A Format of Serious Games for Higher Technology Education Topics
A Case Study in a Digital Electronic System Course

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Abstract—Learning is frequently seen as an awkward activity. This problem becomes worse in technology and science topics, since they are often perceived as cold and difficult subjects to learn. On the other hand, playing is considered funny and engaging, which gives motives to people to do it voluntarily. Moreover, the current increasing use of social networks can represent an opportunity for knowledge and skill development, in particular by enabling students’ collaboration and competition. This has led to the idea of exploiting and investigating the appeal and educational potential of serious games in a higher education context, in particular for technology and science topics. This paper proposes mini-games based serious game format targeting in particular higher education technology and science topics, and exploiting advanced web-based and social networking technologies, able to support easy diffusion and user competition/collaboration. We have set-up a client-server based architecture for the implementation of a prototype for a Digital Electronic System BSc course. Preliminary test results show that users have a positive attitude towards the games, as they give an average rating of 4/5 in terms of desirability. Furthermore, it takes 3 times of replays, on average, for users to achieve good scores. Usability issues are also presented and discussed.

Keywords—serious games; social networks; digital electronics; advanced learning technologies, HTML 5

I. INTRODUCTION

Learning is frequently seen as an awkward activity that is necessary to acquire the needed knowledge and skills. On the other hand, playing is considered as funny and engaging activity, which gives strong motives to people to do it voluntarily. Therefore, Prensky [1] argued that conventional learning is outdated and the modern way of learning is through a real gameplay so that student will learn while having fun. Since computer games are abundant in terms of types, objectives, and effects, Zyda [2] used serious games term to define games which provide a mental contest and are played with a computer in accordance with specific rules for government or corporate training, education, health, public policy, and strategic communication.

Technology and science topics are often perceived as cold and difficult subjects to learn. This can be shown by the fact presented in [3], which mentioned that currently students are less interested in science. In this context, serious games could provide a significant benefit, in particular when dealing with technology and science topics in higher education. In addition, the ever increasing use of social networks, such as Facebook, can represent an opportunity in knowledge and skills development [4], in particular by enabling students’ collaboration and competition.

Therefore, this paper proposes a serious games format intended in particular, but not exclusively, for technology and science topics in higher education, exploiting state of the art web-based and social network technologies. These technologies promote ease dissemination, open platform, and competition/collaboration. Client-server architecture was designed exploiting HTML 5 and Javascript in a prototype for a Digital Electronic System BSc course. Five types of mini-games with three different interaction modalities were developed to provide an amusing learning environment via common web browsers.

II. RELATED SERIOUS GAME STUDIES

Serious games are exploited in academic curricula in the area of management and economics [5], such as Industry Giant II, Zapatism, and Virtual U. Also, a self-developed real time strategy (RTS) game and some game-themed assignments (GTA) were proposed to accompany students in learning computer programming in [3] and [6], respectively. Hence, we can identify two typical approaches in having games incorporated into a course: 1) use commercial off-the-shelf games, or 2) use ad-hoc designed games [7]. The first approach requires the purchase of commercial games and performing purpose shifting of the games, since they were not built for educational purposes. The second approach is more direct. Yet, it is a non trivial task which requires a good game design, both from the educational and entertainment context, which is a complex and laborious process [8, 9].

In order to make the game development easier, some game engines are both commercially and freely available to be exploited [9]. Some examples of game engines are Torque Game Engine (TGE), Quark [9], Unity 3D, and Unreal Engine [10]. The drawback of utilizing these game engines is the need of a plug-in as discussed in [10]. Therefore, exploitation of web technologies has been explored, for instance in using WebGL for developing Oxyblood, a 3D RTS game for learning human respiratory system [10]. Another outstanding work in serious game development for learning is e-Adventure[11], a game development tool to create a point-&-click adventure game by using some pre-created game props e.g. objects, characters, etc. The advantage of e-Adventure is that it is connected to LMS.
(learning management system). Hence, instructor can monitor the progress of the students.

A recent fast-growing trend in gaming is tied with the explosion of social networking platform that not only do provide a site for people aggregation, but also intrinsically spur collaboration/competition. For instance, Facebook [12] provides web gaming applications pool accessible for all Facebook users. These casual Facebook games are very popular regardless of the user sex [13]. Facebook applications, including games, are developed using web-based technologies, such as HTML (Hyper Text Markup Language), PHP (PHP Hypertext Pre-processor), Javascript, and Flash. In order to enable web/game developers to connect with Facebook system, APIs are provided in two major languages: PHP and Javascript Standard Development Kits (SDK) [14].

A recent advancement in HTML technology (i.e. HTML5) also spurs richer web experiences. The work on HTML5 by the World Wide Web Consortium (W3C) and the Web Hypertext Application Technology Working Group (WHATWG) [15] is still in progress, yet most modern browsers have some HTML5 support. A major advantage of HTML5 is that it reduces the need for scripting and it offers cross platforms technology.

We are strongly convinced that such an increasing capability of web technologies in delivering rich interactions should be fully exploited not just for playing casual games, but also for more serious objectives, such as learning and education.

III. GAME SYSTEM

This section explains the proposed game system, including the game format, mini-games templates, collected data, and the social networks platform.

A. Game Format

A game format was designed, instead than a single game, since a format can be applied to several different topics, in various educational domains. The proposed format is a lightweight game with the objective of teaching selected topics in several, generally consequential, steps, according to a pre-defined didactic plan. The game consists of a sequence of mini-games (Figure 1), which should be designed according to the course’s progress stated in the didactic plan. Upon accomplishing a sequence of mini-games related to a topic in a course, another sequence of mini-games related to the subsequent topic of the course will be unlocked. Each topic consists of three to six mini-games, where each mini-game has between ten to twenty cases (Figure 1). A case represents a unit of problem presented to players. For instance, converting binary number 10 into its corresponding decimal number can be considered a case.

Upon accomplishing a sequence of cases (i.e. a mini-game), a score will be assigned to players according to their performance, which enables the game to progress when the players overcome a given score threshold. The current prototype uses a simple scoring method which evaluates the performance time, and the number of correct and wrong actions. The final score range is from 1 to 30, as in the Italian university official mark system.

B. Supporting the Flow

In order to deliver to the player a funny and engaging experience, the flow theory [16] should be kept, by providing at least one of Malone’s intrinsic qualitative factors for engaging gameplay [17] i.e. challenge, curiosity, and fantasy. Therefore, the format has been designed to support an easy implementation of incremental challenges within the time, through some possible simple means: 1) increasing the complexity of the problem (e.g., number of available answers) 2) hiding (or delaying the provision of) hints to the players, and 3) giving time restrictions. These incremental challenges are regulated by a personalized game engine based on players’ performance and teacher requirements. The current prototype for the Digital Electronics course supports only the first type of incremental challenges. In order to deliver this feature, the system divides the cases in each mini-game into three levels. For instance, given twenty cases, the first 5 cases have two possible answers, the next 7 cases have three available answers, and the last 8 cases have four (Figure 1).

C. Mini-Game Templates

The format can specify different types of mini-games – we call such typologies as templates – that offer different gaming experiences and support different interaction modalities. The present prototype relies on the following three templates, out of which five actual mini-game samples have been implemented:

- Click-&-play (Figure 2a, 2b, 2d) requires players to click on an object (the correct or the wrong one, according to the problem)


- Draw lines (Figure 2c) demands players to draw a line between two objects that are considered as matching between each other.
- Drag-&-drop (Figure 2e) asks players to take an object and put it on its right position in a target space.

On the other hand, five mini-game samples can be listed as the following.

- “Numerical Conversion” (Figure 2a) is a mini-game about choosing the correct answer given binary/decimal number to its decimal/binary counterpart
- “Find the Correct Logic Gate” (Figure 2b) game asks the player to click on the correct logic gate.
- “Make the Right Connection” (Figure 2c) connects the table of input/output with its corresponding logic gate.
- “Choose the Right Output” (Figure 2d) requires the player to choose the right output given the presented digital circuit, by clicking on the zero or one outcome digit.
- “Use the Right Logic Gate” (Figure 2e) demands the players to complete the given digital circuit with its input/output by dragging and dropping the available logic gates.

The target user of these mini-games are the second year BSc students in electronics engineering, with the objective of introducing and practicing on binary numbers, logic gates, and digital circuits. All the logic gate notations and digital circuits are designed using DEEDS [18]. The website of these mini-games samples can be found in [19].

D. System Architecture

The system architecture relies on a simple client-server paradigm. The server contains a PHP interpreter, the games, that are playable with any type of devices equipped with a browser, and the database server that accumulates players’ data from the client side using Javascript HTTP Requests. Figure 3 shows the structure of the web-scripts that use HTML5, PHP, and Javascript.

E. User Profiling and Social Networks

The mini-games are connected to social networks. Therefore, they exploit players’ data acquired from the social networks to be stored in a database using social networks’ plug-ins (Figure 3). These gaming data are collected with two objectives i.e. 1) users analysis, 2) data exploitation in a more advanced feature (e.g. personalized learning agents) that is still work in progress. The collected data consist of the students’ interests towards the games and their playing activities such as playing sessions and scores.

In this work, we have used Facebook as the data source for profiling and sharing platform [12]. This is because Facebook has a huge amount of users and Facebook games are popular, also regardless of the user sex [13]. Despite the simplicity of Facebook games as web applications, statistically the number of users is enormous - 53% of the total 500 millions of active Facebook users in 2010 which then grew up to 800 millions in 2011 [13]. Moreover, 19% of the gamers are enthusiastic to play and 69% of the gamers are women [13]. Therefore, differently than what emerged in prior investigation [20], there is no gender issue in playing this type of games.

IV. USER TESTS

A. Methodology

In order to investigate the users’ perception on the game, a user test was conducted. The objective of the test is to investigate the following points: 1) players’ attitude to the game, 2) players’ performance, and 3) players’ preference with regard to the mini-games templates.

Since the system is designed as an open system accessible to the users of the targeted social networks, the players’ profiles are directly stored in the game players’ database when they log into the game system. Hence, all activities, such as playing sessions, giving comments, were recorded during the players’ interaction with the system. Moreover, a pre-survey was designed to capture the players’ background and demography, whereas a post-survey was presented to assess the players’ opinion with respect to the game (Table I).
TABLE I. PRE AND POST QUESTIONNAIRES

<table>
<thead>
<tr>
<th>No.</th>
<th>Questions</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>What is your major of study?</td>
<td>Pre</td>
</tr>
<tr>
<td>2.</td>
<td>Which city do you live in?</td>
<td>Pre</td>
</tr>
<tr>
<td>3.</td>
<td>What is your favorite game genre?</td>
<td>Pre</td>
</tr>
<tr>
<td>4.</td>
<td>What games do you usually play?</td>
<td>Pre</td>
</tr>
<tr>
<td>5.</td>
<td>What do you think about your knowledge in digital electronics in a 1-5 scale?</td>
<td>Pre</td>
</tr>
<tr>
<td>6.</td>
<td>What do you think of using games for learning a 1-5 scale?</td>
<td>Pre</td>
</tr>
<tr>
<td>7.</td>
<td>Which mini game did you like the most?</td>
<td>Post</td>
</tr>
<tr>
<td>8.</td>
<td>What do you think of the agreeability of the mini-games in in a 1-5 scale?</td>
<td>Post</td>
</tr>
<tr>
<td>9.</td>
<td>What have you learned from the mini-games?</td>
<td>Post</td>
</tr>
<tr>
<td>10.</td>
<td>What would you suggest to do for improving the mini-games and the website?</td>
<td>Post</td>
</tr>
</tbody>
</table>

Thus, the sequence of test data collection steps can be summarized as it follows.
1. The gaming-site is published into social networks accounts.
2. Interested players log into the gaming-site using their social networks account.
3. The system retrieves the players’ profiles based on their social networks accounts and stores them into the database.
4. The pre-survey form is presented to the players.
5. The players interact with the system e.g. play the mini-games, comment on the game, and publish their results to the social networks. Players are allowed to replay the game as many times as they desired.
6. The post-survey form is presented to the players.
7. The players log out from the system. Yet, they are allowed to reconnect to the system as many times as they desire.

B. RESULTS FOR THE CASE STUDY OF THE DIGITAL ELECTRONICS SYSTEM COURSE

In a preliminary, one-week data collection, we statistically analyze the data coming from 25 completely voluntary players, who were invited through a simple post on the author’s Facebook home page. The addressed topics are related to Digital System Electronics course, which is done at the second year of the Bachelor in Electronics Engineering at the University of Genoa (Figure 2).

Based on the players’ profiles, it shows that the players come from several countries where most players come from Indonesia and Italy (68% and 20%, respectively), with total average age of 25.8 years old (male: 88%, female: 12%). The statistical playing data for all mini-games comprises of average scores, average playing time, and average playing sessions of the players are presented in Table II.

TABLE II. STATISTICAL PLAYING DATA

<table>
<thead>
<tr>
<th>Mini Game</th>
<th>Average Score (Max: 30)</th>
<th>Average Playing Time (seconds)</th>
<th>Average Playing Sessions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Numerical Conversion</td>
<td>21.59</td>
<td>48.90</td>
<td>2.10</td>
</tr>
<tr>
<td>Find the Right Logic Gate</td>
<td>16.06</td>
<td>33.54</td>
<td>1.50</td>
</tr>
<tr>
<td>Choose the Right Output</td>
<td>15.50</td>
<td>29.28</td>
<td>1.40</td>
</tr>
<tr>
<td>Make the Right Connection</td>
<td>1.00</td>
<td>43.84</td>
<td>2.50</td>
</tr>
<tr>
<td>Use the Right Logic Gate</td>
<td>27.00</td>
<td>42.29</td>
<td>2.00</td>
</tr>
</tbody>
</table>

According to the pre-survey, most of the test users had a background in information technologies, with an average self-assessment on knowledge level on digital logic gates of 3 in a 1-5 scale (1 = no knowledge, 5 = excellent knowledge). In term of gaming exposure, 60% of the test users are playing game occasionally. Figure 4 and Figure 5 show the average playing time and the average score progresses of players within playing sessions, respectively.

Figure 4. Average playing time progress within playing sessions

Figure 5. Average score progress within playing sessions

Given the mini-games in Figure 2, the test users preferred “Numerical Conversion”, “Choose the Right Output”, and “Use the Right Logic Gate” as the favorite mini-games to be played. This looks to be due to the “click-&-play” and “drag-&-drop” templates’ interaction types, that seem more suited for games with a quick pace nature than the “draw lines”. However, we need perform a more focused research on this in the future with more mini-game samples and test users.
In a 1-5 scale (1 = least desirable, 5 = most desirable), users perceive these mini-games to be very desirable with an average rating 4.00 out of 5. Moreover, one of the players reported that he wished there were these mini-games when he took digital electronics system course. Minor comment suggested that the display resolution needs to be adaptable for different display resolutions. Also, classification table of best players is highly preferred, instead of having only the best score record in each mini-game.

C. Analysis

Based on the above results, it can be drawn that players need on average 3 playing sessions to understand the mini-games and achieve a proper score, i.e. above 20, which is sufficient score for passing an exam in Italian university (i.e. 18 out of 30), as shown in Table II and Figure 5. This is reflected on the decreasing average playing time as the players were getting familiar to the mini-games, as shown in Figure 4. Nonetheless, the “Make the Right Connection” mini-game (Figure 2c) seems to be quite hard for the players. As it is shown in Figure 2c, a case in this mini-game presents data that mini-game includes a table - a digital circuit truth table with two binary inputs (A and B) and one binary output (O) on the left side of the screen, which has to be connected (by drawing line) to one of the possible answers (i.e., logic gates implementing the truth table) on the right side of the display. As the players advance, the complexity increases by adding the number of table entries and of possible answers. Apparently, data presentation in form of tables requires an extra amount of time to be evaluated by the players. Hence, either the players make a large number of mistakes due to the time pressure or they do not have enough time to solve it. This requires further investigation on how to present complex problem data (e.g., in form of tables) to the players.

V. CONCLUSION AND FUTURE WORK

This paper presented a format of serious games for higher education with a case study in digital electronics system. Unlike other available games, this game supports various platforms, easy dissemination, and competition via social networks. Five mini-games were developed using three templates. The results reveal that test users (mainly young people who are familiar with the social networks, casual gaming, and the addressed topics) have a positive attitude towards the games by assigning average rating of 4/5 in term of desirability. In terms of interactivity, players prefer “click-&-play” and “drag-&-drop” over “draw lines”, probably because of the quick pace nature of the mini games.

Future work will improve the current system by adding features such as personalized learning agents. Mini games will be extended to other topics (e.g., we are currently working on computer programming). More extensive user testing sessions will be performed in order to better investigate the learning effects of the games.

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