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Research Article

A New Methodology of Design and Development of Serious Games

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The development of a serious game requires perfect knowledge of the learning domain to obtain the desired results. But it is also true that this may not be enough to develop a successful serious game. First of all, the player has to feel that he is playing a game where the learning is only a consequence of the playing actions. Otherwise, the game is viewed as boring and not as a fun activity and engaging. For example, the player can catch some items in the scenario and then separate them according to its type (i.e., recycle them). Thus, the main action for player is catching the items in the scenario where the recycle action is a second action, which is viewed as a consequence of the first action. Sometimes, the game design relies on a detailed approach based on the ideas of the developers because some educational content are difficult to integrate in the games, while maintaining the fun factor in the first place. In this paper we propose a new methodology of design and development of serious games that facilitates the integration of educational contents in the games. Furthermore, we present a serious game, called "Clean World", created using this new methodology.

1. Introduction

In recent years there was a growing interest in serious games (i.e., games for purposes beyond entertainment) because they facilitate the learning process, by engaging the user and increasing his motivation. Eck argues that "games are effective not because of what they are, but because of what they embody and what learners are doing as they play a game" [1]. These kinds of games have been used in a wide range of sectors such as military, healthcare, education, and corporate, among others. However, only a few methodologies were proposed to guide the design of serious game [2]. This is due to the fact that the development of a serious game is a process that involves a high degree of creativity.

The development of serious games, besides the game designers and developers, requires a tight collaboration with domain experts. Notwithstanding the gathering of information via traditional mechanisms (e.g., meetings and interviews with experts) for serious game design can be a difficult task. In serious games the critical point is the relationship between the game and the educational content. But according to Zyda [3] the pedagogy must be subordinate to story. Often the game design relies on a detailed approach based on the ideas of the designers and developers because some knowledge is difficult to integrate in the games, while maintaining the fun factor in the first place [4].

2. Serious Games on Education

Currently, there are several research projects and literature about serious games in very diverse areas but we will restrain our focus on education alone.

The use of serious games for educational purposes can have a very positive effect, since they provide an effective way to engage students in learning activities and have the ability to stimulate cognitive processes like acknowledging displayed information, deductive and inductive reasoning, and also problem-solving [5].

Zielke et al. [6] described a serious game that lets players increase their cultural expertise in simulated Afghan rural and urban environments. It is a serious game for immersive cultural training by creating a living world. A similar serious

game is also described by Losh [7]. This game aims to accelerate a learner's acquisition of spoken Arabic to assist in the rapid deployment of soldiers into tactical situations. Both games aim to prepare the soldiers for real war scenarios. The military industry was one of the first that used serious games for learning.

The United Nations organization has also launched some serious games to support their own initiatives, for example, to learn about the crisis in Darfur, related to HIV and AIDS prevention, and to stop disasters.

The serious game "Fast Car: Travelling Safely around the World" [8] launched by the United Nations Educational, Scientific, and Cultural Organization (UNESCO) aims to provide young people over the age of 16 with accurate and reliable information about HIV prevention, while educating, entertaining, and promoting healthy behavior. While racing on circuits on five different continents and virtually visiting some of UNESCO's World Heritage sites, players will receive information on existing prevention practices, treatment, and care for HIV and AIDS.

"Darfur is Dying" [9] serious game provides a window into the experience of the 2.5 million refugees in the Darfur region of Sudan. Players must keep their refugee camp functioning and avoid the attacks by militias. It allows the players to learn more about the humanitarian crisis in Darfur.

Muratet et al. [10] presented a serious game dedicated to learn computer programming. The basis for their serious game is a real-time strategy game, since it is the genre most played by the target audience. The players can command game entities with their own behaviors and have contests with other players in the multiplayer mode.

Barbosa and Silva [11] described a serious game to teach young students the basic functioning of the human circulatory system. It is a real-time strategy game where the player has to control a group of entities, such as red blood cells, white blood cells, and platelets, to avoid the bacteria. For that, the player has to understand the function of each entity to progress in the game.

Cowley et al. [12] presented a serious game to teach energy efficient knowledge and behavior to users of public buildings around Europe. It is one part of the project Save Energy that, by the use of information and communication technologies and real-time information from sensors and actuators, aims to transform the behavior of users of public buildings regarding energy efficiency.

The United States Environment Protection Agency (EPA) has a web page dedicated to recycling, called Recycle City, to visit and to explore how the city's residents recycle, reduce, and reuse waste [13]. It has also a serious game, the Dumptown game, where the player can create his own Recycle City. When starting the game the player sees Dumptown at its worst; it is littered and polluted, and nothing is being recycled or reused. But the player can start programs that encourage Dumptown's citizens and businesses to recycle and reduce waste. Each time the player tries out a new program, he can see immediately how the Dumptown landscape changes and how much waste he is preventing from going into the landfill.

More recently, Martins et al. [14] presented a serious game in Oncobiology that will allow the player to support clinical decisions with biological data, with the aim of promoting hypothesis-driven clinical research. They decided to develop a serious game as a point and click adventure, because they think it would best fit the theme and experience that they wanted for the player. They opted for a hospital themed game, where the player assumes the role of a medical doctor in residency training, who is put in charge of a clinical case and has to make step-wise decisions based on clinical and biological information.

Allegra et al. [15] describe a serious game that aims to introduce and foster an entrepreneurial mindset among young people. The focus of this game is on the management of a touristic company, in a complex market in which players compete with other companies/players.

Most of the serious games referred to above run on web browsers, which is not a platform dedicated to games. On the contrary, the consoles are platforms dedicated to games. Thus, a serious game designed for a console should be more effective than one designed for browser because players usually associate the games to consoles, which provide a more immersive experience due to their peripherals. A clear example of that is the exergames: games that promote the physical exercise [16], which are a success in consoles (e.g., fitness games).

Nevertheless, there are also some interesting approaches used in serious games and virtual environments for learning, where the knowledge is associated with task-based learning theory. For example, Bellotti et al. [17] proposed a new architecture for a class of serious games, the sand box serious games. The model of these games consists in a virtual world where knowledge is distributed in contextualized tasks spread by the world. In this context, they proposed decoupling contents from their delivery strategy, that is, by creating a task repository. The contents can be embodied in instances of simple task models, such as mini-games, quizzes, visiting a limited virtual world zone, interactions with 3D objects, or conversations with virtual humans. Their approach was later applied in the TiE project, which is designed to promote the knowledge of the European cultural heritage to a wider audience, where a visual authoring tool of tasks was introduced [18].

The same concept of task-based learning (e.g., mini-games, quizzes, and puzzles) was tested for interactivity and serious gaming for educational TV [19]. In this case, the authors have explored how to combine the media-driven nature of TV programs with the active user's participation which is typical of interactive games.

Recently, Bellotti et al. [20] presented a serious game model for cultural heritage that is based on previous works [17, 18] and tested with TiE game. They defined a model for games that are set in realistic virtual worlds enriched with embedded educational tasks, where the tasks are implemented as mini-games. They proposed a top-down methodology for content preparation, starting from a city-level analysis down to the single points of interest and associated tasks, which are instances of simple predefined mini-game/quiz typologies.

Smith and Sanchez [21] presented a strategy for developing mini-games that can be embedded in game-based

training. They described how mini-games can be used for conceptual or procedural knowledge and they also present descriptions of several case studies that use mini-games as part of the learning strategy. They concluded that mini-games have become sophisticated enough to be included in serious games.

Procci et al. [22] described a serious game to teach deploying military personnel about available mental health resources and coping skills, as well as to determine whether the inclusion of mini-games improved learning outcomes. They concluded that including mini-games to provide practice in a game-based training environment such as a serious game improves learning outcomes.

In this paper we propose a new methodology of design and development serious games, which is aligned with the idea of embedded educational tasks in parallel to the main game, for example, through the use of mini-games because they have the potential to reinforce a single or small group of learning objectives by providing engaging and motivating learning experiences. Next section describes in detail the proposed methodology.

3. Methodology of Design and Development of Serious Games

As referred before, in a serious game the fun factor must be maintained in the first place. Therefore, to provide a rich and engaging environment that presents educational goals the best practices of pedagogical psychology are needed. But the best pedagogic practices are those that are interpreted as fun [23].

Real learning does happen in games, and this learning process shares many characteristics with the pedagogy of problem-based learning. Players must solve problems to progress through the game and they can only solve a given problem by accumulating the necessary experience and tools in lower levels of the game.

The pedagogy used is akin to problem-based learning where the structure and narrative of the game provide the purpose of learning and an immediate motivation for pursuing the knowledge required. Furthermore, it must include meaningful problems to solve with the purpose of learning the contents.

The learning must occur within multiple mechanisms, such as mini-games, puzzles, and quizzes, played in parallel to the main game environment but also by the gameplay and solving quests in the game. The educational component must be mainly based on the interaction with these learning mechanisms, where the concepts to be learned are embedded. However, the player must have missions to complete in the main game in order to obtain the requirements and tools to progress in game through the access to these mechanisms. For example, collect several items to be used in a mini-game or in a puzzle for a specific learning outcome. Thus, the player has the opportunity to learn some contents provided by a specific learning mechanism, keeping the main game more fun and engaging.

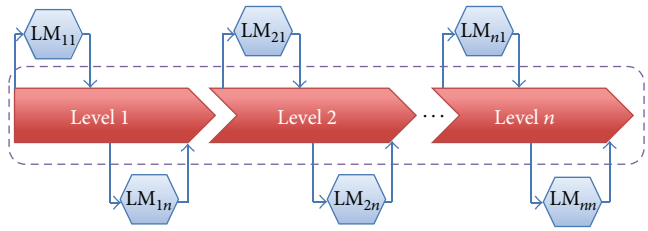


Figure 1: Diagram of our methodology; a game with several levels and the learning mechanisms associated to each layer.

This methodology must be applied also into each game layer, which means that the learning contents can be distributed by all layers. Therefore, the player must have several quests to complete per layer and also several learning mechanisms to overcome, in order to learn the concepts associated to each layer of the game. Figure 1 shows the diagram of our methodology, where a game is divided by levels and each level can be composed by several learning mechanisms (i.e., LM_{ij} in Figure 1). For each layer of the game, the player has missions to overcome as a way to access the learning mechanisms and thus progress in the game.

In short, our methodology proposes two main components for the design and development of a serious game, a main game with quests and a set of learning mechanisms. These learning mechanisms are related with the main game but they are independent and played in parallel with main game. Thus, it is easier to include learning contents in the game by defining independent learning mechanisms.

Note that this kind of learning mechanisms can be diverse, for example, quizzes, puzzles, or mini-games. But the knowledge is embodied mainly in those mechanisms that appear during the game, which means that the main game can be more oriented for fun factor engaging the player more.

4. "Clean World" Game

To test the methodology presented was developed a serious game, called "Clean World." "Clean World" is a 3D game created to raise awareness to environmental problems that we face today and tries to show what we can do to protect nature and keep our planet clean from pollution. For this, it intends to teach important concepts about recycling and renewable energies by combining classical platform and role-play game elements with mini-games and puzzles as learning mechanisms. Thus, the first step in designing of "Clean World," after deciding the theme, was the creation of a story to support the game.

4.1. The Story of the Game. The game takes place on the Anglas islands, in the year 2022. Due to the greed of big corporations, planet Earth is now completely polluted. People cannot walk on the streets without breathing masks due to the polluted air, and the big cities became giant industrial complexes where industries try to explore to the maximum the last resources of the planet.

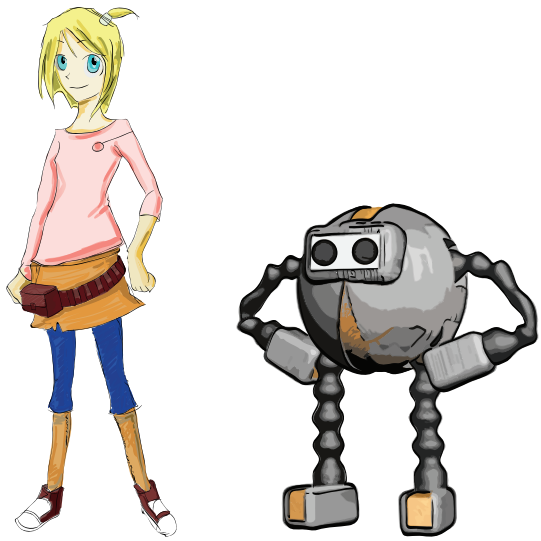


Figure 2: Concepts of Kate and Boris created by the 2D artist.

In one of the Anglas islands, the remote island of Cypricene, Kate, a 16-year-old girl, struggles against a disease that now affects almost the entire human population. Kate is alone on the island and she is too weak to get out. So, she uses technology to find help and builds a small robot with unique abilities, called Boris, which she sends in search of help. Boris is the character that the player controls in the game to search for help for Kate, a nonplayable character (see Figure 2). Note that the use of a robot is related with the theme of the game because the robot needs energy to move. Thus, the player needs to control the energy level of the robot to progress in the game.

After the beginning of the adventure Boris leaves in search of the medical center of the island, in order to help Kate (i.e., it is the first mission of the player in the game). There he meets Dr. Jacob, a brilliant scientist and doctor. The doctor explains to Boris that Kate is sick because she was infected with the Stigma, a new disease that has been affecting the human population almost for a decade. Dr. Jacob explains that the Stigma has no known cure; however, he has been studying the disease for a long time and he believes that the illness is connected to the pollution in the world. He describes to Boris his theory: if we reduce the pollution in the world probably the disease will disappear.

With the medicine on its hand, Boris goes back home to give it to Kate. Feeling a lot better, Kate is willing to test Dr. Jacob's theory with Boris's help. Thus, together they start to clean the island from pollution, starting by recycling the garbage (i.e., it is the second mission of the player in the game).

Later on, Boris meets Tom A. Toe, the engineer responsible for the wastewater treatment plant of the island. Then, with the help of this engineer, Boris starts to convert the plant and the machines to use clean energy sources, like the sun and the wind (i.e., it is the other mission of the player). Figure 3 shows the concepts of Dr. Jacob and Tom A. Toe created by the 2D artist.

Figure 3: Concepts of Dr. Jacob and Tom A. Toe created by the 2D artist.

4.2. Main Game. "Clean World" game was developed to be played with the Xbox controller making it more attractive for players, because consoles games are normally more addictive.

To implement the story, the "Clean World" game was divided in three levels. The first level's theme is recycling of garbage where Boris has to collect items spread through the island. Besides, Boris has to maintain his energy during this task, which means that he needs to recharge his batteries from time to time. For this purpose he needs to return to Kate's home because at this stage he cannot recharge by himself. If he loses all of his energy the player loses one life and starts the level again.

After completing most of the quests in this level, Boris gains a solar panel as a new ability. This solar panel allows to Boris recharging his batteries alone, that is, without returning to Kate's house, which is an advantage to progress faster in the game.

Figure 4 shows an overview of the first level of the game, where we can see some fog to simulate the environmental pollution. As we can see later, in the third level, the environment

Figure 4: Screenshot of the first level, where the environment is polluted.

Figure 5: Screenshot of the second level, the cave.

is less dark because to reach the third level the player has to complete some tasks to clean the environment.

During each level of the game there are several learning mechanisms that the player has to complete in order to advance and finish the level. These learning mechanisms will be presented in more detail in next section.

The second level has a new scenario that corresponds to a cave (see Figure 5). In this level, the player has to collect several items that can contaminate the soil (e.g., toxic garbage). Like in the previous level there are several learning mechanisms related to environmental issues that the player has to complete and that provide valuable information on how we can help to improve the planet's health.

In the third level the player will find a cleaner environment with less fog. This shows to the player that his tasks have had a positive impact on the environment and in Kate's health. The goal of this level is to teach some contents about renewable energies (e.g., using the sun and wind). In this case, the player has to complete tasks such as activating solar panels, building wind towers, repairing water mills, and providing clean and renewable energies to a wastewater treatment plant. Additionally, the player can now use the power of the sun to recharge his batteries using the solar panel available (see Figure 6).

During the entire game the player is assisted by two nonplayable characters (NPCs), Dr. Jacob and Tom A. Toe, who give instructions and quests to Boris. Figure 7 shows both characters that assist Boris during the game. For example, in Figure 7(b), in bottom right corner, we can see a dialog with Tom, the engineer that assists Boris in the third level.

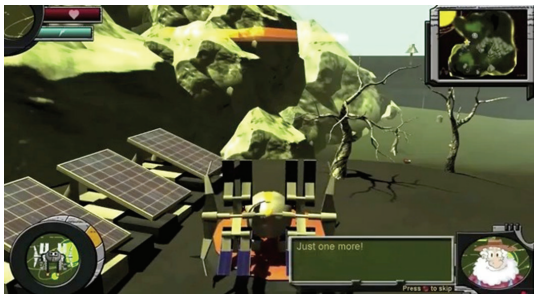


Figure 6: Screenshot of the third level, where the environment is less polluted.

(a)

(b)

Figure 7: Nonplayable characters: (a) Dr. Jacob in level 1; (b) Tom A. Toe in level 3.

Boris has several skills that can be acquired and used during the game. For example, he can simply walk or use his skills to transform into a sphere to roll or even recharge his batteries using a solar panel. His skills are displayed on the bottom left corner of the interface. As we can see, Figures 4, 5, and 6 show these three different skills, walk, roll, and recharge, respectively. On the top left corner of the screen, Boris health and energy bars are displayed. A map of the level is displayed on the top right corner of the screen where the position of Boris and other important information are located (e.g., the location of Kate's house).

Figure 8 shows the workflow of the first level of the game, where we can see the quests and the learning mechanisms of this level. As we can see, the learning mechanisms in this case are the two mini-games referred to in Figure 8.

In Figure 8 we can also see that after completing quest 9, the player obtains a new ability; that is, Boris gains a solar panel that enables him to recharge his batteries by himself.

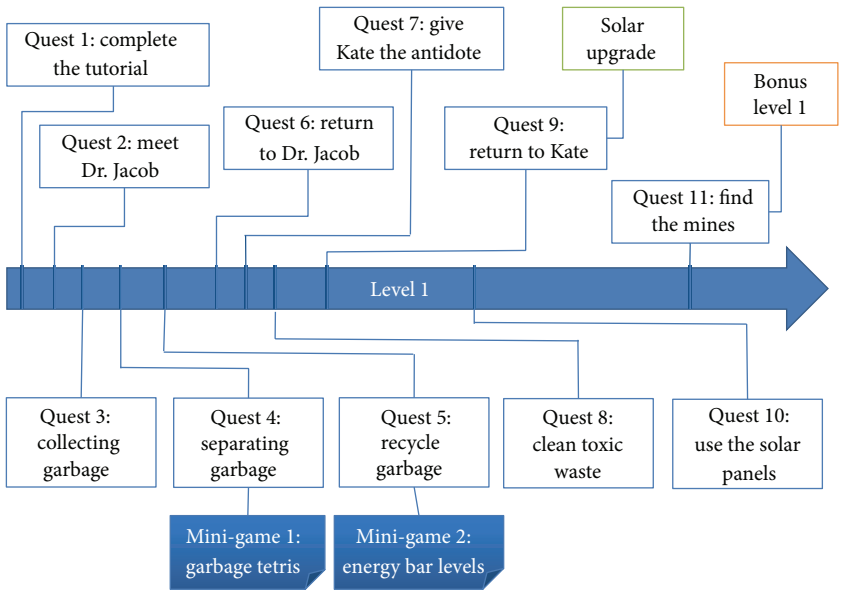


Figure 8: Workflow of the first level of the game, where we can see the several quests and the two learning mechanisms that run in parallel to main game (i.e., two mini-games).

The same strategy is used in the second and third levels of the game. Thus, the player has several quests to complete in the main game and has several learning mechanisms to overcome, in order to learn the concepts associated to the game thematic.

4.3. Learning Mechanisms. To include educational contents in the game without disfiguring it (i.e., keeping the fun factor in first), several learning mechanisms were spread along the game, in particular some mini-games and puzzles associated to the thematic of recycle and renewable energies. These mini-games and puzzles allow teaching some educational content about the environment and how to protect it, such as garbage separation. Furthermore, in all the game the tasks related to garbage collection and separation are associated with the colors of the Xbox buttons, taking into account the type of the garbage, that is, green button to glass, blue button to paper, yellow button to metal, and red button to plastic (see Figure 9).

Some learning mechanisms are based on several successful games that already proved to engage the players. For example, the mini-game associated to the separation of garbage uses mechanics similar to the Tetris game. But the mini-game of energy bar levels associated with the recycling machines uses mechanics similar to Guitar Hero game. These learning mechanisms introduce new gameplay mechanics and diverse experiences in parallel to the main game. This way, the game teaches important concepts about the protection of the environment, through fun, engaging the player with diverse experiences.

In the mini-game based on the Tetris game (see Figure 9(b)) the player has to separate the garbage according to its type using the joystick of Xbox controller.

During the evaluation process with different users we observed that these learning mechanisms were the most exciting part of the game for the players. For example, the mini-game associated with the energy bar levels of the recycling machines was considered very exciting by the players. Although it was a very simple game, its mechanics were very challenging for the players (see Figure 9(c)). In this mini-game the player needs to maintain the energy bars level below the line. For that, the player needs to press the correspondent buttons of the Xbox controller, but only one at a time is allowed.

Figure 10(a) shows a mini-game based on the Guitar Hero game, where the player has to collect the maximum number of items that appear in front of him. Players can move to the right and to the left and have to press the corresponding button to catch the items (i.e., press the button with the same color of the illuminated item).

Finally, Figure 10(b) shows a mini-game that is a puzzle of pipes, where the player has to reorient several parts of pipes to create a path from one side to the other, to create a functional path for energy to pass through. Boris can use the resulting energy to recharge or to give clean energy to other machines.

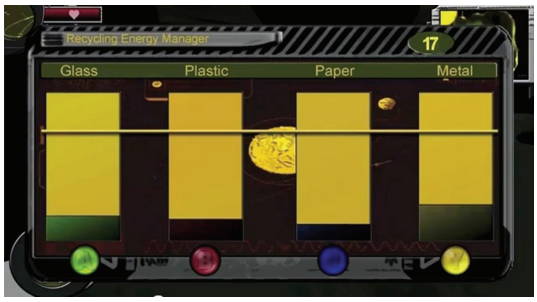
5. Conclusions and Future Work

People differ in their behavior, play styles, and learning methods. But some forms of learning are more fun than others; thus, serious games can provide mutual goals of entertainment and education.

The "Clean World" game aims to teach important concepts about recycling and renewable energies to players. But the players see it more as a game and less as a serious game, which means that educational contents were very well included in the game. The methodology proposed here was to include educational contents mainly out of the main game, that is, as independent learning mechanisms proved to be very efficient. This methodology demonstrated a more

(a)

(b)



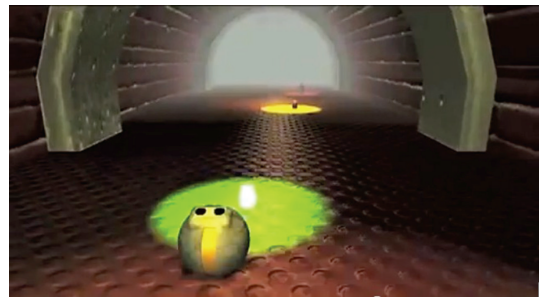
(c)

Figure 9: Xbox controller and two examples of learning mechanisms from level 1: (a) Xbox command; (b) associated to the separation of garbage; (c) energy bar levels associated to the recycling machines.

effective way to create serious games that engage the players, when its learning contents are included mainly in learning mechanisms, as, for example, mini-games and puzzles, since it enables keeping the main game a simple game without disfiguring it with learning contents.

Besides, we could observe that the target people of the game (i.e., young people) liked to play the game and consider it addictive due to the challenge provided by mini-games and puzzles, which means that these learning mechanisms are really effective. But note that this game was designed for the Xbox controller, which is also a controller dedicated to games that are more interesting for players.

Playing "Clean World" helps young people to develop a positive attitude to help the planet Earth. Doing this will increase the chances of the young people to grow and become



(a)

(b)

Figure 10: Other learning mechanisms: (a) mini-game associated to garbage collection; (b) mini-game associated to the recharge of batteries.

responsible adults, recycling, and using the renewable energies.

In the future we hope to include new characters in the game, for example, enemies that compete with the player in some tasks, making the game even more interesting and challenging (i.e., include nonplayer characters). Furthermore, we hope to test the game in some secondary schools to evaluate its effectiveness with more detail, namely, based on a protocol of evaluation of the knowledge before and after playing the game.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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