine that a donor in his 50s will not donate the pancreas but they will not be

able to determine whether a pneumothorax or an enolism history determine the unsuitability of certain organs). This is why, at this level, the player does not need to justify the reasons that an organ is not suitable on the donor information page, they simply decide whether or not an organ is suitable. The immediate feedback at this level then explains to the player each of the reasons by marking them on the donor information page (see Fig 2A).

On the other hand, at the intermediate and expert levels, the player is expected to know why each of the organs is or is not suitable, so he must justify these facts on the donor information page (for example, if the age is over 55 years of age, the pancreas will not be suitable; the player must click over the age to justify it correctly); the immediate feedback then indicates the mistakes and scores the correct answers (Fig 2B). In Fig 2B, this level has 3 different types of immediate feedback; the first one marks the correct justifications with a green check. In this case, the player has selected the abdominal ultrasound result as one of the reasons that the liver is not suitable. The second type corresponds to justifications that are incorrect. The figure shows that the player has selected the chest radiography result as the reason that the lungs are not suitable. However, this is not the correct justification, so the simulation marks it with a red cross. In the third type, the player has not justified the unsuitability. In the figure, several examples of this type of error are shown; one of them is that the player has not justified that the heart and pancreas are not suitable because of the age of the donor.

The expert level includes hiding some of the data in the donor information page; for example, the age or the serology results, forcing the player to ask the nurse for this to be able to evaluate the organs.

DISCUSSION

The use of serious games produces multiple benefits [19–21]. Some of the outstanding benefits are the promotion of active learning and learning-by-doing [22] (Boyle et al), thus making them an adequate learning tool in education [23–26]. Serious games have also been shown to be beneficial in training scenarios, in which the key is to have a rapid execution of the process-based knowledge [27]. However, the development of serious games is a complex activity, especially because of the need to have domain experts and developers working in close collaboration. This is essential for capturing and transferring domain-specific knowledge into the game or simulation, ensuring that the content produced has the uttermost educational value. Among other features, the methodology that we developed for EGDA proposes strategies for effectively involving domain experts in game or simulation development.

In this paper, we present the *Donor's Evaluation*, a game-like simulation developed to capture the hospital transplant procedure in which the EGDA methodology has been applied. This is the first time that EGDA has been applied in such a complex setting. The procedure for donor evaluation is very complex because many factors must be considered with little time for reaction, and its mastery requires experience. This proves the effectiveness of EGDA for capturing and transferring highly specialized knowledge from domain experts to working game-like simulations, even when the knowledge is particularly complex.

The *Donor's Evaluation* is an innovative learning material. In literature, we can find an old case of the development of a simulation to craft a transplant policy policy [28]. Since then, this work and our previous studies represent the first approach to the representation of a transplant procedure throughout simulations, helping in the systematization of the procedures. We hope the content produced helps to spread this highly valuable knowledge to improve deceased donor evaluation protocols around the world.

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