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Green@CU: An environmental game for Residential Accommodation

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***Abstract*—*The importance of using games for supporting behavioural and attitudinal change has been explored in the literature, most recently the games for change movement has promulgated the use of games for supporting altruistic changes that have a positive impact upon the environment. This paper presents a Serious Game designed for University students and its main aim is to educate them about environmental issues. In particular, the focus lies in the importance of saving energy. A user study with 42 participants assessed the feeling of presence of the whole virtual learning experience.*

Keywords—serious games, environmental games, game based learning, immersion

I. INTRODUCTION

Most environmental education scientists suggest that the best strategy to overcome the human exploitation of the world resources is to develop an environmentally literate society [1, 2]. However to achieve this requires engagement with user communities and stakeholders, and importantly requires behavioural and attitudinal change in consumers. In previous studies (e.g. Knight et al., 2010; Rebolledo-Mendez et al., 2009) [3, 4], games and in particular serious games – that is games used for non-entertainment purposes were found to be successful at changing behaviour and attitudes, building upon this research we posited that games could be used for a wider range of behavioural and attitudinal changes including in environmental issues.

Nowadays, sustainability-related issues have made a similar move to the forefront of our social consciousness. The increasing demand for behavioural changes around domestic energy efficiency, natural resource management and the push for ecologically friendly transportation all reflect the importance we now place on environmental issues [5]. The potential of games and simulations in educational contexts is increasingly being recognised. The use of such games takes advantage of the rapid advancement in technology and could potentially deliver a method of learning and training that is more engaging and exciting to all learners. People are turning increasingly towards technology for information, and social networking as well as entertainment. In addition to their use in more formal training or education settings, games have also been used in more informal settings, with the aim of achieving a change in attitude or behaviour. Based on the survey carried out by the International Software Federation of Europe [6], 74% of those aged 16-19 considered themselves as gamers (n=3000), 60% of those 20-24, 56% 25-29 and 38% 30-44. In conjunction with these statistics, using existing technologies such as games on various platforms – home entertainment systems, personal computers, more ubiquitous platforms such as mobile and the net, promotes accessibility and exploits familiarity. This is a novel way to contribute towards resource efficiency by moving on with the existing trend in our relationships with technology.

II. BACKGROUND

By definition a serious game (SG) is designed by employing procedures which do not have as their primary concern how the final arrangement of things within the game environment and/or the game scenario will increase the entertainment of the player. But the fun and entertainment element is not overall suppressed, as a SG's core objective is to combine entertainment with learning with the hope that this combination will make the specific process the Serious Game is build to emulate more creative and appealing, and as a consequence more effective.

For the benefit of later analysis and the reader we provide here a summary of major contributions of the SG approach in designing applications with the aim of combining entertainment with learning. Serious gaming allows to [1]:

- Facilitate knowledge transfer and improve learning effectiveness by turning the learning process into an enjoyable experience.
- Find economic, time saving, effective, qualitative and appealing tools and components to implement educative, training and learning methods.
- Enhance employment potentials by training staff so as to acquire skills as well as improve their technical

capabilities and consequently the competitiveness of the businesses.

- Catch up with technological development and acquire experience in new applied domains. Give a boost to technological capabilities.
- Enhance local development, strengthen regional cohesion.
- Report on successful innovation on pervasive technologies on concrete benefits and results and develop new products and games.

Apart from the above stated benefits SGs have been proved to be successful for maximising end-user's motivation, comprehension, empowerment and retainment of information. Despite of what a Serious Game as practice can offer though, the fact remains that motivation is a key issue in behavioural change and the necessary, for every deferent activity, level of motivation cannot be achieved without some degree of central motivation irresponsible of whether this is internally stimulated or stimulated by the Serious Game environment. While SGs are participatory and involve a degree of role-playing, they also present challenges and rewards, allowing that way the players to experience failure mainly as fun rather than a dreadful event which needs to be avoided; what's more, through failure, entertainment and reward their encourage creativity.

Possibly the most characteristic such case is represented by MiniMonosTM, a virtual world for children six and above. The game's scenario is a relatively simple one, allowing players to create a monkey avatar, socialise with other monkeys, and play mini games. The game incorporates themes of environmentalism and is designed in such a way as to encourage mainly "green" activities both online and offline. Recently, MiniMonosTM success reached the level of been named as one of the "games that can change the world" [2]. As part of the main game activities, players are required to go through a wide variety of mini games, each having something to do with helping the environment, such as recycling trash, cleaning up a lagoon, or growing fresh strawberries.

In what is still currently shaping itself to become the world of Serious Games, there are at least two objects of assessment that often overlap: a) assessment of skills and knowledge acquired through the use of Serious Games, and b) assessment of Serious Games and of some of its characteristics. Attempting to expand a bit more on these two objects of assessment we can say that:

- Assessment of skills and knowledge acquired through the use of Serious Games: This assessment object attempts to answer the question of the effectiveness of the Serious Game for the purpose for which it was created.
- Assessment of Serious Games and of some of its characteristics: This assessment object means to answer questions like: Is it easy to use and easy to learn how to use? Is it compelling/engaging for the target audience? Is the fun effective? In actual terms, asking these questions and examining these issues means going to explore the main aspects which constitute a Serious Game.

In parallel with the educational aspect Serious Games necessarily sustain the fun element within their design and some of the ways to ensure this element is present are the ergonomics, rhythm, and the difficulty levels. The aim of the designed, throughout the designing stages, is to maintain a good balance between all these aspects in order to induce "flow," a state which is characteristic of the player losing track of time and getting absorbed by the gameplay experience. Engagement, involvement and satisfaction, all maintained to a high level during "flow" lead to a better and easier learning experience.

Assessment instruments that can be used to obtain answers to these questions are partly similar to those used to assess the effectiveness of serious games [3].

Based on the ratings for the different criteria, an overall score and cost-benefit-index are determined in addition to a short summary and particular strengths and weaknesses of the Serious Game. The purpose of the cost-benefit-index is to indicate that cheap games are not necessarily bad and expensive titles do not automatically provide a good quality [4].

II. THE CUSTOMER INTERFACE

SGs have demonstrated potential to induce attitudinal and subsequently behavioral change amongst a wide range of audiences. In the specific area of the environment and energy conservation, many similar principles apply to those behind public health issues. In both cases, the need exists to stimulate a change in the immediate behaviors of audiences, which may struggle to perceive the long-term benefits. Games may provide a useful platform for creating the levels of sustained engagement and motivation, and this hypothesis has been explored through a range of projects aimed an energy awareness for households: for example, the Energy Life project [7] focused on the use of pervasive devices for monitoring consumption, forming a game around usage. Other environmental concerns have been tackled through social media; for example the i-Seed serious game [8] sought to create a game within the Facebook platform to promote positive attitudes towards the environment. Other approaches have equally embraced mobile platforms and other emerging technologies to reach audiences with an environmental message [9].

However, simply facilitating an environment for social interaction around an environmental theme does not guarantee social change or learning will occur [10]; indeed, the evaluations of previous game-based approaches in the area have failed to provide a conclusive, empirically-proven solution for long-term behavioral change, despite the proven efficacy of various game-based approaches in other areas such as healthcare.

Recent estimates on home energy showed that 22% of home energy consumption could be saved if people were more environmental aware and were more discerning with their energy behaviours, for example using a light energy efficient bulds, turning off their lights, replacing their boiler with energy efficient[11] . Recent research suggests that a 10% reduction in energy use could decrease fossil fuel consumption by an amount approximately equal to a 25-fold increase in wind & solar power or a 100% increase in nuclear power [12].

The Green@CU is a game designed to raise the awareness of energy consumption on university accommodation occupants (see Figure 1). The overarching aim of the game is to induce attitudinal and behavioral changes to the occupants. The emphasis of the game is to provide players with an ability to apply and rehearse their knowledge on energy reductions techniques within an immersive game environment. The

Green@CU allows the player to control their water, gas and electricity in their virtual house. The Green@CU Game was implemented via using unity3D, which is a game development tool that allows the developer to create games for different platforms, such as the iPhone, Nintendo Wii, Mac and PC.

Figure 1: Green@CU Game Screenshots

The Green@CU interface was based on the Bergeron principles for effective interfaces[13]. Following the guidelines of Bergeron, the Green@CU interface was created with the user in mind.

Green@CU Interface consists of two panels, one at the top and one at the button of the screen (see Figure 2). The button panel provides information about the active quests of the game, hints and tips about saving energy conservation and calling the in game menu. The top panel contains several parameters of interest. The rightmost ones indicate, in this order, the temperature in the current room and the outside temperature. The sliding bar indicates the time of day and the percentage of time remaining until the end of the day. To the right, the 3 numerical values indicate the resource usage up to the current moment for electricity, water and gas.

Figure 2: Green@CU HUD

The logical interface governs the interface behavior, i.e. how physical devices respond to different inputs from the user. The logical interface is crucial for defining the user expectations and is used in order to minimize the user frustration and thus it ensures that the system controls behave as expected. The Green@CU allows the player to configure their level via simply modifying and XML configuration file. The XML configuration file includes the following:

- Items- The player could add/remove items from the scene via simply removing/adding items from the XML file. Each entry the items should specify the item class (i.e. Laptop, Fridge, TV, etc) and the instance name of the 3D object alongside with the item location.
- Exterior temperature. The player could modify the minimum and maximum temperatures which correspond to the different seasons. The temperature outside is computed using quadratic interpolation based on the current time of day.

```
<ExteriorTemperatures>
    <!-- The daily temperature limits for each season -->
    <Season Name = "Winter" Minimum = "-10" Maximum = "10" />
    <Season Name = "Spring" Minimum =   "0" Maximum = "20" />
    <Season Name = "Summer" Minimum =  "10" Maximum = "35" />
    <Season Name = "Autumn" Minimum =   "4" Maximum = "18" />
</ExteriorTemperatures>
```

Figure 3: Temperature Configuration

- Room thermal data specifies the heat coefficients for inner walls – between adjacent rooms, outer walls – between rooms and the exterior, windows and radiators.

```
<RoomThermalData>
    <!-- The heat transfer coefficients for various parts of the house -->
    <OuterWallHeatTransferCoef      Value = "0.001" />
    <InnerWallHeatTransferCoef      Value = "0.002" />
    <OpenWindowHeatTransferCoef     Value = "0.02"  />
    <ClosedWindowHeatTransferCoef   Value = "0.001" />
    <RadiatorHeatTransferCoef       Value = "0.008" />
```

Figure 4: Heat Transfer Coefficents

Green@CU handles the heat exchange process between the rooms, simulating the real-life heat exchange that constantly occurs within a house. The equations are based on a formula which assumes that there are 2 adjacent environments whose temperatures at moment t are $T_1(t)$ and $T_2(t)$. If the heat exchange coefficient is q (as given in the XML above) and the common surface area is S, then after the elapse of a small amount of time, called dt, the new temperatures will be computed using a simplification of the Newton heat exchange formula:

$$DeltaTemp = q * S * (T_1(t) - T_2(t))$$
$$T_1(t + dt) = T_1(t) - DeltaTemp$$
$$T_2(t + dt) = T_2(t) + DeltaTemp$$

- Resource costs (indicating the minimum and maximum speed of resource consumption for every class of resource). The minimum value is for items that are powered off, while the maximum one is for items that are powered on.
- Tasks – Typical quests for the game

The emotional interface adds the element of uncertainty in the simulation by rewarding the user according to his or her decision. The Green@CU uses an online leaderboard and quest based achievement system. The approach taken mirrors the achievements and online leaderboard systems integrated into various gaming platforms such as Xbox Live, Steam, or PlayStation Network. Previous research has shown that the usage of such system could prolong the play and increasing the replayability of the game via increasing the motivation and engagement of the players [12]. Other applications of achievements to increase use and uptake in more serious application areas have demonstrated positive impacts on user experience [14], and the technique is a common trait of many gamification approaches [15].

III. Methodology and Results

In the following sub-section the methodology and the results of a formal usability evaluation study are presented for the Green@CU.

A. Apparatus and Visual Content

Two laptops with an Intel Core i7 Processor and 4 GB of memory were used for the experiments. The laptops were

equipped with an AMD Radeon HD 6750M 1024 MB graphics card and a 17in monitor screen.

B. Participants

During this study, we collected data from 42 participants (25 male and 17 female participants) that were actively involved with the game. 3 Participants were dropped from the sample because they didn't complete the whole questionnaire. The participants were of all ages, but the majority was formed by players aged between 18 and 25 years-old (75%) followed by players aged between 26 and 31 years-old (20%). 75% of the participants were using their personal computers more than 4 hours and they considered themselves as gamers. 42% of the participants were staying on university accommodation.

C. Procedure

It was ensured that each participant was comfortable and at ease prior to the start of the experiment. The participants were told that their data would be used anonymously; along with the data of several others and that the experiment is divided into two main stages. Throughout the first stage of the experiment the participants' will be asked to familiarize with the Green@CU interface (i.e. completing the tutorial of the game) and then play the actual game and the first level. During the second stage the author assessed participants' perceived level of presence and user satisfaction. The presence questionnaire is a modified version of Witmer Questionnaire [16] and is based on seven-point Likert scale. The presence questionnaire was composed by 22 questions. The instructions and the statements that were used during the preliminary briefing were standardized for all the participants. Initially, the participant's age, gender, and background were recorded.

After the completion of the first part of the experiment a modified presence questionnaire was given to the participants for completion [16, 17]. The PQ questionnaire was transcribed into SPPS v17.0 for analysis.

D. Analysis

Presence forms an important subjective measure of a user's virtual experience [16]. In order to create a valid measurement of the presence we have to analyse the factors that contribute in the generation of sense of presence. Many researchers have tried to identify the factors that affect presence by trying to vary some aspects of VE or the interface and measure the effect of presence by asking a small number of questions designed to measure presence directly [18-20]. A different approach was followed by Witmer [21] who tried to divide the factors that affect presence into meaningful groups of similar items such as control, sensory, distraction and realism factors [16, 21].

The above factors which affect presence can be classified into groups of similar items [16, 21]. Hence the data taken from the PQ can be classified into four clusters or subscales:

- **The Involvement / Control Subscale** items which are related to the perceived ability to control the VE, the responsiveness of the VE to the user actions, and the overall involvement in the VE.
- **The Sensory Fidelity** items measure the extents to which the VE was consistent with reality and how natural the overall experience seemed to the user
- **The Interface Quality** items which measures how the interaction devices and displays distracted the participant from achieving his/hers tasks.
- **The Adaptation / Immersion** items measures task performance and how quickly the participants adapted to the VE/game.

According to Witmer [16] the degree of presence experienced in a virtual environment is affected by the "fidelity of its sensory inputs (Sensory Factors) , the nature of the required interactions and tasks (Realism Factors), the focus of the user's attention (Distraction Factors) and the ease of use (Control Factors) where the user adapts to the demands of the environment" [16]. Presence also depends on the familiarity of the user with the environment.

Table 1 shows descriptive statistics of the involvement questions of the PQ. From the table below we can deduce there was a positive reaction to the perceived ability to control the game and, the responsiveness of the game to the user actions, and the overall involvement in the game from the participants (Mean: 4.28, std 1.68).

Table 1: Descriptive Statistics of the involvement factor

Gender	Mean	N	Std. Deviation
Male	4.2083	24	1.44400
Female	4.4000	15	2.06328
Total	4.2821	39	1.68505

Table 2 shows the descriptive statistics of the sensory fidelity in the game was consistent with reality and that the overall experience seemed natural to the user (Mean 4.76, std 1.92).

Table 2: Descriptive Statistics of the Sensory Fidelity

Gender	Mean	N	Std. Deviation
male	5.0000	24	2.04302
female	4.4000	15	1.72378
Total	4.7692	39	1.92575

The next part of the presence questionnaire aimed in assessing the interface quality. Table 3 shows the descriptive statistics of the PQ. The questions of the questionnaire were focused on possible delays between the participant actions and expected outcome, whether the control devices interface with the performance of the activities, and as we can see from the table below that the control devices and displays didn't distracted the participant from achieving their tasks (Mean 3.0 and std 1.01).

Table 3: Descriptive Statistics of PQ

Group	Mean	N	Std. Deviation
male	3.0694	24	1.10326
female	2.8889	15	.88790
Total	3.0000	39	1.01739

The final part of the PQ questionnaire was focused on immersion. The table below shows the descriptive statistics of the adaption/immersion section of the questionnaire. From the table below we can deduce that the majority of the participants quickly of the participants (67%) adapted to the experience (mean 4.37, std 1.244).

Table 4: Descriptive Statistics of Immersion

Gender	Mean	N	Std. Deviation
male	4.5750	24	1.20479
Female	4.0533	15	1.28167
Total	4.3744	39	1.24493

IV. CONCLUSIONS

SGs offer a range of benefits such as making users feel responsible for success according to their actions, match high-quality content and high engagement, turn mistakes into learning elements avoiding the message that an error is something that cannot be recovered, allow problem based learning, situated learning and make users feel more comfortable with the exercise etc. They also offer the ability to participants to assume an active role in a situated and experiential learning process that potentially can alter their behavior.

It is also widely accepted that educational games can increase the attractiveness of learning, giving a powerful tool in the effort against de-motivation and dropouts, two issues largely affecting academic performance and behavior. Moreover, SGs can help to connect specific contents and skills with a friendly environment, where the student or the user is able to play, probe, make mistakes, and learn. More precisely, games employ strategies, such as differentiated roles, visualization of performance and just-in-time feedback, to guide learning and change behaviors.

Additionally it's worth noting that the sample, while quite young, is in fact very much representative for the target audience of student accommodation, but that more research would be necessary to investigate transferability to other types of accommodation & target groups.

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