

Design of an Educational Adventure Game to teach computer security in the working environment

Ciro D'Apice, Claudia Grieco, Rossella Piscopo
DIEM, Università degli Studi di Salerno
Fisciano (SA), Italy
cdapice, cgrieco, rpiscopo@unisa.it

Luca Liscio
CRMPA
Fisciano (SA), Italy
liscioluca@gmail.com

Abstract— One of the emerging requirements for learning in the enterprise is finding new ways to keep the learner engaged. The use of advanced learning technologies that exploit a gameful design should increase engagement and encourage students to make connections between the simulated environment and the real world. This article presents game design guidelines for the development of an Educational Adventure Game and how they have been applied during the development of SIRET Security Game, a game that teaches workers the importance of following computer security policies.

Keywords: *educational adventure game; game design; assessment.*

I. INTRODUCTION

The SIRET project¹ is currently investigating the potential of advanced learning technologies in the working environment.

The most important challenge in designing learning content for the enterprise is finding ways to facilitate *deep learning* instead of *shallow learning*. Shallow learning is mnemonic and repetitive acquisition of knowledges such as word definitions, object properties, sequences of events. Serious Games (i.e. videogame designed for a primary purpose other than pure entertainment) can instead be designed to promote deep learning, that consists in understanding cause/effect mechanisms, being able to explain what learned, developing critical reasoning, managing limited resources, applying old solutions to new problems. These skills are all highly desired in the modern era.

Serious Games that have strong elements of simulation and storytelling provide numerous benefits in an enterprise context: the worker is brought to make connections between the simulated environment and the real world, and analysis and reflection are crucial to achieve the learning goals [2]; simulations provide authentic experiences that involve the student both spatially, providing the illusion of being in the place of the events, and emotionally, through its participation in the narrative.

People often hear concepts like Online Identity Theft, web site sabotages and illegal computer operations (like money transfer from unaware people's bank accounts) and think that the greatest dangers to company security are hackers or organized crime.

A recent research from Cisco Italy reveals that, frequently, higher risks come from inside [1]. We are not talking about boycotting or bad intentions of the employees, but about lack of proper training, unapplied or unverified control processes that cause careless behavior to put company computer security at risk, especially in Italy.

In particular, according to Cisco: 55% of Italian respondents admits to use a unique password for sites and applications and does not change it periodically; company networks are often used for personal, potentially risky activities such as personal banking and online shopping (58%); 70% thinks that their behavior cannot put the safety of the company at risk. In companies that provide for computer security policies, these are often thought as bothersome by employees who, at times, even try to get around them. For these reasons, training workers about possible damages from loss or theft of information and about ways of avoiding them is becoming crucial, but it is also crucial to keep learners engaged and to get the message really across.

This paper will describe the design and development of the Educational Adventure Game **SIRET Security Game**, which tries to assess these concerns. Section II will introduce the concepts of Educational Adventure Game and Storytelling. Section II A will provide related work on the subject, while Section III will describe the existing design guidelines for Educational Adventure Games. In Section IV, the SIRET Security Game will be described. Finally, in Section V we draw the conclusions and describe future works.

II. EDUCATIONAL ADVENTURE GAMES AND STORYTELLING

An Adventure Game is a video game in which the player assumes the role of protagonist in a story driven by exploration and puzzle-solving [3]. The setting is composed of 2D sceneries linked to each other, that the protagonist has to explore to progress in the plot. In order to advance the story, players have to solve a series of puzzles, that typically require to interact with scene objects and with the people they meet.

¹ SIRET – Integrated System of Recruiting and Training - PON01_03024 – The **National Operational Programme** for "Research and Competitiveness" 2007-2013 (NOP for R&C)

This genre is also called “Point and Click” since mouse clicks are the principal means of interaction within the game. These games are characterized by a strong focus on storytelling, comedy and puzzles to solve and by the lack of action sequences or time limit to solve quests. This combination is good for eLearning [4]: educational content can be conveyed in the interweaving narrative and included in puzzles and in the game scenarios, while the player can assimilate the concepts slowly thanks to the absence of time limits. It is also worth noticing that the development cost of these games is limited [11] and this suits well the academic environment, where budgets are not as big as in videogame companies. Adventure Games created for educational purposes are called **Educational Adventure Games**.

The strong focus on plot makes Educational Adventure Games one of the Serious Game genres that exploit the most the Storytelling paradigm, more than roleplaying games (RPGs) and action games [16]. Storytelling means the narration of a story and the process by which it is conveyed to the public[5]. Bruner pointed out the elements characterizing the narrative, defining it as a “*unique sequence of events, mental states, happenings involving human beings as characters or actors: these are its constituents. But these constituents do not, as it were, have a life or meaning of their own. Their meaning is given by their place in the overall configuration of the sequence as a whole - its plot or fabula*” [6]. Narrative is a favorite instrument for the development of cognitive skills and the dissemination of knowledge in the field of business education [7].

A recent classification of Serious Game Genres [8] noticed that games with strong focus on role playing, narrative and simulation are the most useful for the development of Soft Skills like critical thinking and verbal communication. That is the reason why we chose Educational Adventure Games as the genre for developing a Serious Game for eLearning in the enterprise.

A. Related Work

Many researchers approach the design of Serious Games using methodologies taken directly from software project management. For example, in the TIE project [29] the Serious Game *Pappi World* was developed following the SCRUM agile methodology [30] in which a software is developed using small incremental steps (called *Sprints*). An incremental approach was also followed during the development of SIRET Security Game, but because of the peculiar characteristics of Educational Adventure Games, it was also needed to identify and follow design guidelines proper of the genre, which will be described in Section III.

Educational Adventure Games have been used in education since the 90s [9] and are still very much in use [4]. Some examples in the science fields [10] are *Electro Adventure* and *Twisted Physics*, which teach respectively Classical mechanics and Electromagnetism. In these games the player explores a building and finds a problem-solving exercise in each room. In *Twisted Physics* the character gets the key to the next room only after solving the problem: this motivates players and

ensures that learning contents are addressed with a precise order.

The most famous tools for the creation of Adventure Games are Adventure Game Studio (AGS)² and Visionaire Studio³. They both offer a Drag&Drop interface to create games visually, limiting the code that needs to be inserted. However, they are not products designed to produce eLearning content; therefore, their games cannot easily be integrated with Learning Management Systems (LMS) or inserted in a SCORM package. There are three research tools which focused specifically on Educational Adventure Games: StoryTec [4], RealChamber [21] and eAdventure [11]. StoryTec allows creating Narrative Game-based Learning Objects (NGLOBs), in which each scene of the game can be annotated with the skills it provides and with the prerequisites to view it, while players' actions may cause an update of their cognitive profile. StoryTec games, however, can be executed only in the StoryTec player, so there is a problem of interoperability. RealChamber is an example of the potential of Educational Adventure Games for learning in the enterprise. It is a commercial adventure game building tool in which photographs of real locations can be used as the 2D sceneries of the game. In this way it is possible to obtain a certain level of realism while keeping the game computationally efficient. The game engine chosen for our project is **eAdventure**. eAdventure is an open source library developed by the Universidad Complutense de Madrid. It offers most of the main functions of an Adventure Game library but also includes useful functions for learning content creation. eAdventure games, in fact, can be exported using Learning Object standards (SCORM 1.2, LAMS, IMS-CP and so on) and can dialogue with LMS to obtain the learning state of the player and to transmit the learner score.

III. GAME DESIGN GUIDELINES

Adventure Games are a genre with strong conventions, whose user interaction mechanisms have been standardized over time [4]. These games also need a limited set of graphical resources. Designing an Adventure Game therefore essentially involves creating:

- a) the story to narrate;
- b) the world the protagonist explores;
- c) the puzzles the player has to solve.

For Educational Adventure Games we believe there are other two necessary elements:

- d) which learning contents to convey and the most effective way to convey them
- e) strategies to assess the player/student performance.

Jane McGonigal in [13] introduced the concept of “Gameful design” for eLearning content: the goal is to create a didactical material (in our case, a Serious Game) that has the spirit, and not just the mechanics, of a good game. Gameful

² <http://www.adventuregamestudio.co.uk>

³ <http://www.visionaire-studio.net>

Design is based on the “PERMA” approach (**P**ositive emotions; **E**ngagement (or flow); **R**elationships; **M**eaning; **A**ccomplishments). Instead of giving extrinsic motivations for playing (points, levels, achievement badges), Gameful Design provides intrinsic motivations: the very act of playing is a reward for the students. It is a vision much more focused on people and on their positive experience rather than on videogame techniques and mechanics.

While designing story, world and puzzles, we chose to follow guidelines that increase characteristics described in the PERMA approach, because keeping learner motivation high is a key factor in education in the working environment.

Puzzles need to have clear rules and objectives [15]. Also, there should be a good balance of difficulty levels in order to make the game neither too simple nor too hard, to keep the player Engagement’s levels high. It is better to start with simple problems of immediate solution that serve to explain the game mechanics and give the player immediate positive feedback (**A**ccomplishment). Next, the game should gradually raise the difficulty level. Some possible kinds of puzzles are: set of actions to complete in a specific sequence; combining different elements (people and objects); using common object in an unconventional way (e.g. a coconut as a bucket). To increase **P**ositive **E**motions and sense of **A**ccomplishment, the player can be rewarded for completing a task with animated sequences, new areas or new powers to solve more complex puzzles [15].

The **World** should be “interactive” [24]: the player must be able to interact with characters and objects as much as possible, even if it is not needed to continue the story. First, the main setting should be chosen (Realistic or Fantasy? Modern day or Historical period?) For educational purposes, it is important to help the player in relating the game experience to problems of the real world, so the setting should simulate places where the competences taught in the game could be realistically applied. Designing the world means also creating a map of all the locations the main character has to visit, so it is strongly linked to story and puzzle design.

As for the **Story**, it is important to involve the player by creating drama and empathy. This is achieved by providing engaging narrative contents (**M**eaning). As explained by McGonigal [13] if players recognize narrative patterns familiar to them they will be more inclined to pay attention and will assimilate more concepts. One of the most used narrative patterns is The Hero’s journey, common in ancient myths as well as modern day adventures. The concept of the Hero’s Journey was described by mythologist Joseph Campbell in his book *The Hero with a Thousand Faces* [20]: the protagonist leaves the familiar world behind, overcomes a series of trials, receives a reward for his accomplishments and returns home to live a peaceful life. Story design includes characterizing the protagonist and the people he or she will interact with (Non-Playable Characters or NPCs). The fields of cryptography and computer security have long benefitted from the use of *character archetypes*, i.e. characters playing a specific role in the narrative (hero, villain, etc.) and identified using conventional names (Alice, Bob, Oscar and so on) [22].

An important factor in Story Design for Adventure Games is deciding whether allowing the player to **lose**. Losing means:

- a) Receiving unequivocal communication of mission failure (death of the main character, "Game Over" message, etc.)
- b) Allowing the game to enter an *Unwinnable State*, a state in which it is no longer possible to continue (e.g. the player must open a door, but she forgot to take the key from her car and her car has been stolen).

The last kind of player defeat is currently considered a design mistake [28] and should be avoided at all costs. For Educational Adventure Games, it is important to encourage exploration of all the game features, allowing the player to also make mistakes. In order to avoid frustrations, we believe mistakes should not lead to the interruption of the game and the player must be offered opportunities to try again.

As for **Learning contents**, video games are better suited to teach processes, methods of participation and dynamic actions, while simple lists of notions are not appropriated [14]. The learning content should be an integral part of the game, which must simulate real-world applications of the competences we want to teach. Detailed theoretical explanations, however, can be included within the game experience as sequences of texts and images that serve to deepen the concept learned through play. The structure of Adventure Games helps the game designer in placing educational contents[10]. In Adventure Games the player moves within a predetermined set of physical contexts (well defined places like rooms, corridors, etc.), so it is easy to associate learning objectives to each of these contexts, while the road to travel becomes a literal representation of the *learning path*. Another technique described by Amory [17] is dividing the game in different *Acts*, in order to subdivide the learning contents into groups of increasing difficulty.

For **Assessment**, Serious Games have a significant advantage over simple tests: extensive opportunities for tracking user actions, which lead to a more complete student judgment. One of the most used assessment strategies is *In Process Assessment* [18]: player performance is measured during the game itself according to the interactions with game elements. Player’s assessment can be used to adapt in real time the complexity of the game to the player’s skills [19]. This is useful to present a level of difficulty neither too easy nor too hard, so as to keep the player in a state of Flow, the feeling of getting lost in the media element which makes the game intrinsically motivating [13].

Oostendorp et al [19] distinguish five different components of Serious Games that can be affected by adaptivity: the game environment, whose layout can be made easier for players in trouble; game mechanics (e.g. shooting can be made more or less precise according to difficulty levels); NPC attributes, that can change according to the player’s competences; game narrative (order of events); game scenes (whole sections of the game can be included or erased according to the learning objectives). In Educational Adventure Games, that have

standardized game mechanics and fixed layouts, adaptation can be focused on changing narrative, scenes and NPC attributes.

Adaptivity is also useful from an educational point of view, since it allows designing recovery strategies if the system notices that a student fails in learning a concept. As an example, in the Storytelling Complex Learning Objects created in the ALICE project [12] if the player fails assessment tests during the game, the story adapts itself by changing the point of view (Role), the scenario or the formative content, allowing them to see things from another perspective. In the medical Serious Game JDoc, instead, if players fail a mission the game places a new character (a nurse) in the scene, which provides suggestions on how to proceed correctly.

A. Evaluation of Game Effectiveness

In order to evaluate the game effectiveness, we referred to the work by Yusoff et al. [25] which identified the desired characteristics of Serious Games. These features are summarized in Table 1 and constitute a “checklist” that the designer has to follow in order to be sure of covering all the necessary requirements. An important factor in measuring game effectiveness is *transfer of learnt skills*, i.e. measuring effective transfer of knowledge and skills through play. This is usually done [26] by making a group of students experience the game and measuring their cognitive state (using a test focused on the subject taught by the game) before and after the playing activity. Eventual variations in the cognitive state are attributed to the game’s didactic abilities.

TABLE I. SERIOUS GAMES FRAMEWORK ELEMENTS

Serious Games Framework elements	Definition
Clear Instruction	In-game Instructions explain how to use the game
Intended learning outcomes	Learning outcomes are clearly exposed
Instructional content	The instructional content is well structured and subdivided.
Game mechanics	It is easy to interact with the game and system answers are consistent and easy to understand.
Linearity	Students are not confused and are able to follow the plot.
Attention Span	An adequate attention span is required
Interaction	The challenge fits with the target audiences giving the learners the feeling of comprehension and satisfaction.
Learner control	The difficulty level is adequate to the game target, avoiding frustration while being a satisfactory challenge.
Game achievement	The in-game assessment influence the game flow, adjusting it to match the learner’s abilities
Reward	The player feels motivated because of in-game rewards whenever they finish an important task
Intermittent feedback	There is a system of feedbacks and helps that supports the user.
Situated and authentic learning	Students can make correlations with real life applications of the competences they are taught.
Transfer of Learnt Skills	Effective transfer of knowledge and skills through play

IV. SIRET SECURITY GAME

In the Serious Game SIRET Security Game the player takes the role of an employee of a famous Corporation and has to defend corporate data from spies and saboteurs.

The main character has to complete a series of missions in order to be considered worthy of the position of Computer Security Officer. This game is meant to convey the principles of information security: defense against viruses (Malware, Spyware etc.), fraud protection, Cryptography principles. The target audiences are public administration and company workers that want to understand how to implement security policies.

The game is not aimed at Information Technology experts, but to employees of other areas, in order to help them take responsibility and understand that the safety of the company depends on them.

Game mechanics follow the elements of classical Adventure Games: scene elements with which to interact are called *hotspots*; hotspots can be clicked to choose the right action to apply on them (examine, use, talk to, etc.); the main character has an inventory containing objects that can be combined with each other; interactions with NPCs are done following a "Dialog Tree", a graph of all the possible dialogue options.

The following paragraphs will describe how Game Design Guidelines have been applied to the development of SIRET Security Game.

A. Story, World and Puzzles

The game plot contains many elements of classic narrative and of the Call to Adventure pattern [20]. Harry, the main character, is the **Hero** archetype, who receives a mission from his boss, meets the **mentor** (a security officer offering help and advices), solves a series of **quests** and defeats the **villains** (in this case the saboteur Oscar and the spy Eve). Harry’s boss acts as the **Threshold Guardian** [16], a character that tests the learner’s knowledge, by checking which of the quests have been completed and rewarding the player when his work is completed. Some characters in the game have been taken from the archetypes of *Applied Cryptography* [22]: Harry’s friends Alice and Bob, the enemies Eve and Oscar.

The world in which Harry moves is a small office (Figure 1.) composed of 2D pictures created from 3D objects, in order to maintain a certain level of realism while keeping the game computationally efficient. Also for computational efficiency, characters are animated using *sprite sheets*, sets of single graphic images (called *frames*) that are rendered in quick succession to give the illusion of movement.

The player can interact with most of the people and objects in the scene, sometimes also for amusing purposes. In-game puzzles require the player to learn computer security principles in order to offer advice to Alice and Bob, and collect and combine scene objects to act on the information learned.

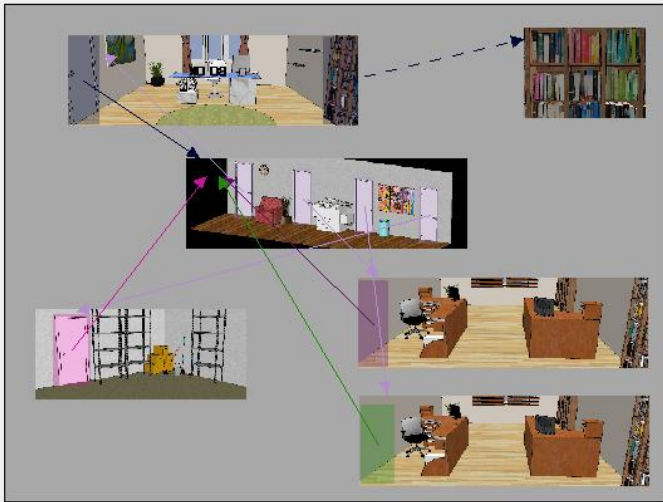


Figure 1. Scene Map of SIRET Security Game.

B. Learning Content Presentation Strategies

In SIRET Security Game learning content can be conveyed using:

- “Book” objects in-game that, if read by the protagonist, convey detailed information.
- Pictures and texts in *Cutscenes*, non-interactive sequences of the game.
- Interactions with NPCs.
- Sets of procedures that the player is asked to follow in order to achieve a specific goal.

We tried to deliver as many concepts as possible through simulations of real situations and interactions with NPCs (Figure 2), in order to maintain a good level of immersiveness.



Figure 2. The protagonist interacts with NPCs.

To allow players to learn the cryptography principles it is better to present the problem as a series of actions to be taken to prevent a spy from intercepting an important message, instead of immediately providing the theoretical notions.

As summarized in Table 1, it is essential that the intended Learning outcomes are clearly exposed in-game: students at any part of the learning experience should keep track of what the current learning goals are and what goals they have obtained so far. For this reason the player at the start of the game receives a *journal*, Harry’s personal notebook divided into two sections:

- Quests:** it contains all the security problems the protagonist has to solve. This section keeps track of completed and uncompleted missions.
- Knowledge:** it summarizes all the concepts the player has acquired. It is a Reference Library that automatically updates each time a learning goal is completed.

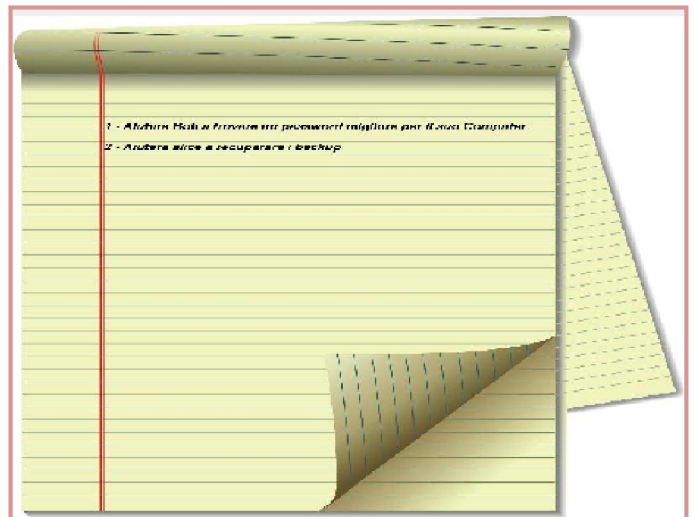


Figure 3. Harry’s Journal – Quests Section.

We decided to divide contents following Amory’s approach [17]: the game is divided into two Acts of increasing difficulty. Inside each act, different challenges are posed to the player in each room of the office building, but he or she is free to roam across all the rooms and solve the missions in the preferred order. That is to help maintain a certain level of engagement: if players are stuck in resolving a specific problem, they can resolve other quests first and avoid being bored or frustrated.

C. Assessment and adaptation Strategies

The assessment strategy we chose to follow is In Process Assessment [18]. From a programmatic point of view, the Adventure Game genre makes designing this strategy easier. Performance tracking is possible by inserting *triggers* (event generators) in the game [23]. The event can be triggered when a certain system variable reaches a specific value (data trigger) or when the player interacts with a scene object (trigger box).

In SIRET Security Game:

- The system exploits user variables to keep track of scores for each of the learning concepts.
- Interactions with people or scene objects trigger events that update user variables or keep track of user actions.

This kind of assessment allows the teacher to understand the reasons behind the player's actions [18]. Assessment also takes advantage of the Assessment Profile feature of eAdventure [11].

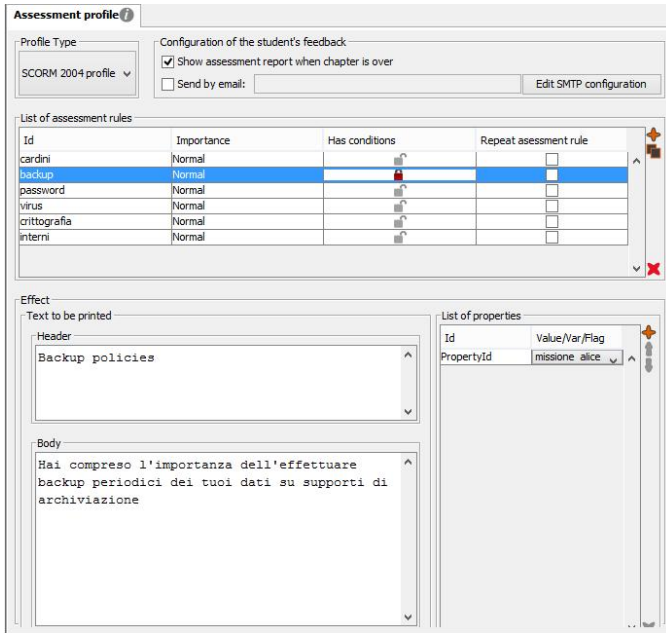


Figure 4. Assessment Profile.

Each profile (Figure 3) is made up of a set of rules (conditions on user variables). When the conditions are met, rules are applied to assess student behavior.

In SIRET Security Game if the system detects that the player is in obvious difficulty (they take too long to solve the game, they perform too many incorrect attempts) the player receives a call from the **mentor**. The mentor is Dave, a senior security officer, which offers help and direct advices to solve the game puzzles. The game adapts, therefore, to the player's actions.

Asking the mentor for tips greatly simplifies the game. For this reason a student who uses the tips should be penalized in the final vote. On the other hand, the purpose of the game is teaching new information, so asking for help cannot always be considered a negative action. For this reason the mentor will give three different kinds of help:

- Veiled: clearer explanation of the problem that the protagonist must solve, to help the player to focus on the goal. No suggestions are given on how to fix the problem.
- Concrete: the player is given a first hint on what to do to solve the problem.

- Obvious: the mentor explains step by step the moves that the player needs to do to solve the problem.

Players will not be penalized for a veiled help. A concrete help will cause a small penalization, while an obvious help will cause a strong penalization.

D. Evaluation of Game Effectiveness

The Serious Game Framework elements of Table 1 have been used as a basis for developing a questionnaire for testing game effectiveness. The questionnaire is composed of a series of statement and the reviewer has to answer how much it agrees (from a scale of 1 to 5) with each statement. A first, internal review of the game has been done using the questionnaire: the puzzles offer an adequate challenge level, the player is rewarded for completing tasks and it is easy to imagine a real life application of the information the player acquires. The review feedback prompted the addition of more in-game instructions to explain game mechanics.

V. CONCLUSIONS AND FUTURE WORKS

SIRET Security Game has been implemented using the eAdventure platform. The game is divided into two acts, for a total playing time of nearly half an hour. It can be exported as a SCORM package, allowing it to be integrated into any LMS and to update the student's learning state according to the game results. After the first internal review, a more detailed evaluation of the game will be done in the future by subject experts: computer security officers of the public administration will experience the game and use the game effectiveness questionnaire to check whether all the Serious Game Framework requirements have been met. Future works also include measuring the effective transfer of knowledge and skills through play. In order to measure the transfer, students of Computer Science could be involved: they will experience the game and a pre and post-game questionnaire will measure any variation in their cognitive state.

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