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Preface

The recent re-emergence of serious games as a branch of video games has introduced the concept of games designed for a serious purpose other than pure entertainment. To date the major applications of serious games include education and training, engineering, medicine and healthcare, military applications, city planning, production, crisis response, just to name a few. If utilized alongside, or combined with, conventional approaches serious games could provide a more powerful means of knowledge transfer in almost every application domain.

This book, *Serious Games Development and Applications*, offers an insightful introduction to the recent development and applications of games technologies in various domains, thus reflecting the multidisciplinarity required in the development of serious games. It includes cutting-edge academic research and industry updates that will inform readers of current and future advances in the area. The book is suitable for researchers, students, and domain experts who are interested in using state-of-the-art games technologies in their areas, as well as game professionals who are trying to gain a thorough understanding of issues involved in the serious application of video games technology. The book is also applicable to programmers, game artists, and management contemplating or involved in the design and development of serious games.

Serious Games Development and Applications arose from the International Conference on Serious Games Development and Applications (SGDA 2011), which was the second conference on SGDA. The First International Conference on Serious Games Development and Applications was held at the University of Derby in 2010. The event has since become an annual conference and is supported by the Gala European Network of Excellence in Serious Games, the TARGET project, which are both partially funded by the European Community under the Seventh Framework Programme, and a number of partners such as the Glasgow School of Art, University of Derby, INESC ID, and Technical University of Lisbon. The Technical University of Lisbon (IST/UTL), Portugal, hosted the second annual conference (SGDA 2011) in September 2011. Besides the papers published in this book, SGDA 2011 also included the position papers of Ben Sawyer, recognized visionary in the field of serious games, Elmar Husmann of IBM and the European Learning Industry Group (ELIG), and Jon Purdy from the University of Bradford.

July 2011 Minhua Ma

Organization

SGDA 2011 was hosted by the Department of Computer Science, Technical University of Lisbon (IST/UTL), in cooperation with the Digital Design Studio, Glasgow School of Art, and the TARGET project, which is partially funded by the European Community under FP7.

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Gaze-Dependent Depth-of-Field Effect Rendering in Virtual Environments

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Abstract. This paper presents gaze-dependent depth-of-field (DOF) rendering setup, consisting of high frequency eye tracker connected to a graphics workstation. A scene is rendered and visualised with the DOF simulation controlled by data captured with the eye tracker. To render a scene in real-time, the reverse-mapped z-buffer DOF simulation technique with the blurring method based on Poisson disk is used. We conduct perceptual experiments to test human impressions caused by simulation of the DOF phenomenon and to assess benefits of using eye tracker to control the DOF effect rendering in virtual environments. Additionally, we survey the eye tracking technologies suitable for virtual environments and preview techniques of the real time DOF rendering.

1 Introduction

Depth-of-field (DOF) of the eyes is the range of distances where objects appear to be in focus for the human visual system [5]. A finite aperture of the eye maps a 3D point from the scene to a circular region in an image, called the *circle of confusion* (CoC). Overlapped CoCs make defocused objects blurred. The DOF effect improves photorealism of rendered images and supports perception of depth [6]. However, important task of this phenomenon is to make a focus object attract the human's attention. In real world, humans do not see blurred areas and to notice defocused objects some cognitive process must be arranged.

In the paper we present a gaze-dependent depth-of-field system, consisting of a high frequency eye tracker connected to graphics workstation. The hardware setup and visualisation software enable capturing observer's gaze direction, computing CoC, and rendering a 3D scene with the DOF effect. The reverse-mapped z-buffer technique with the blurring method based on Poisson disk is used to render the DOF effect in real time.

To our best knowledge, it is the first real time eye tracking setup which does not require head mounted devices or head stabilisation (e.g. chin-rest or bite-bar) to integrate eye tracking with the real time DOF visualisation. So, we are able to test humans' assessment of the DOF effect not disturbed by any devices that could divert ones attention.

We argue that gaze-dependent rendering of the DOF effect is very useful for realistic visualisation of computer graphics. In particular, it is especially

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needed in *serious games* where immersing in virtual environment (VE) plays a primary role.

In this work we conduct perceptual experiments that gather observers' judgements on presence of the DOF simulation in virtual environments. We evaluate humans' assessments concerning using the eye tracker to control the DOF rendering. We also search for the most plausible blurriness level suitable for VEs but adjusting the parameters of our optical model.

In this paper we extend the work presented by Hillaire et al. in [7] and test the gaze-dependent DOF visualisation for a more general virtual reality application, not only for first-person-player game. In contrary to [7] we evaluate the Plausibility Illusion [24], which refers to the illusion that the scenario being depicted is actually occurring, rather than the Place Illusion - a sensation of being in a real place (e.g. immersion in VE).

Additionally, we present the saliency maps achieved during experiment to assess fixation distribution in VE applications. They differ significantly from centre-oriented distributions reported in [27].

The paper starts with a survey of eye tracking techniques (Sect. 2) guided by their suitability for VEs. In Sect. 3 we discuss previous work regarding real time visualisation of the DOF effect. The implementation of our gaze-dependent depth-of-field simulation is presented in Sect. 4. Sect. 5 describes the subjective experiment, depicts its results and compares with results achieved in [7]. We conclude the paper in Sect. 6.

2 Eye Tracking Technologies for Virtual Reality Applications

Eye tracking is a technique of gathering real-time data concerning gaze direction of human eyes. In particular, position of the point (called *point-of-regard*) that a person is looking at is captured [17]. This information is acquired in numerous ways encompassing intruisive and remote techniques.

The most suitable for VE systems are remote techniques that use cameras to capture image of the eye. Even if they require some intrusive head mounted devices [8, Sect. 6], they are still acceptable for many VE applications.

The most common remote eye trackers apply the *corneal reflection* (CR) method. The eyes are exposed to direct invisible infra-red (IR) light, what results in appearance of Purkinje image with reflection in the cornea. The reflection is accompanied by image of the pupil. Captured by a video camera sensitive to the infra-red spectrum, the relative movement of both the pupil and corneal reflections are measured, what enables to estimate an observer gaze point. Commercial eye trackers can achieve the accuracy below 0.5 degree [9,10]. The CR eye trackers require calibration to estimate position of a head relatively to the screen plane. Then, it is possible to calculate the estimated screen-space gaze point coordinates with frequency higher than eye saccades[1]. In our user stud-

[1] The saccades are defined as rapid movement of the gaze-point, characteristic for the human visual system (HVS).

ies (see sections 5) we use the corneal reflection eye tracker manufactured by SensoMotoric Instruments company (SMI RED250 [9]). Detailed reviews of eye tracking techniques are presented in [11] and [8].

The eye tracking is considered to be helpful human-computer interface, especially suited for serious games applications. For example, it is intended to be used in diagnosing of attention deficit disorder (ADD) [4, Chapter 10], or to develop games that allow researchers to capture psychophysiological data, reflecting how players perceive digital games [18]. In this paper we focus on the quality of rendering and serious games are an example of using VEs in which the realism of rendering is particularly important. We argue that the DOF effect should be taken into consideration during visualisation of a serious game environment because it may significantly affect the impact of game on the player. In [1] the depth of field is mentioned as a method of enhancing visual realism of surgical simulators. The need of the DOF rendering in cultural heritage tasks is reported in [2]. In [3] importance of the DOF rendering for flight simulators is highlighted. Serious games should follow the quality of graphics available in the latest computer games, particularly in relation to natural phenomena.

3 Depth-of-Field Rendering in Virtual Environments

In a physical camera, the rays cast on the sensor are subject to refractions produced by physical properties of the lens. They appear in photography as the phenomena named circles of confusion (CoC), with diameter varying according to the ratio of the aperture to the relative distance of the object from the camera. As they blend together, image appears blurred for objects that are closer or farther from the lens focus plane. The portion of a scene that appears acceptably sharp in the image is called the depth-of-field (DOF).

An extended camera model rather than the idealised pinhole camera is needed in computer graphics to simulate the DOF effect [12]. The common method for DOF rendering is to render multiple images with varying view location (camera location) while keeping the point of focus fixed. However, this accumulation technique comes at a high cost of multi-pass rendering. Better performance can be achieved using *reverse mapping* methods [14,13]. The mentioned DOF algorithms suffer from artefacts such as intensity leakage (colour bleeding from in-focus objects onto blurred background), depth discontinuity and occlusion problem at silhouette edges of objects. Recently, advanced techniques were proposed that generate results comparable to off-line DOF rendering based on ray tracing. For detailed review of the real time DOF rendering methods refer to [19] and [22, Sect. 10.13].

In our demo application we implemented the reverse mapping technique [13]. We introduced some improvements to this algorithm to decrease visibility of artefacts (see Sect. 4 for details). We used this simple technique to favour the high rendering speed rather than the accuracy of DOF visualisation. Our main goal was to achieve real time rendering synchronised with eye tracker output.

Previous experiments with depth of field effect controlled by an eye tracker are described in [7]. They involved the reverse-mapped z-buffer method, together with minor artefacts correction. It though suffered from a drawback typical to classic depth-buffer approaches that calculate the blurriness with circle of confusion modelling. They are subject to heavily disturbing depth discontinuity problem when an out-of-focus object occludes the in-focus background. It results in hard edges of blurred object silhouette (see Figure 1, right).

In Hillaire et al. [7] the perceptual experiments were conducted to estimate uers' immersion in VE. They report the increase of immersion feeling for the visualisation setup equipped with an eye tracker. However, they use ASL 6000 eye tracker with the accuracy of less than one degree of visual angle together with a chin-rest to maintain participant's head at the same position. In our opinion, this solution strongly influences the immersion feeling and could distort results of the experiment. Moreover, Hillaire et al. project is based on the first-person-player game engine. The cognitive processes during game-play differ from those experienced during walk through a typical virtual environment. They reduce acuteness of how an observer experiences the DOF visualisation. This problem is even stronger in [15] where eye tracker is not used and a participant is assumed to look at the centre of the screen.

In [7] a technique called auto-focusing was implemented to help translating the gaze point coordinates provided by an eye tracker into actual focus distance. We find this techniques similar to estimation of fixation points based on space and time sampling. They use rectangular region surrounding the gaze point and objects' weights to average saccade movement and sample saccades with 15 Hz frequency.

In our solution, we use a high accuracy eye tracker and an improved algorithm of the DOF rendering. We conduct perceptual experiments based on a typical VE application.

Fig. 1. Left: our solution blurs not only the object interior but also the object silhouette. Right: the depth discontinuity problem, the silhouette of the candlestick remains sharp.

4 Gaze-Dependent Depth-of-Field Rendering

DOF rendering. Our implementation of the depth of field algorithm is an extension to the reverse-mapped z-buffer technique with the blurring method based on Poisson disk samples [13,14]. The algorithm requires two rendering passes. On the first pass a scene is rendered, outputting the colour as well as depth and blurriness factor. The factor is estimated by the CoC derived from the thin-lens model:

$$CoC = a \cdot \left|\frac{f}{d_0 - f}\right| \cdot \left|1 - \frac{d_0}{d_p}\right|, \tag{1}$$

where a is a diameter of the lens aperture, f is the focal length of lens, d_0 is the distance between the focus plane and the lens (objects located in this plane are sharp), and d_p is a distance from an object point to the lens.

The d_0 is equal to the depth value of a pixel corresponding to the current gaze-point captured by the eye tracker. The depth is taken from z-buffer and transformed to world-space. Finally, the offset (60cm) is added to d_0 to take into consideration distance between the monitor screen and observer's eyes.

On the second pass, the image from the first pass is filtered with a variable-sized filter kernel to simulate the circle-of-confusion. The filter kernel consists of 15 samples and its size is adjusted on a per-pixel basis using the value of CoC for the central sample read from a pre-generated, screen-size texture. The samples are then averaged to derive the final blurred colour.

To address the depth discontinuity problem we follow the solution presented in [16] where CoC value is calculated using both originally computed version and its blurred counterpart. As a result, the blur spreads outside the silhouette of a defocused object forming soft edges. The drawback of this method is blurring of background in object's vicinity (see Figure 1, left). Time consuming techniques like multi-view rendering [20] or per-pixels layers [21] techniques should be implemented to solve this problem.

Implementation. In our OpenGL 3.2-based DOF renderer the scene is rendered to a buffer (FBO) with two textures attached: one for colour output, and the second for depth values storage. Then the camera distance from the gaze-point (captured by the eye tracker) is acquired and assumed to be the focus distance. The CoC_o values are calculated with Equation 1 based on the depth values and current focus distance. The values are duplicated and stored in two separate textures: the nearer-than and farther-than the focus plane. The „near" texture is down-sampled to 1/8th of its size in every dimension, in order to obtain the blurred CoC_b values. To obtain the final CoC which determines the actual blurring radius, the following equation is used:

$$CoC = 2 \cdot max(CoC_o, CoC_b) - CoC_o. \tag{2}$$

Finally, the image is displayed on a screen (for the complete diagram see Fig. 2).

The program was implemented in *C#* language, using *OpenGL 3.2* library and *GLSL 1.50* shader language. We utilised the *.Net* based *OpenTK 1.0* library as the application's graphics abstraction layer.

Eye tracking. To query physical eye tracker and acquire screen-space coordinates of the current user gaze point, we implemented independent library utilising its own thread. The library bases on the API delivered with SMI RED250 eye tracker, which tracks an observer gaze direction and returns its value transform to the screen coordinates. The gaze point position is passed to the renderer and is used to compute the focus plane.

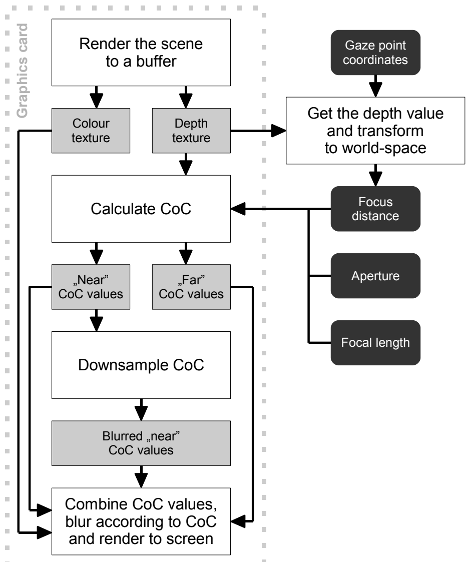


Fig. 2. The gaze-dependent depth-of-field rendering algorithm controlled by data from eye-tracker

5 Experimental Evaluation

To study humans' preferences regarding visualisation of DOF in VEs we conducted experiments based on the application which renders an example virtual environment with the DOF effect controlled by the RED250 eye tracker.

5.1 Participants

21 participants (20 males and one female) took part in the experiment, however only 16 finished it. 5 persons were not able to pass the eye tracker calibration and validation process because of severe errors in the returned data. The participants age was between 21 and 24 years, with average of 21.81 years. They had normal or corrected to normal visual acuity and correct colour vision tested with the Ishihara charts. All participants had basic expertise in imaging (they passed basic computer graphics course). None of them was aware of the technical details of the experiment. They were informed that the goal of the experiment is to judge realism of DOF simulation.

5.2 Stimuli

The rendered scene presents a fantasy-world interior of a magician's house (example screenshots are presented in Figure 3). We built a scene with complexity corresponding to environments used in simple VE systems (the scene consists of over 21 thousand triangles and 14 high resolution textures). We select two different animation sequences (Figures 3c and 3d) and two static scenes (Figures 3a and 3b) showing different parts of the scene. Each animation lasted 15 seconds and a static scenes was exposed for 8 seconds. We decided to suppress participants to navigate in the scene to pay their attention on judgement of the DOF quality rather than controlling VE. However, the animations were rendered in real time and taking control over a camera was possible.

Every scene was rendered in four different ways: without eye tracker control (focus depth and its changes were predefined for each scene) and with full eye tracker control over the DOF visualisation for three different blur levels (aperture $a = 19$, $a = 7$, and $a = 2$ (meaning of the a parameter is explained in equation 1)).

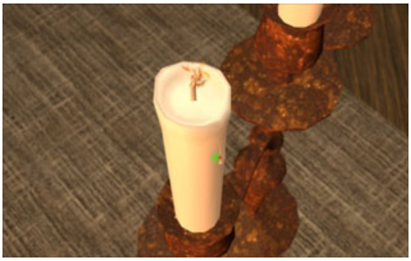
The experiments were run on a 22" Dell E2210 LCD display (1680x1050 pixel resolution, 475 mm screen width and 298 mm screen height) offering good colour and contrast reproduction. Observers sit in the front of the display in 60-70 cm distance. The illumination in the laboratory was subdued by black curtains to minimise the effect of display glare and to focus observers' attention on the VE visualisation. The scene was rendered with 60 fps on a PC with 2.8 GHz Intel i7 930 CPU and NVIDIA Geforce GTX 480 graphics card.

5.3 Experimental Procedure

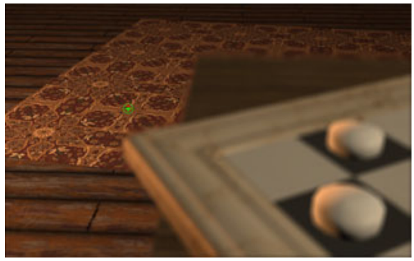
Observers were asked to read a written instruction before every experiment. Following [23] recommendation, the experiment started with a training session in which observers could familiarise themselves with the task, interface, and the eye tracker operation. After that session, they could ask questions or start the main experiment. To ensure that observers fully attend the experiment, two random trials were shown at the beginning of the main session without recording the results. The scenes were displayed in a random order and with a different randomisation for each session. Two consecutive trials showing the same animation were avoided if possible. No session took longer than 8 minutes to avoid fatigue.

The experiment started with the eye tracker calibration. This procedure took about a minute and consisted in observation of the markers displayed in different areas of the screen. The relation between known marker positions and observer's gaze points are used to compute the gaze point in the screen coordinates (in pixels). To assure correct calibration, the validation was executed after the calibration. Each experiment session with the validation error over 60 pixels (roughly 1.5 degrees of the visual angle) was aborted .

In the next step, the actual experiment was applied. We based it on the *single stimulus* experimental technique. The scenes were displayed one by one separated



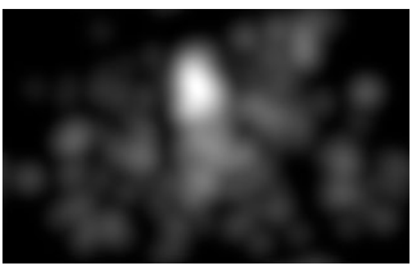
(a) Candle From Above



(b) Checkboard Corner

(c) Fireplace Through Candelabrum

(d) Floor Sweep



(e) Saliency map for Candle From Above

(f) Saliency map for Checkboard Corner

Fig. 3. Example screenshots from the virtual reality renderer. The saliency maps for a) and b) are presented in the bottom row.

by a grey screen with the slider and question: *"Does the presented depth of field effect simulation look realistic?"* . Observers were asked to use this slider and judge the quality of the DOF effect on a continuous scale from *Very realistic*, through *Realistic*, *Fairly realistic*, *Unrealistic* to *Very unrealistic*. The procedure was repeated for every scene.

At the end of each session the observer was asked to fill a questionnaire with questions concerning his age, sight condition and his opinions regarding visualisation of DOF in virtual environments.

5.4 Results

Figure 4 depicts results of the experiment. The participants disliked the DOF simulation without eye tracker control (mean $zscore = -0.78$, $sem = 0.11$). The scenes with eye tracker control and medium blur ($a = 7$) were judged as the best ones (mean $zscore = 0.54$, $sem = 0.07$). The remaining conditions achieved comparable results: mean $zscore = 0.11$ ($sem = 0.1$) for $a = 2$ and mean $zscore = 0.15$ ($sem = 0.11$) for $a = 19$.

ANOVA does not reveal significant difference of the results for various scenes ($p = 0.48$) and observes ($p = 0.99$). The results are also not significantly dependent on the accuracy of eye tracker validation.

In Figures 3e and 3f saliency maps for two example scenes are presented. These maps depict combined fixation points for every observer. For the free-walking tasks in VE we notice the observers' tendency to fixate their attention at the screen centre (reported in [27]), however distribution of saliency maps is strictly depend on a scene content. Moreover, the top-down visual attention scheme (assessment of quality of the DOF effect) induces observers to switch their gazes between near and far objects.

5.5 Discussion

In the experiment we decided to evaluate the Plausibility Illusion (Psi) rather the Place Illusion (PI) [25,24]. The latter one defines a sensation of being in a real place (immersion in VE) which was difficult to reproduce in our experimental setup, even with the remote eye tracker utilisation. On the contrary, observers were able to assess whether the virtual simulation of DOF is comparable to the natural phenomenon and judge a basic concept of the Psi - things happen in the way they should happen.

Our results show the same trends as reported in [7]: the use of eye tracker has a crucial influence on the naturalness of the DOF visualisation.

We found that the accuracy of eye tracker below an acceptable threshold (below 1.5 degrees in our case) is an important factor influencing the results. We noticed that the deviations of gaze positions in the screen plane make the computation of the focus plane difficult, especially for thin objects located in closer planes. In our opinion, the non-intruisive eye tracking with accuracy comparable to the HVS is still a challenging problem.

During the experiment we noted participants' opinions concerning the VE rendering with DOF simulation. Three of them found annoying and verbally reported the lack of eye tracker control for some scenes. The accommodation time to a new focus plane seemed to be too short for some observers. It is an interesting observation since we set this time to 370 ms according to state-of-the-art physiological studies . Participants also reported problems with focusing objects moving in the close planes. Implementation of the smooth pursuit detection should help to solve this issue.

The quality of scene rendering has significant influence on impression of the DOF naturalness. We found rendering without visible artefact more important than complexity of the shading model. A human can accept low quality graphics but artefacts divert his attention and disrupt the DOF quality.

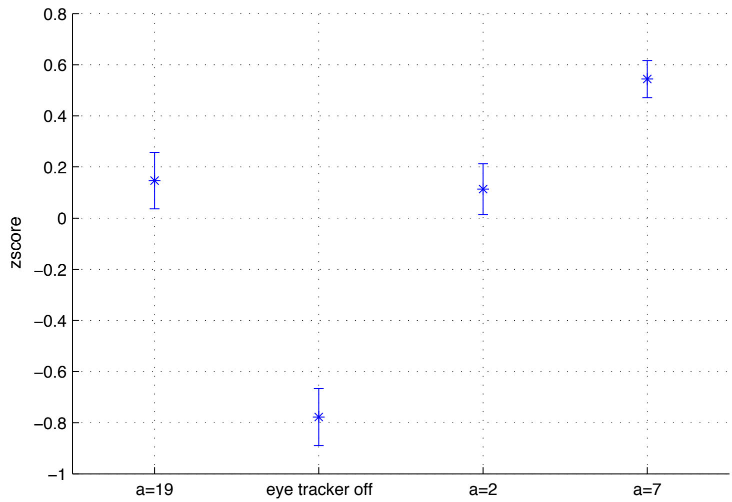


Fig. 4. Result of experiments showing observers' assessment of visualisation quality of the DOF effect simulation. The circles depict the mean zscore for four different DOF configurations: with eye tracker for three blur levels from the strongest ($a = 19$), through barely visible ($a = 2$) to medium ($a = 7$) and without eye tracker (eye tracker off). Error bars show the standard error of mean (SEM) of the zscores measured for every observer and every scene. Zscore values correspond to Likert scale values from Very realistic (positive values) to Very unrealistic, respectively.

6 Conclusions and Future Work

We have presented the depth-of-field visualisation technique in which depth of the focus plane is controlled by the eye tracker device. We conducted perceptual experiments to evaluate humans' impressions regarding to existence of the DOF phenomenon in the VE systems. The results suggest that people notice and prefer the DOF visualisation controlled by eye tracker. The best impression was achieved with the medium blurriness level.

In our hardware setup the eye tracker had limited accuracy (distortions up to 1.5 degrees) which influenced correctness of the blur location and caused blur flickering. To remove this artefact, further studies are needed to improve computations of the fixation point [26]. Development of alternative non-intruisive eye tracking techniques of higher accuracy seems to be an alternative solution.

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Personalized Storytelling for Educational Computer Games

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Abstract. Educational computer games are a highly popular but also a highly challenging field where (technology-enhanced) education meets entertainment/gaming. Ongoing endeavors concentrate on the need to translate the state-of-the-art in conventional e-learning, this regards in particular to technologies of intelligent and adaptive tutoring, to educational games. This is a non-trivial attempt since methods of personalization, such as pedagogical guidance or adaptive curriculum sequencing have a substantial impact on a game's flow, in particular on the narrative. In the present paper we introduce a formal and computable approach to interactive and adaptive storytelling in educational games. This approach, coined macro adaptivity, is based on the idea of merging story models with cognitive domain and learner models. The principles of the approach have been exemplified in an appealing educational game teaching geography for 12 to 14 year olds.

Keywords: Serious games, educational computer games, adaptation, personalization, micro adaptivity, macro adaptivity, interactive storytelling.

1 Introduction

The idea of using the cool modern computer games for serious, particularly educational purposes is thrilling educators, researchers, and developers. The genre of learning games has become a major field of psycho-pedagogical research and those games will definitely play an important role in the future educational landscape. On this playful basis, "serious" games can make learning a more pleasant activity, maybe a more effective activity (for which we occasionally find evidence), maybe more suitable for the "digital natives", but definitely we can reach those children and adolescents we could not reach satisfyingly with conventional educational measures.

As a matter of course, we are still facing significant challenges on our way to create successful educational computer games and we have to invest in further research. Examples are the challenge of controlling the immense costs of learning games that can compete with their commercial, non-educational counterparts, the challenge of finding a suitable balance of gaming and learning, the challenge of real-time adaptation that is so important for the fragile motivation to play, the challenge of finding the

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subtle balance between challenges and abilities, or the challenge of utilising the educational potential of social interactions through (massively) multiplayer games.

A crucial aspect from our point of view is to enrich conventional approach to serious games with the strong capabilities of intelligent and adaptive tutoring In essence, the driving force behind intelligent educational systems is to provide individual learners with individually tailored learning experiences. The aim is to equip software system with the strength of a human teacher, that is, the strength to assess the very concrete needs of a learner and to adjust the teaching (in term so f content, type of presentation, or sequence) according to this assessment. Over the past decades several methods and frameworks for intelligent (ITS) and adaptive (ATS) tutorial systems were developed. An overview is, for example, provided by Paul De Bra [1].

The translation and application of those techniques and methods and technologies to the genre of educational computer games, however, is not trivial. The traditional methods and techniques were developed for non-narrative learning systems and platforms, even for environments which are not requiring coherently designed elements (e.g., learning objects). Moreover, conventional ATS/ITS are based on assessment methods that can easily be analysed by an autonomous system, most likely multiple choice items or cloze texts. Games are challenging the technological state-of-the-art by requiring a non-invasive assessment (e.g., of knowledge or learning progress) and adaptation. In simple words, typical assessment methods such as multiple choice questions or cloze texts cannot be utilized in immersive games because, in all likelihood, popping-up assessments would immediately destroy game flow and immersion. The challenge is to find ways and methods to embed assessment subtly in the gameplay and narrative. In addition, the methods of personalization and adaptation must occur in a non-invasive way as well. Prominent methods are adaptive curriculum sequencing (selecting and re-ordering learning objects) and adaptive presentation (changing the look and feel of a learning environment). These methods (e.g., skipping a learning situation because the systems concludes that the learner already has the related knowledge) are hardly realizable in an immersive games because they would corrupt gaming experience and game flow, ending up with an implausible and confusing storyline without any motivational and educational potential.

In order to enable psycho-pedagogical interventions in educational games, we developed an approach of adaptation on a *micro level*. The approach is essentially based on *Competence-based Knowledge Space Theory* [2]. This framework allows modelling a knowledge domain as formal structure of admissible and meaningful *competence states* on the basis of *prerequisite relations* among the latent competences. As an example, being able to add two integers is considered a prerequisite to perform multiplications. By this means, the number of meaningful states is significantly reduced in comparison to the power set of all possible combinations of competencies. The basic idea of *micro adaptivity* is to perform an assessment of knowledge / learning progress by monitoring what the learner is doing in the game (e.g., which objects are manipulated in which way) and to interpret those actions in terms of available and lacking competencies and competence states in a probabilistic sense. To give an example, if a learner closes an electric circuit as a task in the game (e.g. to open a door) we can assume with a certain probability that this learner knows that the task requires electricity. Of course, one observation is not very convincing but by continuously observing the gaming behaviour our picture of the learner's competence state is getting clearer and clearer. The same principle we can use to make assumptions about other aspects (inner states) of the learner, e.g., assumptions about the motivational state. The probabilistic assumptions are used to provide the learner with suitable interventions, for example, individual feedback or hints that are suited for a specific situation. In this way we can avoid interrupting the gaming flow by inappropriate psycho-pedagogical measures. A more in-depth description of the micro adaptivity concept is given by Kickmeier-Rust and colleagues [3].

Important techniques for educational adaptation such as adaptive sequencing of learning units (learning situations in a game) or adaptive presentation, however, are still difficult. For example, in a game with a fixed story line it is not possible to skip a learning unit because the system concludes that the learner already has the respective knowledge. This would, as mentioned, immediately destroy the story's flow and therefore the gaming experience. To address this problem we developed an approach to merge psycho-pedagogical adaptation with interactive storytelling, essentially to enable an adaptation of the story to the psycho-pedagogical requirements.

2 Interactive Storytelling in Educational Settings

As suggested, in contrast to the micro adaptive approach, methods such as curriculum sequencing require more global alterations and adjustments to the gaming scenario. We term this approach *macro adaptivity*. Research on macro level adaptation and storytelling focuses on the challenge of integrating interactive storytelling with the demands of educational and psycho-pedagogical adaptation (e.g., a sequencing of learning events) in games. A fundamental phenomenon, commonly encountered is the tension between the control over the game by the author and the control exerted by the player over the continuation of the game during play. This phenomenon, referred to as the *narrative paradox* due to the seemingly incompatible interests of author and player, shows the interconnection of two challenges: the composition of an exciting game by an author (authoring) and the continuation of a game at a certain moment during play, ideally adapted to the player's needs (macro adaptation). The narrative paradox represents one of the grand challenges in interactive storytelling [4] and has been in the focus of many authors of the digital storytelling community (e.g., [5]).

A possible solution in highly adaptive games is an open, adaptive storytelling, tailored to the needs or actions of a player and based on more or less abstract rules defined by the author. To a certain extent, this approach exists in several games, which adaptively adjust parts of the game (e.g., difficulty). One central mechanism of macro adaptivity is the application of *Narrative Game-Based Learning Objects* (NGLOBs), modular pieces in the form of generic scenes of which the game is composed [6]. This approach allows defining objects and the rules for their composition resulting in the adaptive composition of these objects to form an engaging game with a coherent story and personalised learning [7]. Moreover, from a conceptual perspective this combines story and learning by linking competence spaces with story plots (Figure 1), which generates game paths, possible and meaningful paths through the game accounting for story model, learning objectives, and pedagogical interventions.

3 An Adaptive, Educational Story Model

Adaptive and interactive digital storytelling basically serves two essential purposes: First, it strongly supports a personalized learning experience by adapting the game's story to individual preferences and by providing the possibility of explorative learning processes. Additionally, it enables the learner to actively interfere with the game and its narrative. Such individual preferences in style and emotional quality are considered being a crucial factor for facilitating learning and for retaining the motivation to play and learn. Secondly, interactive and adaptive storytelling serves the re-usability of learning material by enabling the realization of different stories and entirely different games (even for different learning domains) based on more or less the same pool of atomic story units, patterns, and structures as well as learning and gaming concepts, elements, and objects.

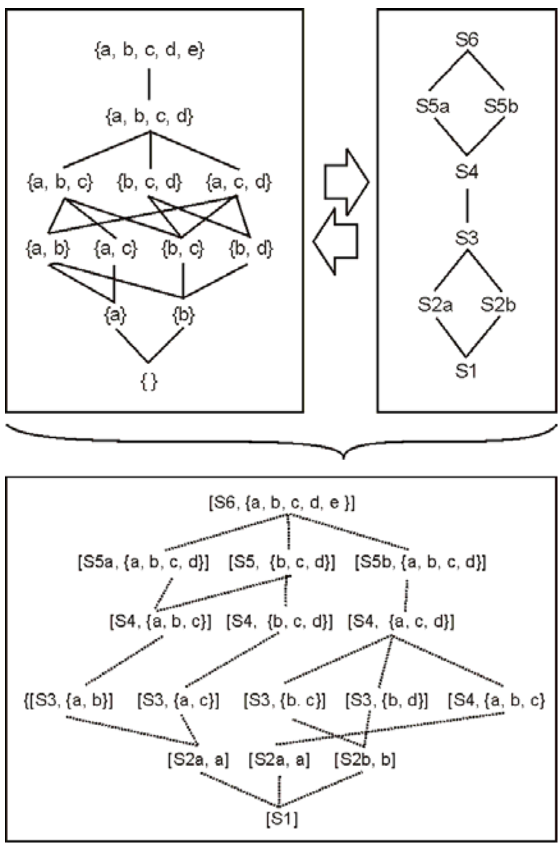

Fig. 1. Conceptual integration of competences spaces (according to CBKST) and story paths towards meaningful and admissible game paths

The present paper introduces the basic concepts of an adaptive story telling framework that allows the system to adapt the story line to the needs and interests of a user. To this end, let *G* be a nonempty set of game elements with $a \epsilon G$ and $z \epsilon G$. In the following, *a* is assumed to be the initial scene, and *z* the final scene of the game. The elements in G are the components of the game, that is, in the course of the game, a sequence $s_1, \dots, s_n$ of game elements is presented to each player. Note that the elements in G can be of quite different character: One might, for instance, think of different film sequences that make up the story of the game. Alternatively, there might be different tasks or challenges, as they are typical for adventure games, or classical knowledge tests or questionnaires.

In order to adapt the game to the preferences and needs of different user groups (e.g., the group of female German high school students under 12), let us assume that any user group can be characterized by a total of N different attributes $K_1, K_2, \dots, K_n$. This means that any N-tuple $(k_1, \dots, k_N) \epsilon K_1 \times \dots \times K_N$ refers to a single user group. One might, for instance, think of the following list of three attributes:

- Gender: $K_1 = \{\text{female}, \text{male}\}$
- Age: $K_1 = \{< 12, 12-15, > 15\}$
- Nationality: $K_1 = \{\text{Austrian}, \text{French}, \dots\}$

In order to retain the user's motivation to learn and to play, we assume that for every user group, there exists a separate version of the game. Formally, this means that for every N-tuple

$$(k_1, \dots, k_N) \epsilon K_1 \times \dots \times K_N ,$$

there exists a nonempty set $SL(k_1, \dots, k_N)$ of possible storylines (cf. The_simplified_updating_rule.pdf, Definition 1). The underlying is relatively simple: The set $SL(k_1, \dots, k_N)$ contains exactly those sequences $(s_1, \dots, s_n)$ of game elements $s_1, \dots, s_n$ for which the following two condions are satisfied: 1. The game elements are compatible with each other, i.e., they provide a coherent narrative; 2. The game elements are appropriate for user group $(k_1, \dots, k_N)$.

Let us in the following assume that the set *SL* refers to a fixed user group $(k_1, \dots, k_N)$:

$$SL = SL(k_1, \dots, k_N).$$

Then, in order to adapt the story line to the individual user of the game, let $N(s_1, \dots, s_n)$ be the set of game elements in G which are compatible with a given storyline $(s_1, \dots, s_n)$. Formally, the set $N(s_1, \dots, s_n)$ can be defined as

$$N(s_1, \dots, s_n) := \{s \epsilon G: (s_1, \dots, s_n, s) \epsilon SL\}.$$

In order to avoid an unintentional abort of the program, we have to guarantee that for every story line $(s_1, \dots, s_n)$ with $s_n \neq z$, there exists at least one story element s in G, which is compatible with $(s_1, \dots, s_n)$. Formally, this can be written as

$$N(s_1, \dots, s_n) \neq \emptyset , \quad \text{if } s_n \neq z .$$

If $N(s_1, \ldots, s_n) = \{s\}$, then the situation is trivial: The next game element that is presented to the user is the game element s. If, however, $|N(s_1, \ldots, s_n)| > 1$, then there are different alternatives that can be presented to the user. To adapt the story line to the user of the game, let us assume a nonempty set I of inner states. Furthermore, for a fixed storyline $(s_1, \ldots, s_n)$, let i_k denote the "inner state" of a user after completion of the game element s_k ($1 \leq k \leq n$). The "combined sequence" $(s_1, i_1, \ldots, s_n, i_n)$ is referred to as learning path.

In the simplest case, the inner state of a user is identical to the user's competence state C: Let E be a set of skills (in the following also denoted as elementary competencies), which are required to master a game successfully. Furthermore, let > be their inherent prerequisite relation in the following sense: We write $e_1 > e_2$ if the elementary competency e_2 is a prerequisite for the elementary competency e_1. This means that a person who has the elementary competency e_1 has also the elementary competency e_2. Since it is a widely-used assumption in *Competence-based Knowledge Space Theory* (CbKST) that the prerequisite relation is a partial order ([8] Definition 0.18), we assume that > is reflexive, transitive, and antisymmetric. Then, according to Birkhoff's Theorem, the prerequisite relation > is equivalent to an ordinal space $(E, \mathfrak{C})$ ([8], Theorem 1.49). In the following, the elements in $\mathfrak{C}$ are referred to as competence states, and the tuple $(E, \mathfrak{C})$ is denoted as competence structure.

Alternatively, the inner state of a user might also describe the user's motivation, interests, or preferred learning behavior. If, for instance, also motivational aspects are taken into account, then the inner state i_k of a user can be represented as a tuple $i_k=(C,M)$, where C denotes the user's competence state, and M represents the user's motivational state.

In order to discuss the most important special case, let us in the following assume that the user's inner state is identical to the user's (unobservable) competence state: $I=\mathfrak{C}$. Furthermore, following the assumptions of Knowledge Space Theory (e.g., [9, 10]) and Competence-based Knowledge Space Theory (e.g., [2, 11, 12, 13, 14]), we assume that at any point in time, the user is in a specific, yet not directly observable competence state $C \in \mathfrak{C}$. Accordingly, let C_k be the user's competence state after completion of the k-th game element s_k.

To adapt the story line to the user's competence state, let us fix a learning path $(s_1, \ldots, s_n)$ and a conditional likelihood function

$$L(\cdot \| s_1, C_1, \ldots, s_n, C_n): N(s_1, \ldots, s_n) \rightarrow [0,1]$$

with the following interpretation in mind: $L(s \| s_1, C_1, \ldots, s_n, C_n)$ is the conditional probability that the game element s is presented next, given the learning path $(s_1, C_1, \ldots, s_n, C_n)$. In order to reduce the complexity of the model, let us assume that the conditional likelihood function $L(\cdot \| s_1, C_1, \ldots, s_n, C_n)$ depends only on the storyline $(s_1, \ldots, s_n)$ and the current competence state C_n but not on the previous states $C_1, \ldots, C_{n-1}$. This can be formally expressed as follows:

Let us assume an uncompleted storyline $\langle s_1, \ldots, s_n \rangle$ (i.e., $s_n \neq z$), a game element $s \in N\langle s_1, \ldots, s_n \rangle$, and competence states $C_1, \ldots, C_n, C'_1, \ldots, C'_n$. If $C_n = C'_n$ then

$$L\langle s \| s_1, C_1, \ldots, s_n, C_n \rangle = L\langle s \| s_1, C'_1, \ldots, s_n, C'_n \rangle, \qquad s \in N\langle s_1, \ldots, s_n \rangle.$$

The resulting model is referred to as *Markovian story telling model* (cf. The_simplified_updating_rule.pdf, Definition 6). Then, for a Markovian story telling model, we can define a conditional likelihood function

$$L\langle \bullet \| s_1, \ldots, s_n, C_n \rangle : N\langle s_1, \ldots, s_n \rangle \to [0,1]$$

as

$$L\langle s \| s_1, \ldots, s_n, C_n \rangle := L\langle s \| s_1, C_1, \ldots, s_n, C_n \rangle$$

with arbitrarily chosen competence states $C_1, \ldots, C_{n-1}$. The resulting likelihood function

$$L\langle \bullet \| s_1, \ldots, s_n, C_n \rangle : N\langle s_1, \ldots, s_n \rangle \to [0,1]$$

provides the basis for tailoring the next game element s_{n+1} to the user's current competence state C_n.

A severe drawback of this modeling approach is that, in general, we only have probabilistic information on the user's competence state at a certain point in time. This means that, in practice, we have to replace the competence state C_k by a probability distribution P_k on the given competence structure $\mathfrak{C}$. Here, as in the following $P_k(C)$ denotes the probability that, after completion of the k-th game element, the learner is in the competence state $C \in \mathfrak{C}$. Correspondingly, we have to replace the previously defined likelihood function

$$L\langle \bullet \| s_1, \ldots, s_n, C_n \rangle : N\langle s_1, \ldots, s_n \rangle \to [0,1]$$

by a conditional likelihood function

$$L\langle \bullet \| s_1, \ldots, s_n, P_n \rangle : N\langle s_1, \ldots, s_n \rangle \to [0,1],$$

which depends on the story line $\langle s_1, \ldots, s_n \rangle$ and the probability distribution P_n. This can be done according to the following formula: For every $s \in N\langle s_1, \ldots, s_n \rangle$, it is

$$L\langle s \| s_1, \ldots, s_n, P_n \rangle := \sum_C L\langle s \| s_1, \ldots, s_n, C_n \rangle P_n(C).$$

Interpretation: $L\langle s \| s_1, \ldots, s_n, P_n \rangle$ is the conditional probability that the game element $s \in N\langle s_1, \ldots, s_n \rangle$ is presented to the user, given the competence state distribution P_n and the storyline

In addition to the formal underlying story-learning model, a key challenge in this context is to find a suitable and fair balance between the initially created story and 'exceptions' caused by user interactions (unforeseen or at least not intended by the author) or educationally inspired adaptations. Examples for such exceptions are wrong paths (not following the instructions of a virtual guide), skipped stations (passing artifacts without interacting), or too long/short interactions with artifacts (causing problems with external and internal time constraints). Moreover, the red thread through the story and therefore through the game must be in line with the learner's learning progress and goals. To accomplish this linkage, finding educationally meaningful, yet immersive and exciting storylines, formalisms and rules are required. Rule building may be based on:

- *External constraints*
  Constraints by the game design, learning progress, learning goal, or prior knowledge of the learner
- *Dramaturgic aspects and story models*
  Aspects including the characteristics and heuristics of story models and narrative structures. For example, plot points should be set at specific times, introductions/explanations shouldn't take too much time, the story climax shouldn't be acquired too early, and so on.
- *Importance of content and individual story elements*
  As far as individual story elements (such as scenes or specific dialogues or content) are attributed by the author with an indicator for importance, higher weighted elements should be preferred. For instance, an author might classify the importance of specific dialogue fragments of a chat station as 'very high' because it provides the answer to a leading question or 'essential knowledge', which the pupils should take out of a museum visit. Contrary, background information about the artist of a painting might be classified as 'interesting' and should only be selected/visualized to the user as far as there is enough time for it.

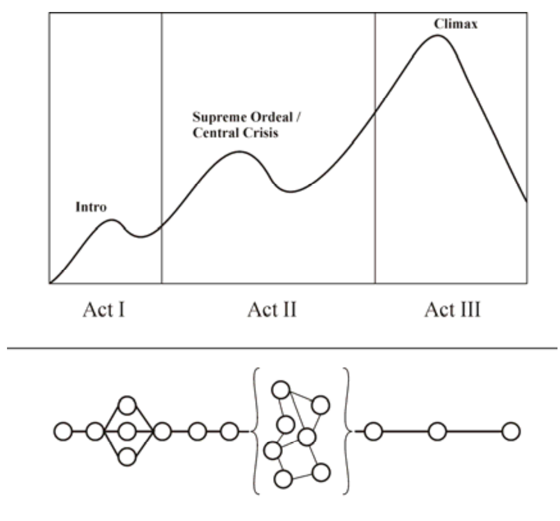

Fig 2. The three act story model and its translation to a sequence of game elements

An overview of well-known storytelling guidelines and its applications in interactive storytelling systems and storytelling-based edutainment provide [15] and [16]. In conclusion, most story models and dramaturgic approaches, especially in the area of scriptwriting, are more or less derived from the classical three-act structure of Aristotle providing an arc model with ‘exposition’, ‘rising action to climax’ and ‘denouement’ (Figure 2).

4 Conclusions

In order to make educational games more mature and more powerful – from a didactic/pedagogical perspective, it is important to equip the game technology with features of intelligent and adaptive tutoring. As outline in this paper, this is not a trivial attempt. We have developed an approach on the micro level that allows subtle hint and guiding of the learner on the basis of a non-invasive, probabilistic assessment. We argued that, in addition to that, the traditional methods of adaptation such as adaptive curriculum sequencing are highly desirable features for a sound and powerful educational adaptation. Such techniques, unfortunately, have an significant impact on the game and its narrative on a global level. To address that challenge, we developed an approach to macro adaptation orbiting around the idea of merging competence structures and a formal story model. Both models can be considered path models for, in the one case, proper educational sequences through the learning materials/content and, in the other case, for plausible and convincing story lines. The logical combination of both models induces a new structure that is composed of a subset of meaningful paths through both educational content and story. On this formal basis, the game system can autonomously identify the learner’s state within the game and within the narrative and, on the basis of specific story rules the system can adjust the global story (or the ambiance/pace of the story). This in turn allows also curriculum sequencing, for example skipping specific elements, without compromising the global storyline. In the context of 80Days (www.eightydays.eu), the outlined approach is integrated as a narration engine, establishing a pendant to an adaptive engine, which is responsible for monitoring learning progress and for providing suitable psycho-pedagogical interventions, and the game engine.

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Impact of the Feeling of Knowledge Explicitness in the Learners' Participation and Performance in a Collaborative Game Based Learning Activity

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Abstract. Despite the growing interest in the Game Based Learning (GBL) literature (Squire, 2005; Gee, 2005), only a reduced number of studies have focused on the collaborative modality in GBL (Harteveld & Bekebrede, 2011). Knowledge Group Awareness (KGA) designates the intersubjective perception of teammates' knowledge. The use of especially designed gaming interfaces allows KGA declaration and displaying support by the introduction of the KGA explicitness systems, called by some authors KGA tools (Buder, 2010).

This paper aims to study whether a structured explicitness of the KGA could play a core role in facilitating and improving collaborative face to face GBL performances. The KGA is operationalized through the Feeling of Knowledge (FOK) declaration. The FOK refers to the feelings a student has regarding his/her knowledge for a specific subject (Hart, 1965), it is defined by the student using a Confidence Level (CL) based in a 3 level scale. We expect that the FOK declaration process will have a positive impact in the learning process based in the GBL task, both in individual and collaborative phases of the GBL activity proposed to the students. However, we expect better performances in collaborative settings with the explicitness of the KGA thanks to the socially shared metacognition process, developed through the displaying of the intersubjective FOK. For this purpose we designed a collaborative SG in the field of finance, introducing an ad hoc KGA explicitness system with the aim of supporting the students' FOK declaration according to the 3 CL. The first is analyzing the impact of the declaration of the FOK in individual performance when playing alone. The second one is analyzing the influence of shared visualization of the intersubjective FOK in the individual and collaborative performances, according to the symmetry of knowledge between dyad members. This environment permits researchers study different variables in order to study four hypotheses on learner's performances and changes in their Feeling of knowledge (FOK) accuracies during collaborative game experience.

Keywords: Feeling of Knowledge, Knowledge Group Awareness tool, Collaborative Learning, Game Based Learning, Serious Game, Management Game, Finance.

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1 Introduction

1.1 Collaborative Learning

The interest in collaborative learning has risen in the last decades: a wide corpus of research has been trying to highlight the advantages and disadvantages found when introducing the collaborative approach in educational contexts (Dillenbourg, Järvelä & Fischer 2007). Collaborative learning can be seen as a method to facilitate knowledge base and argument construction. According to Kim and Baylor (2006), collaboration within peers brings out activity, makes learning more realistic and stimulates motivation.

1.2 Collaborative GBL

Games, simulations, and case studies have an important role in education and training in putting learning into a context (Leemkuil, de Jong, de Hoog & Christoph, 2003). According to Burgos, Tattersall and Koper (2007), teachers are more and more interested in games for educational purposes: games can provide students with specific content and skills in a friendly, save environment. In GBL environments, students can practice without risk.

Collaborative Games transform knowledge into social capital, according to Herz (2001), not only do players ‘own’ their learning (because they have participated in the construction), but they admit ownership in a social context where one’s status derives from peer acknowledgement, which is an incentive more powerful than some traditional teacher evaluation and feedback Collaborative Games provide students with a framework of rules and roles through which they can learn interactively through experience.

Collaborative GBL involve individual and group interpretations of given information and peers to play together in order to construct new patterns and generate new problems (Jacques, 1995). According to Prensky (2002) effective educational game design must achieve a balance between fun and educational value, the author categorizes games into three groups. The first group includes the multimedia approaches tightly linked to content presentation. The second one, the pedagogical approaches that implies a learning criterion relevant for educational games (Harteveld & Bekebrede, 2011), implementing educational aspects affects entertainment value and may affect the impact on learning. In the third group, some researchers repurpose pre-existing games for education (Moreno-Ger et al., 2008) to seek for a correct balance between fun and educational content.

1.3 Challenges of Collaborative GBL

Despite the numerous advantages of collaborative learning in terms of motivation (Järvelä & Volet, 2004), positive interdependence (Johnson & Johnson, 1994) and the development of higher-order cognitive skills (Stahl, 2007), the learners could have preferences towards individual work. Roberts and McInnerney (2007) define seven problems for online group collaboration; they observe students antipathy towards group work and the consequent lack of interest in this kind of educational activities.

This assumption leads to the Free-Rider problem: that is when one or more students in a group do little work and therefore contribute poorly to the group processes; it is probably the most commonly cited disadvantage of group work, and its consequences are a poor group's ability to perform their potential, damaging the morale of peers and even lowering the reputation of the educative institution. Another negative aspect for learning processes that take place in interactive environments such as games, simulations, and adventures is the lack of effectiveness when no instructional measures or support are added in order to guide this process (Leemkuil, de Jong, de Hoog & Christoph, 2003).

Students collaborating in small groups must be able to monitor and adapt their metacognitive processes to possible changes in their motivational state, and therefore determine how much social support may be needed to perform the task. This means the need of regulation for both individual and collective actions in this kind of environments (Azevedo, 2008). It is quite possible, following Munneke, Andriessen, Kanselaar and Kirschner (2007), that arguing does not lead to more understanding of the issue, for example; when people stick to their own viewpoints, or peers do not advance with very strong arguments.

1.4 Knowledge Group Awareness Support in Collaborative GBL

Group Awareness has been focusing attention of Computer Supported Collaborative Work (CSCW) researchers, and only recently have been applied to CSCL. Gutwin and Greenberg (1995, p.2) affirm that group awareness "is required for coordinating activity, managing shared resources, and understanding the overall state of the activity." We consider Knowledge Group Awareness as a type of Group Awareness, focused on the intersubjective perception of the teammates' knowledge. Due to its recent condition, there are few definitions for this type of Group Awareness. Nickerson (1999) defined KGA as a representation of other's knowledge that peers build in a collaborative environment in order to create a shared understanding of a task. Dehler, Bodemer, Buder, Hesse and Wet (2011) define KGA as the state of being informed about partners' knowledge and to share this state of being informed.

Different tools in collaborative learning (and consequently in collaborative GBL) contexts are necessary to foster and support argumentation, in order to achieve a deeper understanding of a subject and a more solid construction of knowledge. According to Munneke, Andriessen, Kanselaar and Kirschner (2007), there is a need for enhancing metacognitive processes. One of the tools that could foster these processes is Knowledge Group Awareness (KGA) explicitness (Brennan et al., 2008), which includes the expression of Feeling of Knowledge (FOK) to facilitate the KGA.

Hart (1965) early defined FOK as the state of believing that present non recallable information will be available later on from our memory. Following Nelson and Narens (1990), judgements of learning and FOK are a part of the metamemory. They propose to distinguish the judgments made during acquisition of knowledge and judgments made at the time of retrieval. The game based learning activity we propose to the students could be considered into this second category. Closer in time, studies redefine FOK as a metacognitive process of how people determine what they know about a question before actually answering it (Reder & Ritter, 1992), as a general process that operates whenever memory is required. According to Schwartz (1994), if a student has a high FOK for an item, then he may choose to spend more time trying to retrieve that item later.

Brennan and Williams (1995) used the term Feeling of Anothers' Knowing (FOAK) to refer to the KGA. In their paper, they introduce the idea that some conversational aspects of the interactions could help to develop the FOAK within a pair or group of persons. Despite the conversational aspects introduced by Brennan and colleagues (2008), we consider the explicitness that could be introduced in the support system of the game to promote the declaration of the individuals FOK and their intersubjective perception. These processes can be achieved through the expressions of FOK and the shared visualization of the inter-subjective FOK information.

According to Nelson and Narens, (1990) monitoring what the student knows provides a basis for predicting future performance and control self-regulation. The interplay between these two fundamental metacognitive components prepares the field for an efficient use of study time. The self-monitoring that occurs during learning has a guiding role in the self-paced acquisition of information. In particular, accuracy in FOK is critical for students, because if their FOK is inaccurate, the allocation of subsequent study time will not be optimal.

From different experiences (Schneider, 1998b; Stipek & McIver, 1989), it has been observed how children can be rather accurate when asked to predict the performance of other children, as compared to their own performance.

1.5 Description of the Collaborative KGA Tools

When students learn in small groups composed from 2 to 5 peers, according to Dillenbourg (1999), mind tools and cognitive tools help students represent what they know (Kirschner & Erkens, 2006) and facilitate critical thinking, deep learning and transformation of information into knowledge. According to these authors, these tools can be semi-structured, as conversations between peers, or structured; ad hoc tools specifically designed to facilitate knowledge declarations. Shared visualisation of personal knowledge is divided into displaying (showing individual FOK) and monitoring (becoming aware of peer's FOK, Buder (2010). Displaying can be forced (all students must contribute) or voluntary. Designers can construct a KGA tool with an open format (like mind mapping tools) or widgets that present a more closed structure, where students can only choose between three possible previously fixed states. Metacognitive feedback given by the tool can be implicit or explicit (student has to actively contribute) as in our study. Last, a Group Awareness tool can be available and changing thanks to student's inputs during all the learning process (e.g. in all game's steps) or only be modified once, for example, in the beginning of the game play, as a set of initial conditions; and remain static. Monitoring can be shown to all the participants (e.g. our tool) leading to an interpersonal comparability of performances and knowledge or only to those who actively choose it (e.g. Janssen, Erkens & Kirschner 2010); this visualisation can be obtrusive (e.g. a fill in form out of the game panel), or not (e.g. a gadget always shown while playing). Since mid 90's, little experiences have been made in this particular field, but we suppose that the less obtrusive a tool is, the friendlier for peers to use it. Designers and teachers have to be able to choose if a KGA tool has to be used as a guide or direct peers' performances. All these elections modify the student's performances.

2 Research Questions and Hypotheses

The aim of the study presented in this paper was to investigate whether the use of an explicit Knowledge Group Awareness tool in an ad hoc designed SG: *Assets Game* improved different learning goals by facilitating personal and interpersonal metacognitive processes and how to evaluate these relations in different GBL scenarios.

The first research question focuses on the individual expression of FOK; when a student plays a serious game without formally expressing his own FOK, superficial learning caused by trial by error performance is expected to take place. The use of a KGA tool, as seen in previous studies, seems to assure deeper learning via personal metacognitive processes. Researchers believe that the individual FOK expression leads to a better performance. (H1)

H2a: researchers also aim to observe if this FOK explicitness not only improves individual performances but also leads to a better FOK accuracy in a two-peer collaborative scenario; that is, when FOK is individually defined but shared with a peer, metacognitive processes take place and improve peer's FOK accuracy.

While sharing FOK is supposed to increase KGA reliability, it is also a focus of interest for this study to observe and measure how much shared visualization of individual FOK is correlated with the improvement of the performance results in a collaborative GBL environment. (Hypothesis 2b)

It has been observed in previous studies (Roll et al., 2010) how an inexistent expression of FOK can lead peers into poor feeling of community and superficial learning outcomes, researchers believe that FOK shared visualization in a dyad collaboration game should also improve the number of formal discussion comments written while game playing. (H3)

Finally, changes in FOK expression across the different stages of a collaborative dyad game should be observed (Hypothesis 4).

In order to measure these five hypotheses, a SG in management has been designed. This game consists in two panels with 12 basic financial concepts that have to be correctly classified by members of dyad teams. Researchers have also designed an ad hoc KGA tool (*Traffic Lights Tool*) and implemented it in the experimental game panels in order to facilitate FOK explicitness, both individual and interpersonal. Control groups don't have access to this tool.

3 Method

3.1 General Research Design

Our research revolved around the scenario provided by a self-designed KGA tool, implemented in a serious game: the *Assets Game*. This SG was designed as the first practical unit of a 29-unit course in finances for non financial experts, and represented, by itself, an introductory but complete pedagogic activity. The users of the game are adult students of corporative management programs who had little experience and knowledge of financial subjects.

This game was designed as a multiple choice game created to achieve both learning and research goals. Firstly, researchers and designers who were in charge of the pedagogic aspects settled the content and the learning objectives of the game. Their prior objective was to provide players with a field of practice on following items. Content goals are focused on management terms as assets and liabilities; students should up by understanding and be able to determine whether a financial item is an asset, a liability or a cost. There is also an important pedagogical objective; students have to actively collaborate when playing in dyads in order to win the game.

Secondly, and in order to test the hypothesis, researchers created the game panels and implemented an ad hoc KGA tool: *Traffic Lights Tool* in two of the four panels of the game.

3.2 Game Design

The *Assets Game* is a face to face dyad game based upon the classic multiple choice questionnaires; it consists in two different panels, each panel containing six rows, one for each concept, and four columns (see panels design).

Concepts have to be chosen as Assets or Liabilities by the users. The 12 items have been carefully depicted by the pedagogic designers with the clear objective of making the process difficult enough to obtain significant results but also to represent a challenging experience for students, who, as seen in the literature review, should naturally enjoy the gaming process.

3.2.1 Traffic Lights Tool Design

In order to facilitate both the individual and the shared visualization of the FOK, and also to avoid trial and error, a knowledge awareness widget was designed and later implemented in the assets game. This tool is a three color icon that facilitates students' declaration of FOK, according to a three grades confidence level (CL) scale. This tool was implemented next to each concept in order to facilitate the FOK for each answer given by the player.

The correct meaning of each color is explained to players before gaming, and it is like follows. The first confidence level (CL1, Red) means that the player is not sure at all of the answer given for the item. The second (CL2, Amber) means the player is quite sure of his/her answer. The third (CL3, Green) means that the player is completely convinced of the item choice.

Fig. 1. Traffic lights tool

3.2.2. Panels Design

Different panels were designed; all of them had the same distribution of 4 columns and 6 rows. (cf. figure 2 and figure 3). A total amount of twelve concepts were classified as follows.

Table 1. Overview of the items distribution across the experimental and control panels

Panel	KGA tool	Difficult items	Medium items	Chat (discussion) zone
Panel 1	ON	2a,5a	1a,3a.4a.6a	3rd column
Panel 2	ON	2b,5b	1b,3b.4b.6b	3rd column
Panel 3	Off	2a,5a	1a,3a.4a.6a	3rd column
Panel 4	Off	2b,5b	1b,3b.4b.6b	3rd column

Each panel had six items that students had to classify as assets or liabilities. All panels have difficult items (carefully chosen by the researchers in order to provide a realistic recompilation of data) in rows 2 and 5. In rows 1, 3, 4 and 6, medium concepts were set. The same financial concepts are set in panels 2 and 4 and in panels 1 and 3 in order to give experimental and control group the same activity. The difference between experimental panels 1 and 2 and control panels 3 and 4 is the KGA tool *Traffic Lights Tool*, used only in panels 1 and 2.

The third column is designed in order to give a controlled but not compulsory "chat space" for the members of the dyad to write down their doubts or comments about each item.

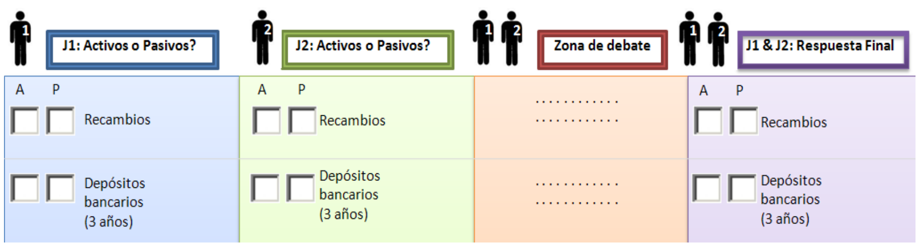

Fig. 2. Control panel 3 example, with 4 rows view without FOK explicitness

The KGA tool *Traffic Lights Tool* is used in all the columns of the experimental panels (1 and 2):

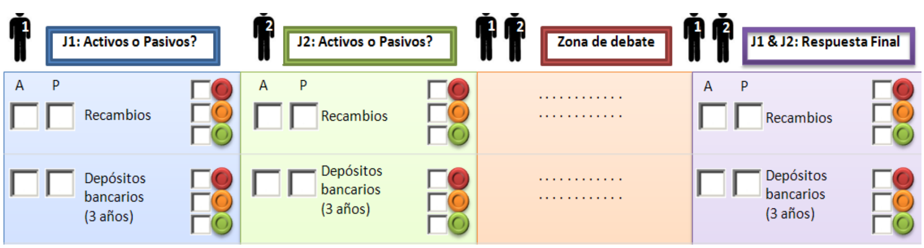

Fig. 3. Example of the experimental panel 1, with 4 rows and KGA tool to facilitate FOK expressions

3.3 Game Play

At the beginning of the game. In order to begin the game, panels are distributed as follows:

At the beginning of the game, panel 1 is given to one member of the dyad and panel 2 to the other. Each member of the team writes its name and answers the 3 item questionnaire as S1 (student 1).

For control group, panels 3 and 4 are distributed, each member of the team writes its name and answers the 3 item questionnaire as S1 (student 1).

During the game. When both students have filled their panel first column as S1 (5 minutes max), they interchange panels; each student writes his/her name in the top of the panel, as S2 player of the panel and fills in the second column, each student has 5 minutes left to fill this individual part.

Next step is collaboration: dyads have a 10 minutes time lapse to discuss the answers for each item chosen in the two panels; they have to agree on the different concepts and make clear their difficulties and doubts using column 3, if they want to, in order to write down the most important items of their discussion.

At the end of the game. The game finishes when the 4th columns of the panels are completely filled within the mutual agreement of both members of the dyad; that means each dyad finally answers 12 items, 6 from panel 1 and 6 from panel 2 if they are in the FOK explicitness group and panels 3 and 4 if they are in the control group. The dyad with a higher collaborative score (higher number of correct answers in column 4) is the team that wins the game.

4 Methodology

A quasi-experimental experience was carried out in the context of an "in-company" management program in a face-to-face modality. The experience had a total duration of 25 minutes. The designing of this collaborative SG and the implementation of the KGA tool (the *Traffic Lights Tool*) leads to different scenarios. In this first experience, in order to test the hypotheses concerning metacognitive processes and their influence in gaming and learning performance, FOK explicitness was chosen as the independent variable (IV), and dependent or outcome variables (DV) studied were: student's individual and dyad performances and, within the experimental group, the evolution of the FOK explicitness. IV was measured trough the *Traffic Lights Tool*; all members of the experimental group should compulsory express their CL through the tool. DV were measured. First column shows individual performances, second column for FOK accuracy in the experimental group. Third column: formal discussion cues, and finally, fourth column for collaborative (dyad) performances.

Table 2. Expression of FOK and consequent performances and reliabilities

Level of expected learning goals achievement in GBL scenario.	Without FOK explicitness (IV) Control Group	With FOK explicitness (IV) Experimental Group
Individual gaming (column 1 of the panels)	Poorest performance	Better performance
Collaborative gaming (columns 2, 3 and 4)	Poor performance	Best performance

4.1 Participants

In order to conveniently set the collaborative scenario described above, researchers divided the participants into two groups with the same number of participants:

Control group: using panels 3 and 4 (without FOK explicitness).
KGA tool (*Traffic Lights Tool*) users' group: using panels 1 and 2.

Before starting the game, the professor assisted by the researchers, divided the participants in dyads as they were distributed in the classroom. Before the gaming experience, all participants were asked to fill in a 3-item questionnaire. In this test, participants were asked about their age and their financial knowledge and experience; assuming knowledge as the previous studies carried out by participants and experience as their previous and present job activities which were directly related to finances; the questions had to be answered in a 5-point Likert scale from 1: no accordance to 5: totally in accordance). These two questions were set as five-level Likert scale items. After this previous questionnaire, students began playing the finance game as described in section 3.3. The game ended when all dyads had answered their panels. After gaming, observers collected the game panels. In order to make a quantitative study of the internal and inter-personal metacognitive processes defined in the hypothesis, researchers collected the following data written directly from each student in his panel and transcript them into an excel file. In addition to the information written by students in the panel game we have transcript Annotations written by dyads in the third column and the informal direct observation during the game play.

This first experience was run within the context of an introduction to finances session called "*Análisis y Planificación Financiera I*", from the "*Finanzas Corporativas*" subject inside the Esade's Program for Management Development (PMD). The number of participants was of 18 management professionals from different sectors including sales, marketing and operation experts with an average age of 37.63 years; an average finance knowledge of 2.25 (from the 5 points Likert scale) and a finance experience of 2.31 (out of 5). The observer chose, as they were sitting, in class, eight students as the control group and the other eight as the experimental group using the *Traffic Lights Tool*.

5 Results

As the number of participants in this sample was 16, distributed into two independent groups (FOK and Control group) following a normal distribution, a t-test was run in order to examine the significance of the results for the different hypotheses of this study. We used an alpha level of .05 for all statistical tests.

The first hypothesis (H1) aimed to study the performance of students having the FOK system at the individual phase of the game**.** After an equal variances *t*-test failed to reveal a statistically reliable difference between individuals explicitating FOK (M=5.13, SD=.835) and individuals in the control group (M=5.13, SD=.991), $t(14)$ =.000, p=1.000.

The second hypothesis (H2) was declined in two sub hypothesis. The first one (H2a) aims a better performance of the students having the FOK system at the collective phase of the game**.** The equal variances *t*-test failed to reveal a statistically reliable difference between no shared visualization of FOK (M=5.25, SD=.886) and dyads explicitating their FOK (M=5.50, SD=.535), results indicate: $t(14)$ =.683, p=.586.H2b assumed a significant relation between the FOK shared visualization and a better dyad performance. An equal variances *t*-test was run, and failed to reveal a statistically reliable difference between the control group dyads performance (M=5.38, SD=.744) and the collaborative answers given by FOK explicitating dyads (M=5.50, SD=.756), $t(14)$ =.333, p=.744.

The third hypothesis (H3) affirmed that the number of recorded comments in the communication zone should be higher when dyads had shared their FOK. The equal variances t-test revealed a statistically reliable difference between the control group discussion cues (M=0.75, SD=.463) and those formal discussion cues written by dyads that had shared their FOK in the third phase including the debate comments (M=1.75, SD=1.669), $t(14)$ =.683, p=.03.

The last hypothesis (H4) assumed a increase of the FOK accuracy across the different stages in the FOK explicitness group. A paired samples *t* test failed to reveal a statistically reliable difference between FOK explicitness across the different game phases: the individual phase 1 (M=5.13, SD=0.991) and teammate correction phase 2 (M=5.50, SD=.535) $t(14)$ =.893, p=.402. No differences were shown between the second phase (M=5.50, SD=.535) and the phase 4 of collaborative decision making of the assets (M=5.50, SD=.756), $t(14)$ =.000, p=1.000.

6 Discussion

This paper aimed to study the importance of KGA declaration and FOK explicitness as metacognitive processes in collaborative GBL performances, both at the individual and the dyads level. The overall results of this quasi experimental research, showed some differences between the groups using the FOK system during the different phases of the game, and those playing without the FOK.

At the individual stage, the FOK was supposed to increase the self reflection and metacognitive process and then improve the performance. However, the students using the FOK and the control group had no differences in their performances, rejecting the H1. The lack of significant difference in the students individual performance could be attributed both to size of the sample, but also to the homogeneity in the financial background of the students.

After considering the impact at the individual level, we studied the differences of the introduction of the FOK at the dyads level (H2a, H2b). The students using the FOK performed slightly better than those without the FOK, but these differences were not significant. In this case, even if slightly better, we could suppose that the presence of the FOK indicator promoted the collaborative discussion and facilitated the explicitness of the FOK at the collaborative level. According to Buder (2010), the explicitness of the FOK, through the use of KGA tool is expected to promote the awareness of the team-mates' FOK. In the case of face of face, this explicitness that is promoted through the KGA tool could be also developed through the face to face exchanges, which could explain in some extend the lack of significant differences in this face to face version of the collaborative GBL.

During the collaborative debate, we observed a significant correlation on the amount of discussions between the group using the game with the FOK system and the control group (H3). Dyads using the KGA tool were more effective in discussions before final answers than those in the control group. We could say that we observed the Brennan and Williams (1995) believe that some conversational aspects of the interactions could help in the development of FOAK within a dyad or group. This result is important because it points to the need for designing collaborative tools for enhancing discussion by the use of FOK indicators, both in face to face modalities and in the computer-based systems (e.g. synchronic discussions tools). This significant result is aligned with the direct observations of the face to face discussion performances between peers the teacher and the data collectors had observed during the collaborative discussion.

Finally, considering the possibility of the evolution of the FOK across the task duration, we studied FOK accuracy from a longitudinal approach (H4). This last hypothesis pretends that after sharing individual FOK, peers should be more able to correctly explicit their own FOK in the next step of the game. Carrying out a collaborative discussion with having the explicitness of the teammates' individual FOK, is supposed to help students' to increase their accuracy in the FOK decision making. Nevertheless, results show no differences between accuracy of FOK in the different phases of the collaborative GBL. This lack of differences could be understood by the homogeneity, within the FOK students' group, in their previous knowledge and experience on finances.

This first study results scope is limited by the number of the students participating in this collaborative GBL task. Despite of this limited sample, this experience opens a field for further studies analyzing the impact of the use of FOK explicitness both in face to face and computer based GBL.

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Virtual Location-Based Indoor Guide

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Abstract. This article proposes a solution for user localization in indoor areas using the compass, accelerometer and Bluetooth of a mobile device to calculate the user's position within this virtual environment, for it to be used in both entertainment-industry mobile games and serious games. The user's position is viewed through a 3D virtual environment representing his real position and orientation. The basis of this solution is the utilization of a mobile Bluetooth-enabled device, such as a PDA, where the application is deployed. The application will then use the mobile phone's Bluetooth to determine the Received Signal Strength Indicator (RSSI) of beacons located within the area. This information is then used to determine the virtual position of the user by triangulation. Additional sensors, such as the accelerometer or the compass provide extra precision and compensate the latency that the Bluetooth positioning solution provides. This solution has proved to be reasonably accurate, inexpensive, and very usable, as it uses virtually no input from the user (since the input the user provides is actually passive). Also, it does not conflict with any other Bluetooth devices, such as other mobile phones.

Keywords: Mobile, Indoor, Localization, Bluetooth, 3D Environment, Virtual Guide, Serious Games.

1 Introduction

Having accurate information about people's location in indoor environments is crucial for some applications such as e-commerce and e-museums. Solutions such as GPS and GSM location systems, for example, are very inefficient when used inside buildings, as their coverage is either deteriorated or nil. Acquiring relaying hardware that could enhance the signal inside these areas, therefore granting a better performance for the location, could solve this problem, and is often used. However, the required components are usually very expensive, especially since the necessary number of relays would vary according to the area being covered, making this solution less practical.

This article proposes a low-cost solution for creating a system that is able of providing indoor-location information using Bluetooth and modern handheld devices. The idea behind this project is based on the utilization of small, inexpensive Bluetooth devices that are placed on the area to be covered, such as Bluetooth badges or pens. These devices are registered on the handheld during a calibration phase and

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are used for triangulation. However, to enhance system accuracy, the mobile device used for location may also contribute by providing information from other sensors such as accelerometers and digital compass. These extra bits of information are weighted and mixed together to produce a final calculation over the user position and orientation. Also, this system is targeted to achieve several goals besides the indoor localization of users, such as maintaining user privacy and provide near real-time information, since all the calculations are decentralized from the infrastructure and performed directly on the mobile device. This guarantees that no personal or private data is stored in external servers, since the external Bluetooth devices are only used to broadcast their own address.

This article starts by presenting an overview of the existing technologies and relevant areas in section 1.1. The methodology used for this work is presented in section 2, which is divided in four parts, namely application, calibration, localization and alternative data sources in sections 2.1, 2.2, 2.3 and 2.4, respectively. The obtained results are presented in section 3. Finally, section 4 presents the work conclusions and perspectives of future work.

1.1 Previous Work

Indoor Localization

Some work has been developed for indoor-location, using several distinct technologies. Veljo Otsasson et al. [1] conceived a system that was able of providing user position inside environments using GSM triangulation. The idea behind this project is to use wide fingerprinting that uses GSM cells that are strong enough to be detected but too weak to be used in communication, in addition to the six cells defined in the GSM standards. This system has many advantages such as the range of signal coverage, the fact that any mobile phone could be used for positioning and that the system would be highly tolerant to power shortages. In order to be able of detecting the user position accurately, this system requires some calibration that was performed by measuring both the 802.11 and the GSM signals in each division of the tested areas. By using the proposed algorithms that held the best results, this solution was able of reporting the user location with a median localization error between 2.5 and 5.4 meters.

In a different perspective, the Cricket project [2] uses both Radio-Frequency (RF) and ultrasound signals to identify a user's position. The utilization of both sensors is based on the fact that RF propagates in non-linear and possibly unpredictable ways inside buildings. Therefore, it was necessary to consider alternative ways of providing increased precision to the position calculation. So, to perform the calculations, the beacons send concomitantly RF and ultrasonic signals. As the speed of sound is smaller than the transmission speed of RF signals, the later will arrive sooner to the listeners. When a listener receives a RF, it uses the first bits as training information, enables the ultrasonic receiver and waits for the ultrasound emitted by the beacon. The calculation is then performed by using both the strength of the RF signal and the time difference between the arrivals of each signal. One of the great advantages of this project is the low cost that is required to buy all of the components. The error rate reported for mobile devices is however, somehow big, being around 20-25%.

HP also developed a solution that uses infrared beacons instead of ultrasound and typical RF emitters, called HP Cooltown [3]. To find its location, the user must point its infrared-enabled handheld device to the infrared beacons. This has the clear problem of requiring user interaction to work, but on the other hand, this method also protects the user's privacy, since he only interacts with the system when he really wants to.

Finally, F. J. González-Castaño and J. Garcia-Reinoso [4] developed a system that attempts to provide user location in indoor environments using only Bluetooth devices. This proposal uses a network of bluetooth devices, organized in hexagonal grids. Each node is either a slave or a master node. The user is equipped with a Bluetooth enabled or Bluetooth badges and broadcasts its address to the nodes. Every slave node receives the RSSI value from the user and sends it to the master node. The master node performs every calculation to triangulate the user position based on the RSSI values that were received as well as the slave nodes positions and sends the computed data to some servers that will use that information for some service. This approach is very expansible since the system is able of auto-configuring itself automatically. Also, there are no collisions with other existing devices, because the work is centralized on the slave and master nodes which conform to a specific protocol. However, given that all the calculations are done by the master nodes the system may become quickly overloaded which brings performance problems in terms of response times, depending on the number of position calculations and Bluetooth devices in the network.

Serious Games

Serious games often rely on virtual environments and user interaction with it to get their message across. A good example of such games is VR Phobias [9], a virtual environment used with the goal of helping its users overcome anxiety disorders and phobias (most notably arachnophobia and the fear of driving), wielding interesting results (92% successs rate with only 4.5% of participants dropping out). Another example that relies heavily on virtual environments would be Biohazard [10], a serious game bent on training firefighters in how to act during a terrorist attack. Considering that this game does rely on field-based exercises, the accuracy of, and interaction with, the virtual environment where the action takes place is very important. So, time of day, wind speed, temperature and number of victims are but a few of the variables this game has to offer regarding its environment. An issue that appeared during the development of this game was the importance that players give to small details. These details help build a true immersion and real simulation for the player.

Considering how much Serious Games have evolved in the last years, both in number and quality [11] it is reasonable to assert that realistic virtual environment design and interaction is an increasingly important aspect of serious games.

These types of non-entertaining games, however, have yet to broadly make use of location-based services and mobile computing (two aspects covered in this paper that are known to work together [12]). However, since mobile location-based games are not only doable, but also an increasingly stronger trend [13] (thanks to the growth of smartphone usage), it is only natural for Serious Games to be able to follow.

This work pretends to create the interaction paradigm and virtual environment for a future location-based mobile serious game.

2 Methodology

The first step towards the resolution of this problem was to create a solution that was able of receiving any type of sensor data and return a position. For that, it was necessary to have some calibration results from the sensors, so that the range of values was known and the distances that those values correspond to. By doing so, it is possible to compute a linear calculation based only upon these two points. However, if possible, some intermediate values could be used for a more precise interpolation, if needed, increasing the overall accuracy of the solution. Therefore, prior to developing the solution itself, both the 3D environment application and the calibration tool were needed.

2.1 3D Environment Application

Thanks to the increasingly more powerful devices that surface to the market, the usage of a completely 3D environment for immersive user-location and augmented reality is possible. So, as the mobile calibration tool was being developed, another application was also developed, the 3D indoor guide.

This application was based on OpenGL ES 1.1 in order to achieve good hardware-accelerated graphics that nowadays most smartphones are capable of. For starters, a parser for .OBJ 3D model files was implemented to ensure that realistic models would be usable in the guide. Also, intermediate drivers for Bluetooth, accelerometer and compass were developed to ease the access of these features. Finally, the inclusion of POIs (Points of Interest) was made.

Fig. 1. Screenshot of the application, showing a POI (depicted as a box with an 'I') with the description of it being "PC Jacob"

These POIs, as seen in Fig. 1, are basically a 3D model that is separate from the room model itself and include a description string that only shows up when the users' virtual position is close to that object (within a radius, specified in a .XML configuration file) and they are looking at that same object. These can be useful, specifically in a museum guide scenario, as the users would have to physically approach an item in order to see the meta-information with their devices. Additionally, it could be used in a medical search and rescue serious games, where the players would have to approach virtual victims and tag them in accordance with the severity of their injury.

Fig. 2. Screenshot of the application showing a class room with some points of interest

As it can be seen in Fig. 2, the application features no options or active means of input whatsoever. The only input is natural actions such as moving around or looking (aiming the phone) at objects. The aim is to allow the user to focus on retrieving information from the application and exploring rather than providing active and slow manual input.

2.2 Calibration

A simple, mobile, calibration tool was developed with the single purpose of selecting the sensors that would be considered by the application, so that it does not conflict with other Bluetooth devices. This simple application finds every Bluetooth device that is detectable in the area that is being tested and lists it on the device. To perform calibration, the user must select each of the relevant devices and save the RSSI value for each distance that is to be used. The values saved in the calibration tool will then be exported in an XML file that specifies which sensors are to be used and also some other information that is to be used within the application, such as the position of points of interest (POI) and the 3D model filenames.

It is important to notice that the calibration distances are not fixed. The granularity of the measurements and the distance values that are to be used in calibration may vary according to the environment and the Bluetooth devices being used. This calibration step only needs to be performed once and the application is ready to be used with the same XML file in every other run, unless maintenance is required.

Fig. 3. Screenshot of the calibration tool (on the left) and part of the xml it generates (on the right)

2.3 Localization

To find the user's location, the application starts by an initialization phase in which the data that was saved in the XML file is read. As mentioned above, the XML file contains a set of RSSI-distance value pairs for each sensor. These values are read onto a hash map during the initialization. When the application loads, the Bluetooth receiver is enabled and the device starts to look for nearby known devices that have addresses that were registered within the XML file during the calibration. If at least three values are found, the software uses a triangulation algorithm that uses the obtained values and calculates the user's position. For each of the sensor values found, the application searches the hash map for the calibration points read from the XML file and finds all the intervals in which the obtained sensor value is contained. Since the RSSI variation is much greater when the device is near the Bluetooth beacon [5][6], the algorithm weights the possible found intervals by giving slightly more relevance (~10% more) to the calibration values that are more distant.

Each of the RSSI values obtained represents the radius from a circle, whose center is the position of the sensor that originated that value. In a first step to perform triangulation, two of those RSSI values are used, as well as the positions of the respective sensors. If the circles intersect then three points are saved, namely the two intersection points and the point where the line defined by the circle centers crosses the line defined by the two intersection points. With these three points saved, the algorithm searches for a third sensor that defines a circle that intersects the previous two. To do so, it simply checks if any of the intersection points calculated previously is within range from the sensor's radius. If that is the case, the intersections between the first and third circle and between the second and third circle are calculated. Finally, the midpoint of each of these intersections is used to calculate an average for the user's position.

There are two clear problems with this algorithm. The first problem appears if one of the circles is too small, there will be no intersection with any other two circles. If this happens, it means that the user is actually very close to the sensor itself and that is the reason for such a small radius. To solve this case, the user's position is snapped to the sensor position as long as it is within the map-defined bounds. The precision of the value that triggers this snapping behavior is controlled by a parameter that can be set in the application configuration. However, there is a second problem. Even if the circle is not sufficiently small to cause the user's position to be snapped, there might be times where one circle is contained inside another circle. These cases happen when the user is relatively close to one sensor, and far away from other sensor that has a very wide range. Also, this might also happen when the sensors are too close to each other and the user is close to one of the sensors. This causes a logical problem since the intersection points can't be calculated. But, since this means that the user is close to one of the sensors, the solution is to ignore the intersection calculation (since it wouldn't be possible, anyway) and consider that the central intersection point is the center of that circle.

The final position is calculated by using the values obtained from the hash map inside the triangulation algorithm. This algorithm produces a final set of coordinates based on the interpolation of the three points that were found, if any, using the method described above. This process guarantees that the coordinates conform to the specific environment, in a somehow pessimistic form, since the farthest values have more weight than the closest.

2.4 Alternative Data Sources

Since the Bluetooth takes some time to obtain the updated RSSI values (as it requires a new search for Bluetooth devices each time), it was necessary to compensate the usage of these values in the meantime with values from other sources. The modern PDAs and mobile phones are usually equipped with accelerometers and magnetometers. By using the accelerometer data, it was possible to develop a rather sensible pedometer that indicates if the user has walked. Additionally, the accelerometer data also allowed for the creation of a module, capable of determining the 3D orientation of the device. Mapping this orientation of the device with the OpenGL camera, allowed for a pseudo augmented reality interaction with the virtual environment (see Fig 4. below). As it can be seen, the virtual view is very consistent with a probable position of a user (in this case, a student). As such, it could be used as a means of input for indoor gaming, where the player would take full control of the avatar movements, mapping his own physical movements to the avatar's [13].

Note that the user is only providing passive input to the device, meaning that virtually no experience is needed with the handling of the device, or the application. The walking direction is given by the digital compass and introduced into the application. So, in case the Bluetooth fails or the handheld takes a long time to receive RSSI values, the user position is updated with the information provided by both the pedometer and the digital compass.

Fig. 4. Screenshot of the application, showing how the virtual camera can match realistic perspectives of a user's position, yaw, pitch and roll

This raises a significant problem that can't be overlooked. With the pedometer it is possible to know if the user walked and the compass provides the direction he was facing. However, it is impossible to know if the user walked backwards. Theoretically, this could be read from the accelerometer values, but due to the variations that are usually read, it would be very difficult to know accurately if the user actually moved backwards. In these cases, the only solution is to wait for the Bluetooth triangulation to reposition the user to the correct position, or try to use other sensors such as Wi-Fi or even the camera, although this is out of the scope of this project. Another possible solution would be to read data from a gyroscope and cross it with the data collected from the accelerometer. This would allow us to identify if the user moved backwards (from the accelerometer data) while looking forward (by using the data collected from the gyroscope). Unfortunately, the device available for testing lacked this sensor.

3 Results

To test this project, an application was built to reproduce the user movements inside a 3D environment, by using an HTC HD2, running a custom Android build and OpenGL ES capable harware [8]. The virtual camera placed on the scene turns automatically its direction to face the correct direction and pitch when the user moves the mobile phone, by using values read from the accelerometer and compass values. These values are submitted to a simple filter to avoid unwanted noise and to increase precision. The device was calibrated for each of the bluetooth sensors, registering their Bluetooth address and the values at several distances that were previously marked. These results are presented on Figure 5, for one of the sensors, in terms of dBm and distance. The distance is measured in centimeters and, for convenience the Bluetooth dBm values are represented using absolute values.

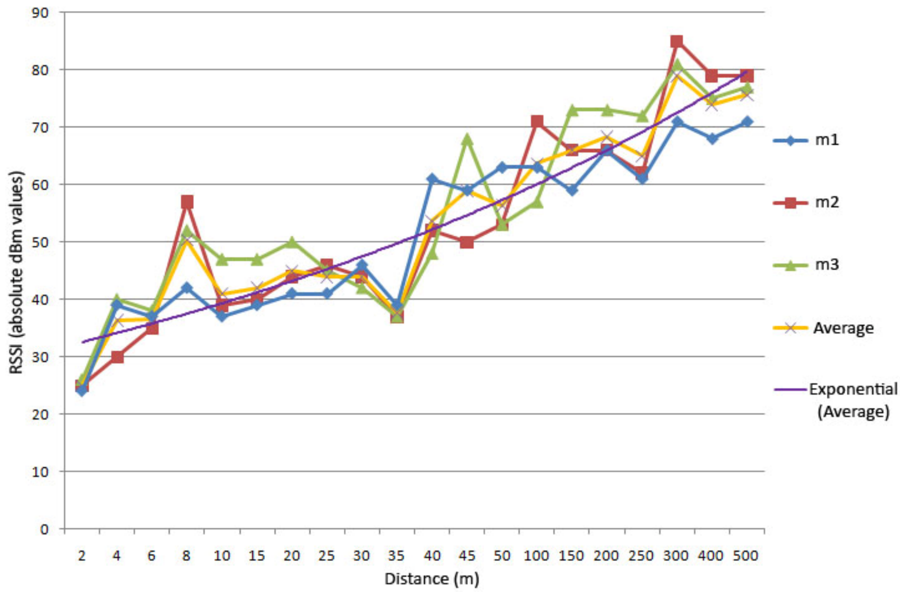

Fig. 5. RSSI values read during the calibration phase, according to several different distances in three distinct measurements. The graphic also presents an average calculation for the values and an exponential curve calculated from the average points.

The tests took place in a room with 71 m^2 with a near-square shape. This room was modeled in 3D and exported to the .OBJ format in order to be easily imported by the application. In the virtual environment, the whole scene transforms correctly according to the angle in which the user is pointing the device with minor differences of ~2 degrees. Also, the pedometer works very well if the model has the correct dimensions or the step size and the sensitivity are correctly configured for an average person. Even without using Bluetooth localization, if the starting points for both the virtual scenario and the user are aligned, the system is able of tracking the user with great precision (< 3 meter, for a correct step and sensitivity calibration). The room scheme and the approximate Bluetooth beacons positioning is presented in Fig. 6.

The Bluetooth location system is able of positioning the user correctly in a scene. However, during the testing sessions, some noise was registered making the virtual camera jump from one location to another at some times. This effect was reduced by using noise filters during signal capturing and also by using the position history to infer the probable position of the user. This avoids all of the signal peaks that are sometimes registered due to noise and signal reflection, but are still inefficient when the signal varies more noticeably for longer periods. Such problems happened mostly when using a Samsung S7330 as a Bluetooth beacon, since the signal emitted by this device is very unstable and has very large fluctuations. However, although the test space was

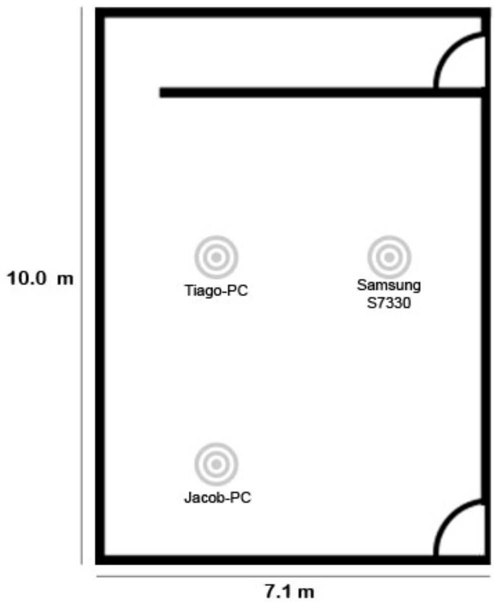

Fig. 6. Room scheme and Bluetooth beacon approximate positioning

relatively small (and the number of Bluetooth devices was also small, since there were only three testing units) the positioning with general Bluetooth devices does not have any type of collision problem. This happens because the addresses are registered during a calibration phase, and provide indoor-localization with high accuracy (~1.5 meters) when combined with another sensors. The final results are shown on Table 1. The accuracy for each method in each case is presented on Table 2.

Table 1. Obtained distance measurements using different methods and devices

Reading	Linear (m)	Inv. Quad. (m)	Realistic(m)	Device	Real Dist. (m)
1	0.28	0.83	0.306	Jacob-PC	0.40
1	3.73	4.34	3.5	Tiago-PC	3.20
1	4.68	4.41	3.6	Samsung	4.0
2	0.32	1.26	0.3167	Jacob-PC	0.40
2	3.73	4.34	3.5	Tiago-PC	3.20
2	4.89	3.89	3.0	Samsung	4.0
3	0.32	1.26	0.3167	Jacob-PC	0.40
3	5.41	5.57	5.0	Tiago-PC	3.20
3	5.32	6.33	4.25	Samsung	4.0
4	0.32	1.26	0.3167	Jacob-PC	0.40
4	3.73	4.34	3.5	Tiago-PC	3.20
4	4.89	3.89	3.0	Samsung	4.0

Table 2. Accuracy percentage for each of the different methods and devices

Reading	Linear	Inv. Quad. (m)	Realistic(m)	Device	Real Dist. (m)
1	70.0%	48.2%	76.5%	Jacob-PC	0.40
1	85.7%	73.7%	91.4%	Tiago-PC	3.20
1	85.5%	90.7%	90.0%	Samsung	4.0
2	80.0%	31.7%	79.2%	Jacob-PC	0.40
2	85.7%	73.7%	91.4%	Tiago-PC	3.20
2	81.8%	97.3%	75.0%	Samsung	4.0
3	80.0%	31.7%	79.2%	Jacob-PC	0.40
3	59.1%	57.5%	64.0%	Tiago-PC	3.20
3	75.2%	63.2%	94.1%	Samsung	4.0
4	80.0%	31.7%	79.2%	Jacob-PC	0.40
4	85.7%	73.7%	91.4%	Tiago-PC	3.20
4	81.8%	97.3%	75.0%	Samsung	4.0
Average	79.2%	64.2%	82.2%	---	---

The above tables represent a usual situation where the mobile device is able to pinpoint its real location thanks to some Bluetooth devices nearby, recognizable thanks to the XML file. The four readings were made without moving either the mobile phone or the devices. However there was a considerable discrepancy in the third reading. This was due to a person being between the mobile device and two of the beacons, effectively altering the read values. Still, these values were actually very accurate. The latency between readings would vary between 5 and 10 seconds, varying from 2 to 1 Hz refresh rate respectively, which is acceptable, for indoor navigation. It is important to notice that the measurements took place in a room with 5 to 10 persons, moving around without any pattern. During the tests, some other Bluetooth devices entered the room or walked nearby. These facts created some noise in the positioning and beacon detection but not sufficient to invalidate the calculation. This was mostly due to the fact that a medium number of points (20 RSSI-distance pairs) were used in the calibration.

4 Conclusions and Future Work

The proposed methodology described above achieves the goal of providing a simple, inexpensive and ubiquitous indoor localization solution. It is capable of pinpointing the user's location with reasonably high accuracy. Also it provides an alternative form to bypass the Bluetooth location technique's high latency by using the accelerometer as a pedometer.

The user interaction paradigm used in this project can hopefully be used in future serious games as it provides a realistic and unobtrusive way of providing feedback to the application. Also, considering that most serious games attempt to emulate a particular environment, the possibility of playing location-based serious games, in order to do a more realistic simulation, is both appealing and doable with the approach presented in this paper. However, this interaction paradigm may be unfit for people that can't be physically present in the real environment (and thus see the benefits of location-based interaction rendered useless) and also for the people that are unable to move freely through the real environment. This could be solved by allowing a mixed interaction paradigm, one that would allow also the usage of the mobile device's touchscreen or keys as a means of replacing physical passive input.

The solution described in the previous chapters heavily depends on a calibration phase that could require too much time and effort to perform without a tool designed for that purpose. However, the utilization of the small calibration software greatly reduces the required time and expertise to configure the system, making it accessible to users without great computer knowledge and proficiency. The application is not designed to be auto-configurable, since it needs to know at least which Bluetooth sensors shall be used and two RSSI values for two given distance points to perform the triangulation. After the calibration has been done, there was no need to perform it again, even when other Bluetooth devices entered the area. Since the application knows which addresses shall be considered, there are no possible collisions between other Bluetooth devices. There exists, however, some noise due to the influence of other Bluetooth emitters, creating some fluctuations in the readings. These fluctuations are also noticeable when there are more persons in the room, increasing when they are moving, since this affects the reflection of the signals. Nevertheless, this problem proved to be irrelevant due to the fact that in most situations, the PDA is in range of more than three well-known Bluetooth devices, therefore using all of the values to compensate for eventual errors. Even when the application is run with only three sensors, the effect of the noise induced by people and from other Bluetooth devices greatly depends on the calibration. Finding more RSSI-distance pairs during the calibration makes the application more reliable and error-resistant.

According to [7], the RSSI values are more inconstant and vary greatly and in possibly unpredictable ways depending on the environment and devices being used. Instead, the Bit Error Rate (BER) or Link Quality (LQ) metrics should be used for greater precision. Yet, this was not possible, since the underlying software did not provide any access to these indicators and therefore, RSSI had to be used instead. Attempts were also made to use the iOS Bluetooth features to develop to an iPhone, but it also wasn't possible to obtain access to the BER and LQ information. From the methods depicted in Tables 1 and 2, the linear method also has a reasonable performance, but is much more susceptible to the signal fluctuations induced by noise and possible reflections. The inverse of quadratic function presents the worst results, although in some cases the values are much better than the other methods and this method performs better when the user is farther from the beacons. The realistic method, which calculates the position based on several points obtained during the calibration held the best results, with an average accuracy of 82.2%.

Furthermore, the user's interaction with the application is greatly simplified, as the user needs only to aim the phone at the areas from which he wishes to receive more information from. This has been proven to be quite a successful feature, although it was only tested with few individuals. Some of these individuals didn't possess any kind of technological background. However, all of them were able to grasp the applications concept and the ways to use it with no problem. Further testing of the application will be required in order to fully validate the interaction paradigm. Additionally, an increase in performance and precision is also considered needed, in order to make the user's experience as seamless as possible.

This solution could be improved by using computer-learning algorithms to increase user localization precision, especially when the Bluetooth signals are weak and/or combined with accelerometer information. The software could use this method to learn how much the virtual position should be changed according to the accelerometer values, when the application is waiting for new Bluetooth RSSI values. Also, this information could be complemented with a better filter for the accelerometer and prediction algorithms, typically used in network games, to compensate for possible loss of signal, and with the usage of extra sensors (most notably a gyroscope sensor).

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What Can Bits Teach about Leadership: A Study of the Application of Variation Theory in Serious Games

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Abstract. This study was conducted with the purpose to explore the potential of serious games to utilize systematic learning variation. We employed a methodology that followed the learning study method, while we also introduced experimental and control groups in order to allow for more direct comparison. In this study we did not have control over the employed serious game (vLeader) and thus had to implement our experiment through its supplementary materials. The study explores a systematic approach towards serious games design. This study provides weak evidence of greater stakeholder awareness by the group that has experienced variation. Its exploratory findings provide a valuable contribution that could inform design of future serious games.

Keywords: serious games, learning study, variation theory, leadership.

1 Introduction

Serious games have been widely appreciated as an attractive and accessible form of experiential learning. However, development of such games often is not informed by an established educational theory. In order to investigate this, we have undertaken an investigation in one of the most challenging learning topics – leadership skills. To address it, we have conducted a study with vLeader – a simulation game.

This paper reports the results of a serious game study within a university context. The study aimed to explore the potential for serious games to utilize systematic variation to enhance learning. This research goal was motivated by *variation theory* [1]. According to this theory, students' learning can be supported through controlled variation. By subjecting particular features of the object of learning to variation, these are being brought to the learner's focal awareness. This study aimed to apply this principle within a serious game and to evaluate whether this leads to an improvement in learning.

The study used the single-player game vLeader, developed by Simulearn Inc. The game aims to support learning within the domain of leadership. It was chosen because there is already some empirical evidence that vLeader is an effective learning tool. Sidor [2] reports several studies that show that the game has a positive impact on learning when compared to more traditional methods of learning. vLeader is discussed further in the corresponding section below.

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2 Method

Use of vLeader was embedded within a masters-level degree course run at UCL. The class consisted of 60 students from different management degree programmes that were taking part in a class titled *Leadership, Ethics and Communication*. The first 5 weeks of the course were dedicated to the topic of leadership. Use of vLeader was embedded within the first 5 weeks. In addition to the game, the course had a number of other activities dedicated to the topic of leadership including lectures (reviewing different theoretic models of leadership), case studies (shedding light on practical complexities and videos (demonstrating leadership behaviours in action).

For this study we used a modified methodology for the evaluation of learning effects in serious games. We chose to adapt the *learning study* [3] in order to evaluate a serious game. As a research methodology the learning study is an attempt to take advantage and combine controlled experimental studies with an incremental improvement method called lesson study. The learning study is used to evaluate by comparison of learning effects between subsequent deployments of a course, introducing improvements over the iterations. In order to fit in a single term we have attempted to provide two comparable learning conditions within a single class.

The study used a *between-subjects design*. The independent variable was variation, which included the conditions variation (the *experimental group*) and no variation (the *control group*). At the beginning of the study, the students were randomly assigned to either the experimental condition or to a control group. The separation between control and experimental group was implemented through the written instructions for each scenario, called *activity sheets*. These are described in detail in the materials section.

2.1 Procedure

The study consisted of three major stages: learning, assessment and post-study interviews. The learning stage was influenced by the available game scenarios, the experimental between-subjects design and the procedure for handling each of the scenarios. The learning stage occurred over 5 weeks. During this period, five hundred-eighty minute classroom sessions were used for teaching. In each of these sessions, only a part was dedicated to the study in order to introduce the game scenarios, to administer study materials, and to facilitate group discussions around the game playing experiences. The rest of the classroom sessions were used for delivering lecture materials on the topic of leadership. The game playing experiences took place individually in between these classroom sessions.

In Week 1, the students were introduced to the game and the study. Students were given 10 minutes to do the pre-test questionnaire. The course tutor then continued with the course lecture. Towards the end of the 180 minutes, the first game scenario was introduced and the students were each handed a paper-based version of the activity sheets. Students were then encouraged to play Scenario 1 of the game at a time of their own choosing prior to the next classroom session. This introduction to the game was disrupted by a fire alarm and subsequent evacuation of the whole building. As a consequence the introductory session was less elaborate than originally intended.

In Week 2, the 180-minute classroom session incorporated a 10 to 15 minutes group discussion that focused on the students' experiences of Scenario 1 of the game and relevant leadership theory. Typical questions in these discussions were addressed to how each of the game characters behaved and whether students could relate these game experiences to real life examples. Towards the end of the session, the tutor introduced students to Activity Sheet 2 (provided online) and Scenario 2. Again, the students were encouraged to play the game prior to the next 180-minute classroom session.

During the remaining weeks, a similar pattern was followed: the game scenario introduced the previous week was discussed in relation to relevant leadership theory in a short 10 to 15 minute session and, at the end of the class, the next game scenario and activity sheet was introduced. However, due to the restricted number of classroom sessions dedicated to leadership, it was necessary to introduce and encourage students to play 2 scenarios in one week (Scenarios 2 and 3). In the final session (Week 5), following a short discussion of the fifth and final game scenario, the post-trial written assessment test was administered.

2.2 Learning Assessment

Written assessment tests are a widely used form of assessment in studies of learning technology [4]. Free-form written assessment methods can be used to measure deep learning [5]. The study employed written assessment tests before and after exposure to vLeader as a measure of learning that took place.

University ethical guidelines meant that the study's learning assessment was extracurricular i.e. it did not contribute to the students' final course marks. Because the students experienced different conditions (one with variation and one without), and we hypothesised that variation would aid learning, it would have been viewed as unethical to incorporate marks from the study assessment in the student's final course marks.

For this study, a bespoke written assessment questionnaire was developed. It consisted of 3 open-ended questions and 7 Likert-scale questions. Responses to open-ended questions were examined via content analysis.

2.3 Post-Study Interviews

After the learning and assessment parts of the study were completed, a series of in-depth interviews were conducted. The aim of these interviews was to further explore students' perceptions of the game and application of variation in particular.

3 Materials

The study used the vLeader game, accompanying activity sheets and the written assessment tests.

3.1 vLeader

vLeader is a simulation-based serious game that aims to provide a practice environment in the domain of leadership skills [6]. The vLeader serious game embodies its own theoretical framework which also informs the design of the game. An introduction to the framework is available to players via the instructional materials that the learner can access through the menus of the software. Although this framework was not considered important for the purposes of the course, there was no way to restrict students' access to it. Therefore students were told that they are welcome to explore it themselves, but they should consider it only as one of many possible theoretic frameworks about leadership.

Fig. 1. A screenshot of Scenario 4 of vLeader, showing a scenario setting, subtitles (blue area above), red-green opinion sliders and blue idea progress indications. Ideas listed to the left are ones that are not currently brought to discussion, ideas on the right are the ones that have already been passed (agreed). All scenarios feature similar meetings around a table.

The game provides learners with role playing experiences within a series of simulated business meetings (see Fig. 1). The game developers argue that business meetings are prototypical situations for practising leadership. The game dynamics are based on three variables: the player's influence, group opinion towards the player and tension in the meeting. Personal influence determines the power of player's opinion. When the player suggests a new idea, they put their personal authority at stake. If the idea gets approved, their personal authority increases. Group opinion represents the attitude of participants in the meeting towards the player. If a player manages to find an effective balance in their interactions with the characters in the room, the opinion towards the player improves. Finally, tension is measured through player's ability to manage the conflicts in the room. Players get the opportunity to review their performance on each variable at the end of each scenario.

In vLeader, players interact with the game by exchanging positive or negative signals towards character or ideas. Ideas in vLeader represent topics that are being discussed. Progress in the discussion for a particular topic is represented by a progress indicator (see the blue progress bars in Fig. 1). Players can send a positive or negative signal for a particular idea or a particular character using clickable opinion sliders (also see Fig. 1). Each slider is coloured in a red-green gradient. If the player clicks on the green side of the slider for a particular character, their avatar makes a positive comment. The comment is negative if they click on the red side.

The exact utterances that emerge are limited and can often be unrealistically repeated. Simulearn Inc. argue that this issue is of secondary importance and helps students not get distracted from the main learning focus, being the intentions behind each particular utterance. They have taken a decision to restrict the interaction interface to the intention of what is being said. Simulearn Inc. argue that in leadership situations, it is not as important what exactly is being done, as rather why exactly is it being done.

The game scoring mechanism consists of 6 values (see Fig. 2). These values are grouped in two components: 1) *leadership score*, which combines a *power*, *tension* and *ideas* sub-score and 2) *business score* based only on passed ideas in the scenario, which consists of *financial performance*, *customer satisfaction* and *employee morale*. These are the only immediate feedback that students get for their performance and thus it is expected to influence their behaviour in the game.

vLeader consists of five game scenarios. Students get access to play a scenario only when they pass all previous ones. The first scenario is designed to get the player used to the interface and involves managing one subordinate. In the second scenario, the player is required to manage two subordinates who have a latent conflict between them. The third scenario puts the player in a meeting with both superiors and subordinates in the organisation. The fourth scenario represents a situation where the player has the least formal power in the meeting. The fifth and final scenario features a crisis situation of the company management, after the occurrence of a risk event, and the player is only one of several attending managers.

3.2 Activity Sheets

vLeader is usually delivered together with a Student Workbook. In this workbook, there is a strong coupling between the simulation and the corresponding theory. Within the current study, the workbook was considered too restricting by the course tutor. So, for the purposes of the current study, a set of dedicated *activity sheets* were developed by the researchers – these adapted information from the Student Workbook to make it more relevant to the course requirements. The activity sheets were approved by Simulearn Inc. and the course lecturer. The activity sheets also provide a means of introducing variation into the game experience.

The activity sheets consisted of six sections: learning objectives, scenario background, business scoring tables, goals, hints and reflective questions. The sections were clearly distinguishable, providing students with the opportunity to use them selectively, according to their own preferences.

The *learning objectives* were one-sentence descriptions of the intended learning outcomes for each particular scenario. The activity sheets were used to connect each game scenario with a particular lecture. The *scenario background* section provided students with a written description of characters and ideas in the scenario. These were directly transcribed from the introductory information texts, delivered by the game. The *business scoring tables* provided a transparent scoring mechanism for the value of passing each particular idea. They represented a balanced scorecard of business score points that players receive when they pass certain ideas within the game. They were thus crucial towards high performance along the business score component of the game performance scoring (see details on game scoring below).

The experimental and control conditions were implemented via the performance *goals* and *hints* sections of the sheets. For the control group, the goals and hints were directly transcribed from the vLeader Student Workbook. The goals and hints for the experimental group were amended for Scenarios 2 to 5 so that they focused mode narrowly on one specific aspect of leadership each. Marton and Pang's [1] variation theory recommendations identify four necessary conditions of learning: contrast, separation, generalization and fusion. *Contrast* stipulates that in order for a quality to be discerned, a mutualy exclusive quality has to be experienced in parallel. *Separation* emphasizes that certain dimension of variation can be discerned only if other dimensions remain invariant or vary independently. *Generalization* complements separation by focusing on the fact that discerning of a certain value in a dimension is easier when this value is kept constant when other dimensions change. Finally *fusion* stipulates that the interplay of two dimensions can only be appreciated when the two dimensions vary in simultaneously. These were brought into practice in vLeader as follows:

For Scenario 1, a decision was taken not to introduce variation because the original scenario already employs contrast in encouraging students to perform different styles of leadership in order to be able to compare them. Students were asked to be directive, participative and delegative in playing subsequent games. This was intended to allow them to compare how different styles influence other participants in the meeting.

In Scenario 2, variation was introduced through the hints section by focusing on the original concept from the Student Workbook and allowing for separation of time planning. The original text focused on keeping in mind the end goal and planning for preparatory work that could pave the way towards it. The introduction of variation to the other group, on the other hand, asked students to initially try to directly aim for the final goal, and in subsequent play that to try to plan for sub-goals as means of preparatory work. When instructed not to plan, the intention was that even those that were naturally inclined to do it, would deliberately postpone such an activity for until after they play. This approach was intended to underline the difference of whether to plan before a meeting or not.

Scenario 3 explored different approaches to the conversation with regard to who dominates it. The original activity sheet suggested first dominating and then letting others dominate, as this was done in all previous scenarios. The introduction of variation provided goals that suggested supporting someone else in the conversation and then subsequently striving for a better balance. This allowed students to clearly distinguish the effects of taking sides in a conversation. The focus of variation in this case was on generalization on the introduction of personal bias in a conversation.

This found its continuation in Scenario 4, where it was intended to allow for clearer generalization on the role of personal influence, specific suggestions for who to liaison with. Whereas the original instructions suggested "building an alliance with one or more characters for a strategic purpose", generalization was strengthened by explicitly suggesting to ally consecutively with the two different characters that opposed each-other to a strongest degree. This allowed for more controlled and exhaustive variation, focusing on the two opposing sides in the conversation.

Finally, variation in Scenario 5 was intended to allow for clearer separation of performance from business results. To do that, students were encouraged to aim for as balanced business score (regarding its components) as possible. The intention was that while they still play for high results, they would aim for balanced business score components, which would allow the power and tension scores to be separated from the idea-related business scores.

The last section of the activity sheets was designed to encourage students to reflect on what they had learned in the scenario. This included questions that students were asked to answer before playing in order to plan for their success and others that were intended for after playing as a means of retrospective reflection. The success planning involved an engagement strategy for each meeting. It focused on intended ideas to be passed and balance between signals sent to people and ideas. The reflective questions concerned satisfaction with results, what styles of leadership were used and what parallels to reality students could make.

3.3 Written Assessment Test

These tests were developed in collaboration between the researchers and the course lecturer. A mix of open-ended questions and fixed-response questions were used to try to capture different levels of learning [7]. The students were given 10 minutes for the test, so answers had to be short.

The first three questions (Q1, Q2 and Q3) were open-ended. Q1 aimed at capturing the respondent's general conception of leadership. Q2 presented a situation that students were expected to be familiar with. It depicted a situation in which the student was part of a team that had to deliver, but there is tension within the team, a theme covered by Scenario 2. The experience of variation in Scenario 2 was expected to lead to a greater awareness of the need to break down solutions into sub-goals. Those who experienced variation in Scenarios 3 and 4 were expected to recognize their role as only a factor in collective decision making, rather than individual decision maker. Finally, students who experienced variation in Scenario 5 were expected to consider all three aspects that corresponded to the business score: financial performance, customer satisfaction and employee morale. Q3 presented another problem situation. Students were required to explain how they would resolve it. Similar to the previous question, the experience of variation in Scenarios 3 and 4 was expected to lead to greater appreciation for collective decision-making and variation in Scenario 5 – again appreciation for the corresponding three business aspects.

Q4 included 7 statements about leadership: students were required to indicate their level of agreement a Likert style response scale with five options from 'agree' to 'disagree'. For four of the statements (Q4i, Q4iii, Q4iv, Q4v, Q4vi and Q4vii) it was expected that students in the experimental group were more likely to agree. For one statement (Q4ii), it was expected that students in the experimental group were more likely to disagree.

4 Results

The results of this study are reported in three sub-sections: student involvement, in-game performance scoring and answers to the written assessments.

4.1 Student Involvement

While some students played the game quite actively (one student in particular playing as many as 75 games over all scenarios), a number of others did not engage with the game at all i.e. there was no data collected for 14 out of the 60 students (23%).

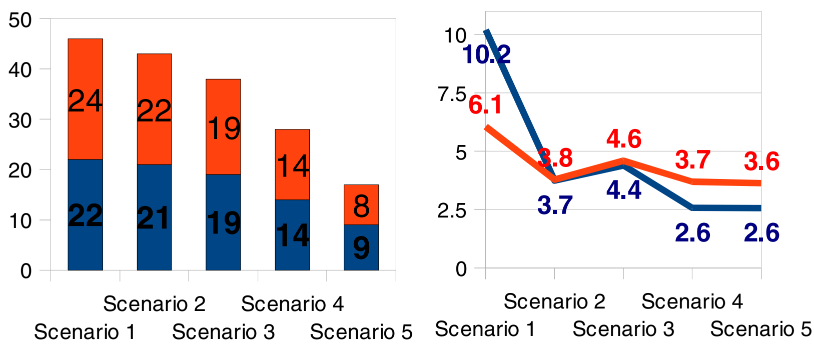

Fig. 2. (left) Number of participants; (right) Average number of plays per participant, according to scenario and experimental group

The students showed gradual reduction in their involvement with the game, both in terms of scenarios played (see Fig 2a) and number of plays per scenario (see Fig. 2b). The number of students that played the game fell from 38 for Scenario 3 to 28 for Scenario 4 and only 17 for Scenario 5. Over the prolonged use of the simulation game, students seemed to prefer to play between 3 and 4 games per scenario.

Since a group of students (23%) did not play the game, it was decided that a third group should be formed. This non-player group is treated as an additional group in the analyses below. In order for variation to work, students had to have at least several different experiences with the game. For this reason, it was decided to include in the non player group also students that played the game just a few times. This was defined as students who played Scenario 1 up to two times and subsequent scenarios no more than once. As this group was not created through random allocation, the results related to this group should be treated with caution e.g. it's possible that differences are due to factors other than game play.

4.2 Written Assessment

Pre- and post-study written tests were used to measure student learning. Of all 60 students on the course, 57 filled in the pre-test assessment sheets. 50 filled in the post-test assessment sheets. A total of 47 students managed to complete both the pre and post-test written assessment. This resulted in the following sample sizes for each of the conditions: 17 students in the experiment group, 16 students in the control group and 14 students in the non-player group. This section presents the results of the analysis of the responses to the written assessment questions.

The first three open-ended questions were analysed using content analysis. Written answers were examined in order to design a bespoke coding scheme that would capture all content within the answers. After that each response was coded with a set of binary codes for each question. The unit of analysis was words for Q1 and sentenced for Q2 and Q3. Non-hierarchical coding was used, meaning that certain content could be assigned several codes.

There was a noticeable change from the pre- to post-test session in the students' answers to the open questions with students providing shorter answers in the post-test sessions. During the in-depth interviews, students have explained this in terms of the gradual erosion of their motivation. Further findings are outlined in the Table 1 below.

Table 1. Questions and corresponding findings after the application of content analysis

Question (unit of analysis)	Finding
Q1. How do you understand leadership? What example could you name? (word)	Mentions of "influence" in responses showed a 32% increase when describing leadership from 15% at the beginning of the study to 47% at its end. A 24% drop in examples of leadership provided – from 62% to 38%. However, there were no statistically significant differences across the experimental groups.
Q2. You are working together with two other colleagues on a project. One of these colleagues regularly skips meetings and seems distracted when you discuss the project. His work has been of poor quality. What would you do? (sentence)	No observable tendency or other findings.
Q3. You work in a start-up with two other people. A major client has delayed a planned payment and as a result the company in turn cannot make a payment due by the end of the day. Your colleagues start an argument whether the company should stop working with that client. What would you do? (sentence)	The group subjected to variation shifted its focus of attention towards the customer, whereas the control and non-playing group shifted their focus in the other direction: towards the company.

Words were used as unit of analysis of Q1. Analysis of the vocabulary, used by students' responses to Q1, showed that the percentage of student responses talking about *influence* has increased from 15% at the beginning of the study to 47% at its end. This change was stronger in the variation and control group (with 47% of students in the variation group using *influence* to describe leadership) and weaker in the non-player group (where the term was used in 21% of the responses). Percentage representation of changes can be seen in Fig 3a.

There was also a noticeable drop in number of students that provided an example in their answers as it was requested. Whereas at the beginning of the study 62% from the considered 47 sets of beginning and end tests provided some form of an example, at the end of the study only 38% did. One possible explanation for this could relate it to the decrease in student engagement by the end of the study.

Q2 and Q3 were problem cases and thus the chosen unit of analysis was sentences. Content analysis of Q2 did not lead to any observable tendency or other findings. Fig. 3b above shows change from the pre- to the post-test session in mentions of each stakeholder type in the responses to Q3. It suggests that those students who experienced variation were more inclined in the post-test session to mention customers and less inclined to mention the team. Students in the non player and control groups showed the reverse trend: they were less likely in the post-test session to mention the customer and more likely to mention the team. Both in the experimental and non player group there were fewer mentions of the creditor in the post-test session.

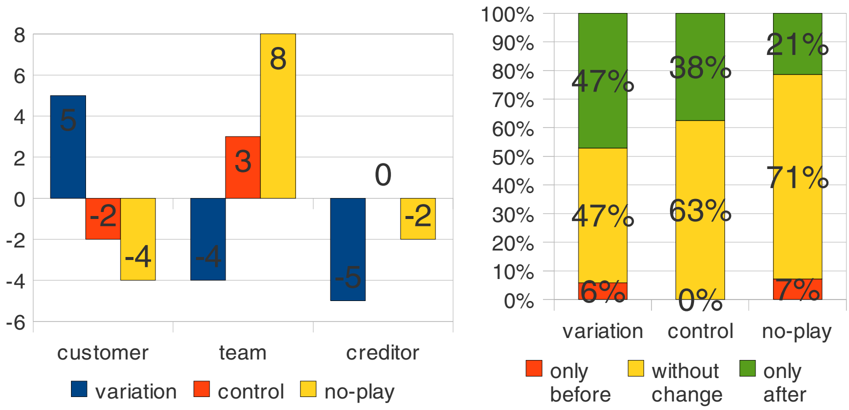

Fig. 3. Change in students responses from pre- to post-test sessions (left) employing influence to explain leadership in Q1; (right) mentioning particular stakeholders in response to the situation in Q3

Of the 47 students that completed the pre- and post- test written assessments, 3 did not provide complete responses to all the Likert-scale questions either. Thus, 44 remained in the analysis. This resulted in reduced group sizes – for the experimental: 15 participants, control: 15 participants, and non-playing: 14. A series of one-way analysis of variances found no statistically significant effects for these questions (the F and P values are shown in Table 2).

Table 2. ANOVA results for the ordinal Likert-scale questions (in all cases, d.f. = 2)

Question	**F**	**P**
Q4i. Anyone can become a leader.	2.61	0.0857
Q4ii. Leaders either focus on tasks or people.	0.77	0.4709
Q4iii. The same leadership principles apply in all cultures.	0.02	0.9793
Q4iv. Leadership is about getting people to do the right tasks.	1.06	0.3561
Q4v. Leadership is about gaining influence over people.	0.13	0.8777
Q4vi. Leadership is about involving others in idea generation and decision-making processes.	0.72	0.4906
Q4vii. Leadership is about empathy and objectivity.	0.07	0.9324

4.3 In-Depth Interviews

In this sub-section, we report some qualitative results from the semi-structured interviews. During these interviews, students were asked about the different perceptions and approaches when playing the game.

In the interviews, some students explained why they did not engage with the game as much as expected. Two reasons were identified. Some students said that, initially, they were unsure of the relevance of the simulation game to their final class grades and, to be on the safe side, they engaged with the game actively. However, later on they realised that their game scores would not affect their class grades. This eased the pressure they felt to play the game. A second reason, reported by students, concerned increased responsibilities as the term progressed, leaving less time to play the game.

During the interviews, two different ways of engaging with the game emerged. Some students took a more exploratory approach to playing the game, trying different strategies to see what happens. Arguably this allowed them to experience greater variation. Others focused mostly on the scores they could achieve which didn't allow them to experience variation in the intended way.

Possibly related to their approaches to the game, the way students approached activity sheets followed in two distinct patterns. Following one of these two approaches, some students, much as it was intended when the activity sheets were designed, read the first activity sheet to understand its structure and from then on used the other activity sheets selectively, according to the perceived value of each of their sections. For different students this would include considering the ideas table, but noticeably goals and hints where variation was embedded. Several students complained that initially they wrote down the answers in their success planning and reflective questions sections, but because there wasn't a dedicated discussion on each of them, they lost their motivation to work on these sections during subsequent weeks. Discussions during weekly sessions were short and thus did not relate to each reflective questions in detail.

According to the other way, reported by students in the depth interviews, some of them played the game ad-hoc and not having considered the activity sheets at all. This had the effect of neutralizing any differences between the groups, related to variation, as introduced within the study design.

5 Discussion and Conclusion

The objective of this study was to examine how variation theory could improve the learning experience of a serious game. It has provided insights into some of the practical and methodological difficulties that can be encountered in this process.

Answers to Q1 showed that students were more inclined to describe leadership in terms of influence, which indicates how their way of thinking of the subject has come closer to that of researchers in the field, see in e.g. [8]. Although this was a common trend between all the groups, it was stronger with those playing the game, which indicates that the game could have helped them to reconfirm what they've been taught in the class.

These results in Q3 could be attributed to experiencing variation in scenarios 3, 4 and 5. The first two of these scenarios emphasized the role of others in the decision-making process whereas Scenario 5 focused on awareness about the three business aspects: financial performance, customer satisfaction and employee morale.

In this study, we employed the activity sheets as supplementary materials. One problem was that many students ignored these sheets and thus those in the experimental condition did not experience variation at all. One particular way to overcome this is to embed variation more directly into the game. At least for the purposes of studying the effects of variation, it is important to ensure that variation is embedded directly into the game, so students cannot find a way around it.

Another clear problem in capturing the effects of variation concerns the declining levels of student involvement over time. This meant that the sample size was declining for later the scenarios where some of the variation was employed.

Some students indicated that they were disinclined to participate given the fact that their game-based learning would not be assessed in the final course assessment, especially when the amount of work from other courses increased. It would not be easy to change this fact in future studies. University ethical guidelines require that students are assessed only on learning experiences they all have equal access to. If students are allocated to different conditions in a study design, it is not possible then to assess them on the content of the learning experiences in those conditions.

An alternative solution would be to use other kinds of incentives. For example, in certain contexts, it may be possible to give the students course credits for fully participating in the study. The reduction in the length of supplementary learning materials (like the activity sheets) would be a straightforward way to help increase student motivation. According to student feedback, activity sheets need to be made shorter, preferably restricted to one page. The sections about learning objectives, scenario background and context and learning refection could be removed from them and, if found necessary, communicated to students in a different way.

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Serious Game for Introductory Programming

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Abstract. For beginners in computer programming, the learning curve can be in many cases quite steep, especially if it is their first contact with this area. Plus, the traditional learning methodologies are usually based on doing countless exercises that aim to cover many areas, but are often disconnected from each other and can become tiresome, as they offer little immediate rewards to the student.

Nowadays serious games technology offers tools that may have potential to help computer programming students to become more engaged on their learning through a `learn while having fun' approach. This paper aims to generally describe our approach on the creation of a platform for deploying serious computer games for the teaching of any computer programming language. We will begin by describing the game mechanics, followed by the general system architecture and its data model, finalizing with a small conclusion.

Keywords: serious games, programming, e-learning, unity3d, domjudge.

1 Introduction

Serious computer games have emerged in recent history, but serious games have always been part of human culture as far as we know. Of course in ancient times, serious games took the shape of campfire fables told by grown ups to children to pass some kind of knowledge. Through these fables children were able to better understand the serious concepts being passed on to them instead of just being told directly.

Today's computer ever developing technology allows us to create more and more complex systems that can help us use gaming for learning purposes, allowing us to go beyond the simple fables told in the ancient times. Learning how to program can be enhanced and encouraged through this type of approach, by creating a serious game that is both a conduit of knowledge and experience and at the same time a fun task. But it is important to keep in mind that the serious games' emphasis must be placed on the educational objectives rather than the fun part, for they are primarily tools of education and not games to entertain [1].

The challenge we address in this paper is the building of a computer platform that allows the deployment of serious games that aim to assist on the learning of programming fundamentals with as much level of customization as possible, when creating a new game. Also, it has to allow the teacher to supervise, follow up students' progress and give them feedback. For this end, the game engine Unity3D was selected due to its rich features, its growing community, available resources and its ability to be deployed on the Web [2].

M. Ma, M. Fradinho Oliveira, J. Madeiras Pereira (Eds.): SGDA 2011, LNCS 6944, pp. 61–71, 2011.

2 Related Works

Inside the digital domain, a serious game can be defined as a contest played with a computer, which uses entertainment to develop training for military and corporative skills, education or use on health, public policy and strategic communication [15]. In education, research and interest has grown rapidly, and this can be noticed, as many European projects concern on design of educational games [14].

It is a well documented fact that there is a problem with Computer systems majors [8], since universities experiment a decrease on student demand [12], and abandonment because the low motivation from students towards difficult programming courses [14]. As this is of great concern between researches, heads are being turn towards using video games as a motivator for students in computer curricula and research [10].

Reviewing the work done by others brought on the table ideas on what can be applied onto our approach for the programming serious game. There are different approaches that researches have taken to tackle the problem on student motivation for Computer Science courses. Projects like Alice [9] and MUPPETS [13] propose software tools that allow students to create animations and virtual worlds through “programming-like" graphic commands. Another approach is the one taken by researchers at the University of North Carolina with the Games2Learn project in which they are making undergraduate students create small games about programming principles for novice students, like the game Wu's Castle [10] that helps students understand better the concepts of arrays and loops.

With a bigger gaming approach there are projects like IBM's Robocode, now public via SourceForge project, a framework for programming tanks and compete against tanks of other players in a multi-user environment [13]. Epsitec develops games like Colobot [11] where the objective is to solve several missions, which range from gathering resources, building structures, commanding robots to perform tasks and defend the land, a complete game in 3D. The Meadow is a game where developers created a custom engine to meet their university course expectations, where students control virtual sheep via C-Sheep programming language [8].

Authors agree that the new generation of students, the \Plug & Play" generation is more guided towards visuals and 3D environments, and so there is an interest on these kinds of interfaces to meet the expectations from these students [8]. On our approach, we decided to try with a 3D world since immersion is an important aspect in our project that may help students to continue with their programming studies. Also to meet the requirements of the courses given at the University of Porto, we are developing the project as an open platform, that could adapt to any programming paradigm and languages used at the faculty.

A tool made in house can also be designed to attend the needs of the specific population of the university and be modeled to reach the academic objectives of their courses.

3 The Mechanics

Every game has a set of rules that indicates how it is meant to be played by the players - the game mechanics - serving as a basis for the gameplay; if the mechanics are designed focused on the player, the final game may have a stronger quality.

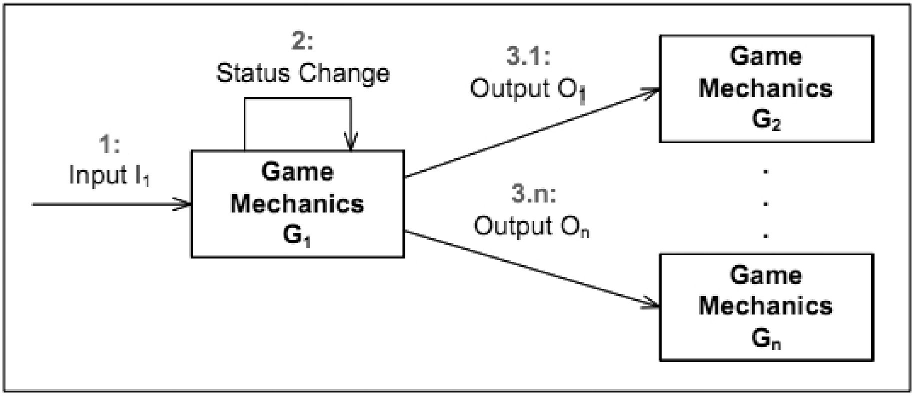

Fig. 1. Game mechanics interaction

Mechanics of serious games are similar to those found on commercial video games, but since the main objective of each is different, there are some differences to be aware. Whereas commercial video games' main purpose is to entertain and the mechanic used in them allows for various modes of play, they incorporate outcomes of leisure along with strong focus on presentation and storyline; serious games for education have a different path. Educational games focus on learning outcomes that are dependent upon an appropriate pedagogy and the underlying game mechanics and how the content is integrated into the game so the learning is intrinsic to play [4].

The system proposed in this paper is an educational platform providing serious games designed taking in consideration a set of specifications to meet the academic objectives to which it is aimed. Therefore, the game mechanics for this platform have to be designed and implemented with flexibility to provide distinct learning objectives for different programming courses. This paper will cover the core mechanics proposed for the nature of the serious games to be provided by the platform.

3.1 Project Specification

The project is being developed with an instructive stance, and since the definition of serious games differ from that of commercial video games, the specifications and objectives are defined clearly within the academic vision of the course.

The core mechanic should be mostly about solving problems via code understanding and programming, adding playful mechanics seen in commercial games as a way to aid in the immersion of the player and improve a continued use of the game. During programming it is common to have errors; the mechanic has to support this approach without penalizing the player too much. The design should ensure that the player keeps trying to solve the exercise, meaning that motivation is at hand and that the challenge does not compromise the advance of the student within the game. The general design of the game mechanics must be open enough to be able to cover other languages or technology courses. Teachers should be able to customize the game design to adapt it to their courses. Therefore, the design of the game should be general and open, in order to allow for further edition of the design, while keeping the flow and script of the game.

3.2 Proposed Core Mechanics

Given the three main specifications of the project, it can be said that the game core mechanic is basically to interact with the world via coding and scripting. The game is based on the programming fundamentals class, so the main learning objective is to use programming concepts to advance through the game. This section describes the core elements of the mechanics that meet the aforementioned specifications.

- The player-token of the game is a character and its robot companion. This token receives input from the player to interact with the virtual world of the game. The main character is the one that interacts with the virtual world while the robot sidekick is the one that gives academic advice to the player and prompts the main mechanic of the game: programming;
- The main interaction with the world is done by coding through the terminals scattered in the game. Each terminal presents one or various programming quests to solve. The correct solution of a problem triggers an interaction with the objects on the room, giving access to other areas, clear a hazardous object of the area, or get more info of the game plot and story. If the obligatory quests are not cleared the player will not be able to advance;
- The world of the game is designed as a series of levels that have one to N number of interconnected rooms to explore. The rooms have several kinds of objects that construct a general puzzle. To clear it and continue the game, players have to solve the programming tasks;
- Players can keep a mini inventory of items found during exploration of the levels. Items can be used to aid the player, to complete other quests or educative information about the problems that are being solved;
- Players increase their global and level score depending on the quests solved within the level. Getting some special items and solving optional harder quests increases the final score for the player. The score can be followed by students and teachers;
- Penalization to the player comes as reduction of points from the score. A quest has a number of points assigned if completed successfully. Incorrect code input has a limited point reduction from the full point value of each quest. A compiling error has minimal effects since it may be the most common problem. Several failed attempts of a compiled code mean more points deducted from the initial value of the quest;
- If the player reaches a limit number of tries, another path can be open to help develop the abilities of the student. This will bring a series of rooms that would have easier and guided challenges to helps student develop skills. At the end the character gets back to the room he was supposed to reach, to try to fulfill the normal quests;
- Code clues come from recovered logs, from the Robot Sidekick or by intervention of the teacher of the course. Two types of help are planned. The first is a set of tips and lessons that give a little bit more insight on the programming concepts seen during the level. The second one is the set messages that the Robot Sidekick or teacher can give as tips if the player starts to fail at the quests.

These mechanics are the ones that define the main functionality of the game and serve as a basis to have an overall open mechanics that can be applied to other courses. By open it is meant that on a matured version of the game, a group of academic staff could edit it to construct a new game using concepts of other informatics areas and courses. The instructors editing the game could apply other type of problems, tutorials and clues to the game to prepare it for another class, without having to edit or design the core functionalities of it. This is the main problem we seek to solve and an important objective when designing the game mechanics.

4 The Implementation

In order to successfully implement the mechanics discussed in the previous chapter, it was decided to use a client-server architecture, as shown in figure 2. From this image three distinct packages are visible:

These packages are connected to each other through either a local or a wide area network, such as the Internet. At the core of this platform the server package manages all aspects of the platform. The client package is the interface which users use to interact with the platform and finally, the DOMjudge package handles all source code evaluation. These components will be further explained in the next sections.

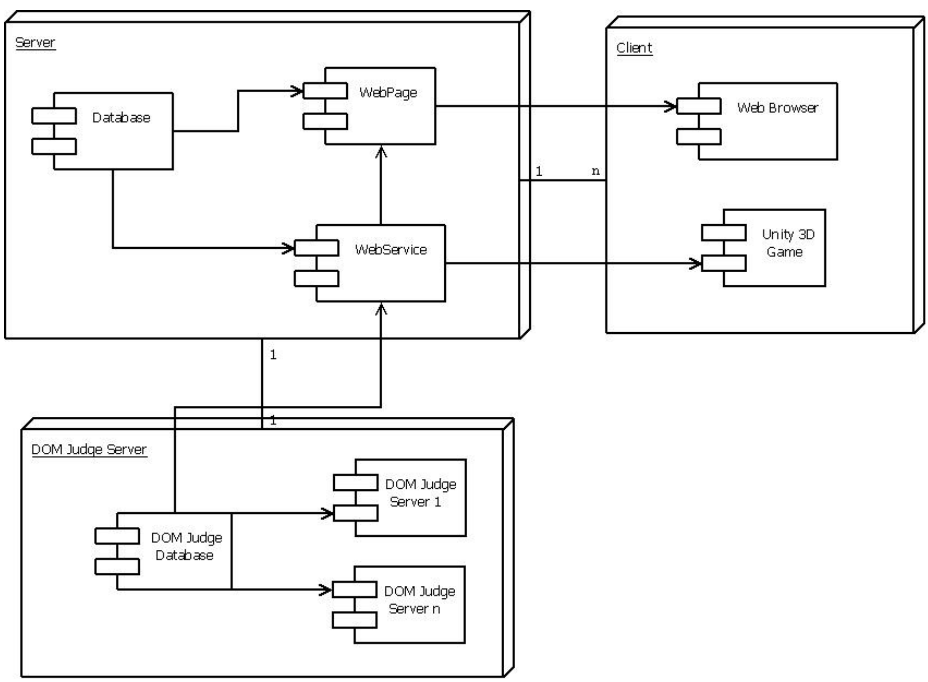

Fig. 2. Platform architecture

At this stage, both the server package and the client package have been partially implemented, and a prototype has been created as a proof of concept. The server package is still missing the web page, but the web service and database have been implemented. On the other hand, the client, although working well, will only be considered fully implemented once the server is complete and functional.

4.1 Server Package

The server as whole can be described as the heart of this project, pumping data to its components and other packages. Its mission is to interact with the other packages by managing and processing all information. This package is composed by three components:

– Web page - This component serves two main purposes: first it serves as the way through which the teacher creates and configures the game with tools like map editor and quest/exercise editor (more on this in the next chapter), and secondly it serves as a conduit for the teacher to follow his students progress through the game as well as it allows each student to see his own progress and receive feedback from his teacher;
– Database - This is where all the data regarding both the web page and the game is stored;
– Web service - This component handles all major game logic, controlling the game behavior and feeding it with all the necessary data required to build the virtual world with which players interact. This includes map data, quests (exercises), objects, tips (knowledge teachers may wish to add as a an extra way of helping their students with the exercises) and game plot information.

4.2 Client Package

To access the web page and the game, the user simply needs a recent version of any of today's browsers like Mozilla Firefox, Opera, Internet Explorer, etc.

The game itself was created through Unity3D Game Engine (free version) which allows the deployment of rich 3D applications that can be embedded into web pages. Through this functionality, the game will be able to be embedded into the web page, providing an all-in-one package for the students, automating and simplifying its access. This means, by login into the web page, the student automatically has access to the game without any need for manual software installation other than the Unity3D Web Player plug-in for web browsers.

The game itself is able to generate distinct games (but within the same scope) on run time, based on the data it receives from the web service. The game is meant to be mostly an end terminal and as such, most decisions are made on the server side, as explained before. This greatly limits the possibility of cheating by attempting to alter the game normal functionality.

The game starts by requesting game settings information, like the name of game or the location of the textures used in the game. The selected textures are then pulled back to the game for later usage in building the virtual world. Once this is done, a menu appears requesting the player to log in. By logging into the game, the server creates a session (or regenerates it if one was already assigned to that particular account) and returns the session and profile information back to the player. After logging in successfully the player can select one of ten different profiles, each one giving him the chance to start the game from scratch.

Upon selecting a profile, the game shows introductory menus that, depending on what was defined on the database, can show for example the initial plot/story information and after the intro a menu describing the game controls and how to interact with the game is shown.

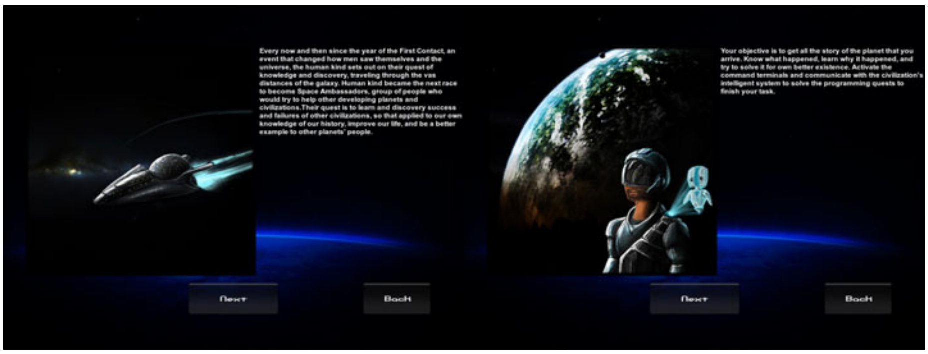

Fig. 3. Intro menus present in the prototype

Following the help menu, depending on the profile settings, the game requests the map where the player is supposed to be and a virtual 3D world is generated. Within this newly created world, the player is able to interact with several objects and move freely through it. These objects are:

- Quest terminals - These objects are the way through which players accept programming exercises which allows them to progress in the game, like enabling or disabling another object that prevents them from continuing the game, and by which they submit the program they believe to be a solution to the exercise;
- Data pads - These can be used to extend the game plot or give information about an exercise to help the player solve the problem;
- Force fields - These can be placed in narrow places, for example to prevent access to an area;
- Teleporters - These teleport the player to a specific location;
- Lights - These provide illumination to the scene;
- Doors - These allow the player to travel between maps;
- End game object - It looks like a door but it is meant to be the game exit, the final door, and by using it, a menu appears congratulating the player for completing the game.

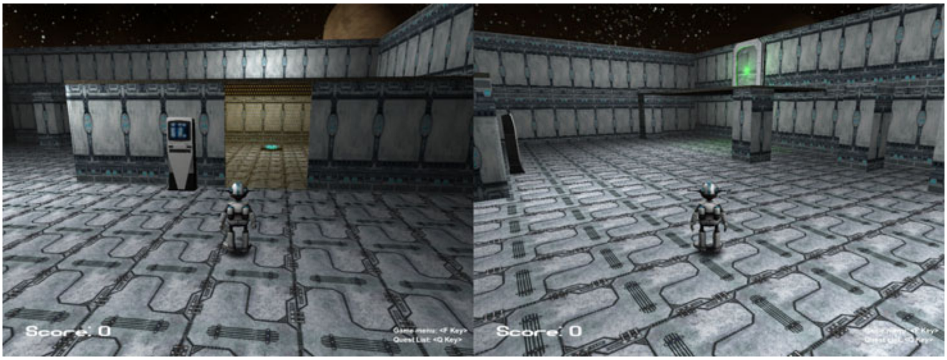

Fig. 4. In-game images

The quests, as mentioned before, are in fact computer programming exercises presented in a way that it feels it is part of the plot and the player needs to solve it if he desires to continue his adventure. Figure 4 shows two images of the first map of the prototype created to test this platform. The image on the left shows a terminal and to the right, a force field. The terminal contains the following quest:

Disable the Force Field

This force field receives energy from five power generators.

To bring it down, get the value of the five power generators and return the number of generator that has the least amount of energy available.

Objective: Write a program that receives 5 numbers and returns the position of the smallest of all.

Behind the force fields there is a teleporter which needs to be activated by another terminal. After activating and using the teleporter, the player is teleported above and has to hop around the room, like a normal platform game, to reach the door that leads to the next room. The exercises required solutions to be programmed in C++ language, but could easily be any other language. More on this reviewed on the next section.

4.3 DOMjudge Package

In order to evaluate the programming exercises, the selected system was DOMjudge, which is known for running programming contests like the ACM-ICPC regional and world championship programming contests [7].

The basic functioning of the automatic assessment can be described as follows:

– A solution for a problem is submitted by a team and stored in the database. Upon compiling and running, both compiler and program outputs will be stored and accepted or rejected;
– The first available Judgehost checks a not judged submission against the input-output data and marks it as judged;
– The result is automatically recorded and the team can view the result and the scoreboard is updated.

DOMjudge benefits from a distributed architecture, based on a client-server framework. Its foundation lays on the main DOMjudge server, which runs a MySQL database for keeping the submissions and in a variable number of Judgehosts that can be set up to mark the submissions (as it is shown in figure 2). The authors developed the system with security as one of the main concerns, providing detailed documentation on how to keep the installation secure and fail-proof [6].

DOMjudge is open-source, supports a wide array of programming languages and can be easily configured to support more. Moreover, a computer-based assessment system that integrates with Moodle was already developed and tested in this faculty taking advantage from this system [5]. It features a secure connection to a DOMjudge server through the use of web services and not only it serves as a proof of concept, but also as a basis for applying those web services in the game.

So, at each submission the system first starts by asking the server to accept the quest and if all goes well the profile is updated by setting the quest as an accepted quest. At this point a solution can be submitted in order to solve the problem, but only one at a time. Once a solution is submitted, the web service verifies if it is a valid submission and if so, adds it to the DOMjudge database. The DOMjudge then treats the source code, as described above. The game, on the other hand, will go into a state of waiting for a result, in which at each every few seconds sends a request to the web service for a status update on the solution result. Once the result comes in, it is processed in the web service, making all the necessary logic, and the game mimics the same logic, but the web service takes precedence over the game data.

5 Tools Used

To accomplish this project several tools are being used:

The web service is programmed in C# over .NET 4.0 Framework and to connect to the databases, MySQL Connector 3.3.6 is being used. The database used on both packages are MySQL >= 5.2. In order to run the web service, IIS 5.0 and 7.0 were tested and work perfectly over Microsoft Windows XP Professional or Microsoft Windows 7 Professional.

As for the game, it is supported by the engine Unity3D, which allows web deployment. This engine also supports both Microsoft Windows Operative Systems as well as Mac OS X, which both were tested and ran flawlessly during the tests to the prototype.

The DOMjudge servers, during the tests, were deployed on two virtual machines running Debian GNU/Linux, while the database and control website were on a third virtual machine, also running Debian GNU/Linux.

6 Conclusions and Future Work

At this moment, both the game and the web service are implemented, remaining the website with its game generation and teacher student interaction features.

In order to test the platform, a game prototype was implemented and tested by a group of students. The participants' feedback on the game was very positive and at the end of the tests each of them filled a survey. This survey gave a new perspective, showing what still needs to be improved, like having more types of objects with which to interact with, adding sound to the game and the amount of information regarding the solutions evaluation results.

The web page with its configuration capabilities and teacher/students interaction is the main part that remains to be completed. As this gets implemented, the prototype will come in handy to test and help deciding the best ways the implementation process should follow. These include changing map formats that allow different and richer map layouts, communication protocols, exception handling, more objects, different ways to interact with quests and the way they behave upon completion.

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Game Design Evaluation Study for Student Integration

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Abstract. This paper presents the evaluation of a serious game project, where the primary goal was to develop a set of collaborative game levels on a virtual campus, in order to help the integration process of newcomer students to the university. The global activities that can be performed by the students were designed for a group approach in a controlled virtual environment. For the present work we have selected Second Life for the implementation of these collaborative "game levels". A prototype evaluation was conducted to collect results with a sample of university students. With this data, some conclusions were extracted in order to delineate future developments.

Keywords: Student integration, virtual worlds, second life, serious game development, game design, collaborative games, group dynamics, problem solving.

1 Introduction

The integration of newcomer students to the university can be an overwhelming experience, especially for individuals with a more introverted personality in large courses which, in extreme cases, can even lead to the abandonment of the course. In an attempt to help student's integration process, the Faculty of Engineering of the University of Porto (FEUP), at Portugal has provided several activities organised in a preliminary mandatory course named "Projecto FEUP" with 2 ECTS (European Credit Transfer and Accumulation System)[1].

Having in consideration the huge impact and constant evolution of online communities, social networks and virtual worlds for collaborative activities, the use of these realities in the context of student integration seems like an interesting option. Although several technologies have been analysed for this project, like for instance Unity, UDK, Torque and XNA, the Second Life "metaverse" appears to be a more flexible and fast way to implement our needs in the context of virtual simulations and simple multiplayer games.

Other activities could obviously be implemented outside the scope of a virtual context, but in this case, with near one thousand new students each year, the infrastructure, costs and time needed to implement could be heavily reduced with the use of a digital serious game.

Recently, with creation of a virtual place of Porto University in Second Life, an additional opportunity to reinforce this multitude of approaches has emerged. The new objective is to design and implement, in a parcel of the private region (island), a

M. Ma, M. Fradinho Oliveira, J. Madeiras Pereira (Eds.): SGDA 2011, LNCS 6944, pp. 72–82, 2011.

virtual space for students to meet and interact with each others, through a set of specific digital game levels that need to be played in team.

Another important goal is to promote common experiences between newcomer students and promote their communication and collaboration. To achieve that, each student should create their own avatar with a name and personal characteristics and complete a series of challenges – in future editions of the course, these challenges may even contribute to the final grade (as a reward mechanism) - possibly there will be no penalisation associated, that is, there would be other ways to get the same points of grade with other activities.

With all this in mind, the core task of this work involves the development of several collaborative game levels with very simple and specific objectives. The best approach to implement a suitable interaction design and adequate game mechanics in this work are not obvious, but a survey on some works that are related with the area of team integration and collaborative game design helped to shape structural concepts.

2 Related Work

A project called eScape [2-3] studied and analysed the adequate implementation of puzzle games in a virtual multiplayer environment. The experiment was applied to a total of six groups of four players, where each one was in an isolated room. It also collected the interaction player data trough the use of several methods. The conclusions that resulted from this work provided a better perception and knowledge in multiplayer puzzle design and collaborative gaming in general.

Another project named EduTeams [4] was initially developed as a case study, becoming afterwards a commercial product. The main goal was to broaden the core skills of students in elementary and secondary schools. That includes teamwork, communication, planning, problem solving and logical thinking. The result was a multiplayer system with several team based activities. During the evaluation of the case study, professors reported some benefits in classroom. They perceived that some students were more motivated, more extroverted and better aware of the importance of teamwork.

Revolution [5] is another serious game that gathers students in a virtual world. Here, the main objective is to give players better perceptions of the American Revolution, granting the possibility to interact as an inhabitant character of the colonial city of Williamsburg. This game uses role-playing principles and provides seven class options of characters and a non-linear narrative story determined by the player's choices, resulting in a complex simulation of the political and social system of that time. Nevertheless, the results of this project revelled that the gap between experienced and non-experienced users can compromise the end result and experience of the simulation.

Serious games are also used for integration purposes. One example of that is game developed by the company PT Inovação [7] that has the objective of adapt recently arrived workers to their new environment and with extremely satisfactory results.

The Second Life environment is often used by universities and schools for teaching and research, as educators are constantly looking for the potential of games in virtual worlds to foster experimental and constructivist learning methodologies. Ohio

University within the Science and Technology Enrichment for Appalachian Middle-schoolers (STEAM) project developed a series of educational games for science classrooms. Some examples are the Fruit Fly Genetics and Weather Challenge [6].

3 Game Concept – Ideas and Requirements

The project is codenamed "FEUP Adventure" and its main purpose is to be a "lightweight" experience generator for newcomer students at FEUP.

As the whole purpose of the exercise is to provide amicable experiences to users, it follows naturally that the game should be played in teams of humans, in a cooperative and adversarial environment. Other parts of the "Projecto FEUP" course team students into teams of 6 to 8 players and these teams should preferably be kept and used to enhance "team-effect".

One of the problems of the project was the high number of students that should be integrated under the virtual platform. Each year FEUP has more than 800 newcomer students, so, coping with such high numbers is a requirement and as such games should have several rounds and or different levels to foster all *vs.* all experiences. Naturally, levels should have at least variety and preferably increasing complexity in order to create stimulating challenges.

Another strong idea is to have some kind of reward mechanism: in similar projects, some reports state users tend to lose focus and just wander around when there is no reward or competition involved.

It was also considered that joining "Projecto FEUP" and "Aventura FEUP" with the previously existent Second Life island branded with the University of Porto (U.P.), was interesting in order to foster both activities and would allow for the necessary basis for development of the game. Naturally, the development platform should have near real time response and some kind of physics engine or at least interactions should be easy. The 3D part and the persistent world were considered optional.

It was also considered that fostering communications was interesting and students should preferably (but not mandatorily) seated in the same classroom. As with other "classes", timing is of the essence and timing constraints should be in place, also in order to cope with the very large number of students.

Another idea is that not all students would be familiar with these technologies and that a small trial area (that would not break the novelty) would be interesting. Users should thus have an area to test physics outside of the gameplay.

As with many other games, it was considered that teams should change sides in the games and that the games should, of course, be balanced and equitable. Circumventing game rules and un-ethical behaviours should be avoided and punished in the game rules.

Also due to the large number of students involved, preferably, little or no supervision should be needed. There may also be in-game supervision for remote players.

3.1 Game Concept - Design

The proposed solution to coping with many students is set up the games into groups of 4 teams. A competition between teams is used to reinforce the focus on the tasks ahead, where a classification system is implemented and rewards are available accordingly with the results.

Three levels were found to be an adequate number for the test purposes at hand. Each level needs to be played by two teams (acting team and opposite team), and the three different levels are played with distinct teams, assuring that all teams will face each other (as depicted in table 1). For example, initially, team A will oppose team B and simultaneously, team C will play against team D.

Table 1. Team Distribution by Level

	Teams
Level 1	A *vs.* B C *vs.* D
Level 2	A *vs.* C B *vs.* D
Level 3	A *vs.* D B *vs.* C

The proposed virtual space has three game rooms and a free practice area (Fig. 1). The levels are based in physics, moving objects and orienting the avatar of the player's character. There will be no flying available in the parcel due the nature of the levels, and therefore, the practice area will allow the students to become more aware of the interaction with the avatar and test the actual game mechanics before the game begins.

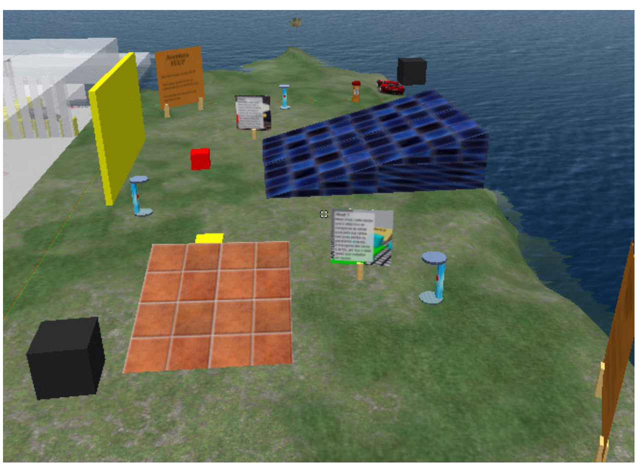


Fig. 1. Practice area in the FEUP Adventure game

3.2 Proposed Game Levels

Each level is composed by a specific set of rules and objectives, designed to promote the creation of collaborative and adversarial experiences. Levels are to be simple but allow different strategies, still demanding human communication, thus promoting interaction among colleagues.

The game at Level 1 is called "Crate Carrier" (see Fig. 2) and is a 6 *vs.* 6 player level, where the objective is to score the most points possible during a limited time (e.g. 5 minutes). Each team will score points by carrying crates over their ramp and dropping them into a moving platform. To ensure a balanced game for each team, the position of the objects is symmetrical and in the beginning all team members will start on the top of their ramp. The crates were designed to be heavy objects, hard to move and control singlehandedly. To score points it is also required synchronisation between the players, as they must all push together at the exact time the platform passes underneath. This level offers several strategies that can be adopted by the teams, but players can not stand in the opponent ramp.

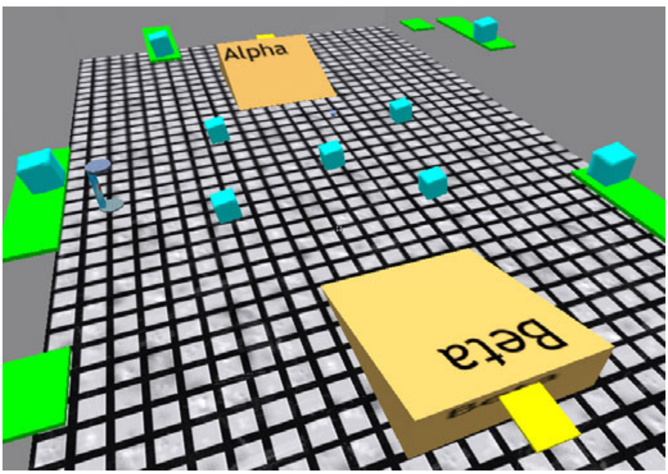


Fig. 2. Map for level 1 of the FEUP Adventure – "Crate Carrier"

Level 2 is called "Sliding Spheres" (see Fig. 3) and it is proposed that four players of a team play and the objective is to score the points during a short limited time (e.g. two and a half minutes). Each team will score points by direct falling spheres trough a ramp into a large target. Each time a sphere hit the target the team will be rewarded with one point, but there will be two members of the opposite team that will try to catch the spheres with a block. The block wall can only be moved along the sideway of the ramp, in this case, only to the right or left. If any spheres touch the block wall, it will disappear. The spheres will appear in intervals of five seconds and the two teams will be present in the same room, with four players in the respective team ramp and two players on the other ramp trying to catch the enemy spheres.

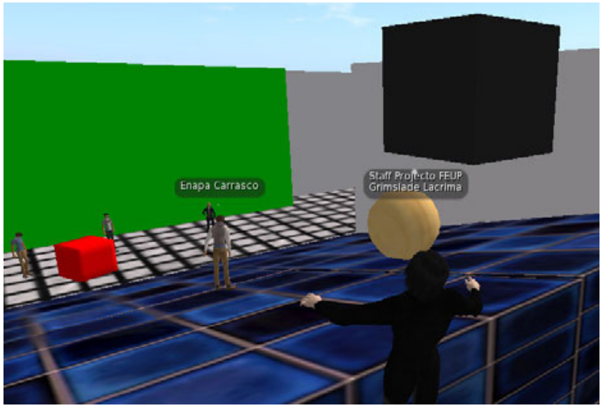
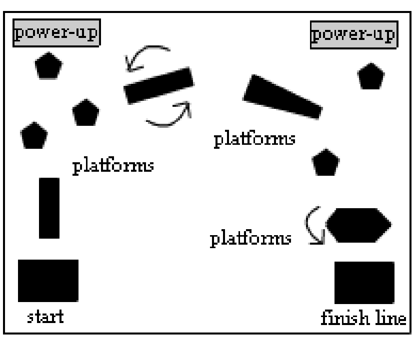


Fig. 3. Map for level 2 of the FEUP Adventure – "Sliding Spheres"

Level 3 is "Jumping Platforms" and was initially conceptualized to be a more complex level (see Fig. 4), but technical limitations related with the avatar translation restrained some of the initial ideas. Essentially, the game consists in a large room with several objects that work as platforms and obstacles. Each team will be represented by four players and the objective is to reach the finish line by the same four players the soon as possible. In this case there are no points, only time. The timer will stop only when the last team member reach the finish line. Due to the nature of the game, it will be needed one session by team, in opposition to the other games where one session abridge the results for two teams.



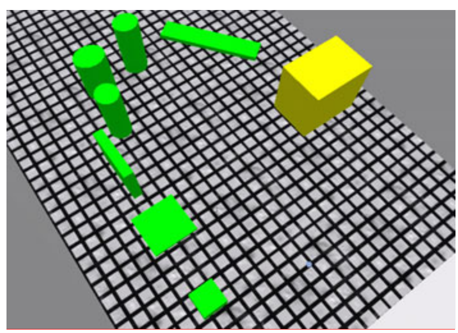


Fig. 4. Conceptualized map for level 3 - "Jumping Platforms"

In related work projects there are also reports that some students tend to use some disruptive behaviour during gameplay. It's necessary to consider that students may use the game mechanics to completely counter the active team tasks. For example, a single player could be on the top a ramp and easily prevent any coordinated work by the other team. To avoid this, students' avatars can not cross adversary ramps or platforms. The game has to be well balanced in order to avoid too much frustration, especially when a team is working together.

4 Evaluation

The prototype evaluation was made with a sample group of 12 students during the initial weeks of their first lecture year. No grades were associated with any gameplay. The operations were implemented in classroom with the supervision of assistants; each one had the task of monitoring and collecting student's behavior during gameplay. Students were organized in two teams for testing the idealized game levels in practice and in the end a final inquiry was filled and submitted by 11 students.

The previous experience in games and virtual worlds by the sample population of this study was very important for data analyses and eventual conclusions. As showed in figures 5 and 6, although the great majority of students had no previous experience under the SL platform, a significant percentage play games in general and game genre preferences by the sample population were broader.

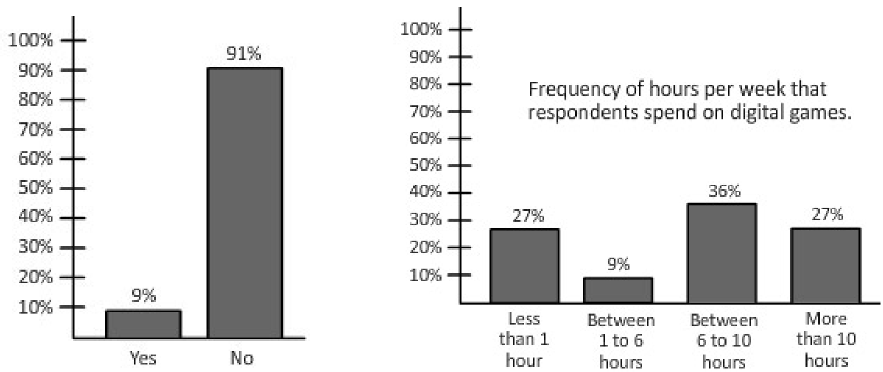


Fig. 5. Students previous experience in Second Life platform before the game (Left Graph) and frequency of hours per week that respondents spend on digital games (Right Graph)

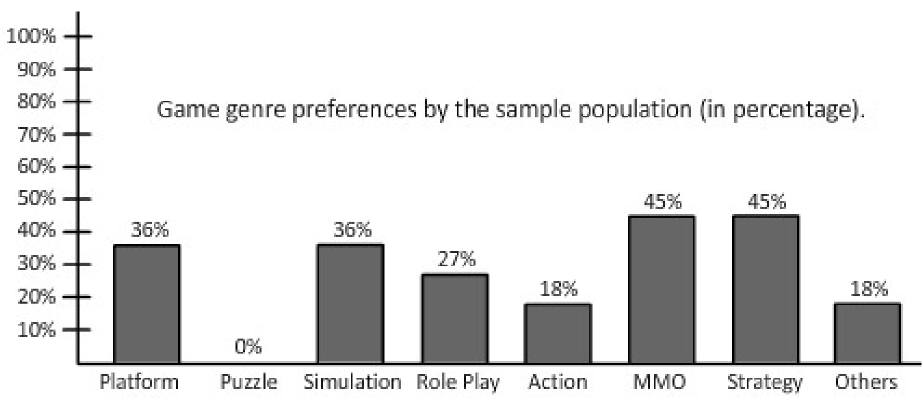


Fig. 6. Game genre preferences by the sample population (in percentage)

The first process involved the student's adaptation to the Second Life virtual world, before starting the game itself. Although students had low overall experience in Second Life platform (Fig. 5), the observed platform interaction and student feedback provided the idea that, in general, this adaptation was easy and fast.

The following step consisted in distribute the students in two teams (Alpha and Beta) and that process, under the pre-established method, consisted in the use of Second Life Groups. This approach revealed to be lengthy, resulting in about thirty minutes to setting all up. Probably a better solution would evolve the use of wearable objects, thus reducing the team setting up duration and eventually differentiate better the members of each team during gameplay.

Before the games begin, the students were able to practice and understand the games rules and objectives in the training area. This stage occurred normally and students didn't present major questions or problems at this point. The inquiry proved that fact, as student feedback indicated a complete understanding of rules and game objectives (100%).

During the course of the game some observations were noticed:

- As expected, there were clearly initial attempts of disrupting the opposing team game. The foreseen solution of expelling players from the opposing team area worked and players give up those strategies. Although in terms of game design this could be a possible option for a team strategy, we believed that operations of that nature could eventually ruin the experience in-game, preventing an already hard objective of being ever accomplished and therefore make the majority of the team efforts useless and frustrating.
- There was observed team work and communication and the recorded data by mediators showed that occurred 109 attempts of communication between team colleagues during the first two levels and 54 were registed by students themselves on the third level (as a parallel activity).
- Only 8 occurrences of communication between opponent team members were registered.
- External signs of fun and frustration were detected, where in total 90 occurrences of fun and 50 of frustration were recorded. In this case, 88% of the frustration signs happened in level 3 (Jumping Platforms Level).
- Only a single student didn't reach the third level finish line and there were no objective attempts by their teammates to aid in someway. All other students that had finished the course were distracted or doing other activities.

Although the game objectives were essentially understood by the students, a few questions emerged during gameplay (Fig. 7). Good indicators were observed in the inquiry as it shows that students felt an overall need to communicate during the game, reinforcing the notion that these game design approaches could promote communication between players.

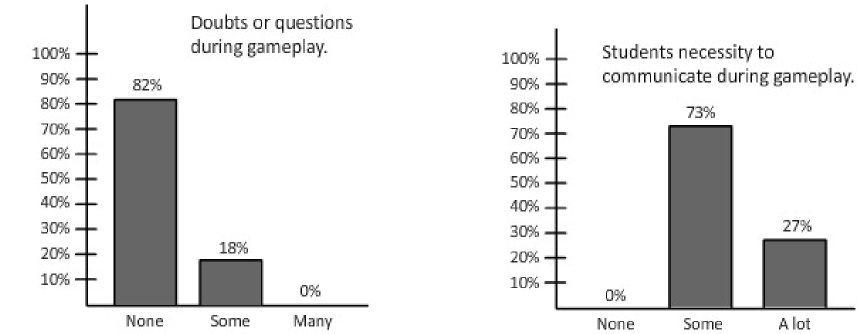


Fig. 7. Doubts or questions during gameplay and students necessity to communicate during gameplay

On the other hand, the majority of students didn't acknowledge the help of teammates (Fig 8) and only a single student recognised the existence of team leader during the game (and was incapable of identify him afterwards).

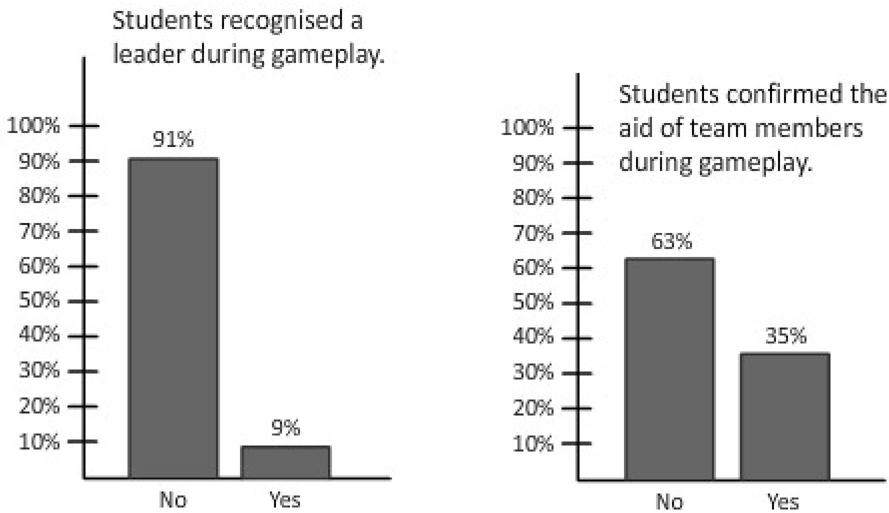


Fig. 8. Students reports on leader recognition and team support

Although the preference in terms of level was well distributed (figure 9), the third level (Jumping Platforms) was considered by the vast majority as the hardest or as the most frustrating. As we ponder a little more on this matter, some factors may have contributed to this result. First of all, the end result of the level was far away from the initial concept and the objective was more centred in the skill of each individual than in the efforts of teamwork. Besides that, there was needed some level of precision in the jumps, and the used engine may not offer an adequate performance in that interaction process.

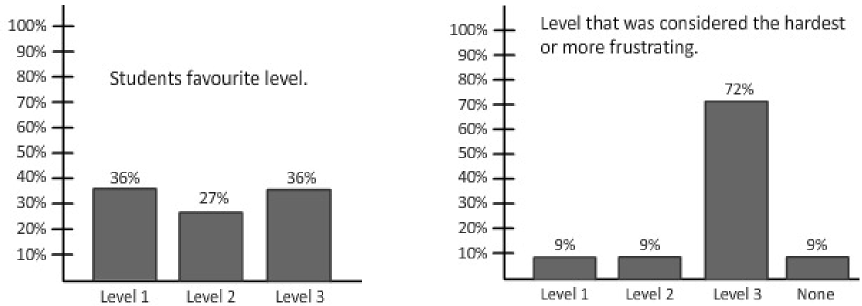


Fig. 9. Students favourite level statistics and level that was considered the hardest or the most frustrating for the students

During observation it has became clear that the system response to a jump was significantly affected by latency and further analysis may be needed to determine if the cause derives from network performance, processing performance, the engine predefined action or a combination of the three. Nevertheless, the third level was still the favourite for 36% of the students, demonstrating that being more difficult also could mean being more challenging and appealing.

A rating scale questionnaire (Likert) was also conducted and the students mean average response to the questions is showed in the Table 2:

Table 2

Questions	Mean Average
“Did you like to play this game?”	3.73
“Were you able to play it well?”	3.69
“Was the end result satisfactory?”	3.77

5 Conclusions and Future Work

After analyzing the data gathered in the evaluation process, some results, conclusions and thoughts for future works have risen.

First of all, the proposed game mechanics proved to be a plausible option for promoting communication between team players. This is an important factor in the project objectives, as we advocate that communication is a key element in social interaction, relationships and therefore student integration in universities.

Observations related with teamwork tactics and teammate support fell short to expectations. Probably different and rethinking strategies need to be used to improve this result. It was obvious for us that students were not very focused in the tasks ahead (even with the activity inserted in the context of a discipline) and players' indifference to a teammate with difficulties should be prevented. We believe that a better objective reward system could be useful to this situation and force a higher level of commitment during the game, when either to help during the game tasks or by simply offer moral support (very significant for the project objectives).

Independently of whether or not is important to promote leadership within the integration process, the proposed game design proved to be very inadequate. In this case, we believe that a game design more centered in players with different roles/abilities should be more suited for this goal, instead of having players complete equal in their traits.

The student sample also demonstrated an easy adaptation to the platform and the game levels, but this could not be the case for students with less experience in playing games.

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Towards a Serious Game for Portuguese Learning

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Abstract. Language learning resources are constantly evolving alongside technology. One of such resources is REAP.PT, a system which aims to raise users proficiency in the Portuguese language in an interactive manner. Its current features include text-based exercises. This paper describes the evolution of REAP.PT aiming on locative prepositions used to describe the spatial position between objects. In this new REAP.PT, exercises take place in a 3D environment, and are complemented with gaming aspects to make them more appealing to students. The game scenario is an office, where each room contains different exercises. Completing exercises awards the student with points that unlock harder rooms. This provides the student with a challenge and a sense of progression. We believe that with these gaming aspects, students will have increased motivation to complete exercises.

Keywords: Computer Assisted Language Learning, Serious Games, Pictorial Exercises, Portuguese.

1 Introduction

Nowadays, people have come to expect more from language learning tools. The purpose of the REAP[1] [1] (REAder-specific Practice) project, is to create a tutoring system for second language learning taking advantage of CALL technologies based on Natural Language Processing [2]. The system focuses on vocabulary learning by providing the students real documents featuring target vocabulary words in context.

In order to offer an interactive and individualized experience to the students, these have the possibility to define their topics of interest, which allows the system to present the most suitable documents for a specific student. The documents are extracted from the web, and because of this, students have access to both recent and varied readings.

[1] http://reap.cs.cmu.edu (last accessed in June 2011).

M. Ma, M. Fradinho Oliveira, J. Madeiras Pereira (Eds.): SGDA 2011, LNCS 6944, pp. 83–94, 2011.

REAP has been ported into European Portuguese as REAP.PT (REAder-specific Practice PorTuguese) [3], and current development includes an automatic syntactic and semantic exercise generator. While REAP.PT has been constantly evolving since being ported, no step had yet been taken away from text-based exercises. The addition of a 3D environment opens up many possibilities both in terms of the exercises that can be made and in the ways that they can be presented to the student.

The main contribution of the work described in this paper is to provide a 3D environment filled with objects with which the student can interact. In this environment, students perform exercises that focus on the verbs and prepositions used to describe the spatial relations between two objects. Exercises consist in asking the student – represented by an avatar on screen – to perform different actions. These include rearranging the position of objects so that certain spatial conditions are fulfilled, as described by the following example:

"Put object A **on top of** object B"

In some exercises, instead of requiring the student to perform an action, the game may show an object and ask the student to provide a written description of its location. Another category of exercises requires the movement of the avatar, teaching expressions like "turn left" and "go down the stairs".

Some accessibility utilities are also available to the student. One of them is the possibility of clicking on a certain object to check its definition in a dictionary. Another is the integration with the text to speech (TTS) synthesiser already in use in REAP.PT so that the student is able to hear the instructions, as well as any words s/he selects.

This document is structured as follows: Section 2 gives an overview on the REAP.PT system; Section 3 describes the state of the art regarding Serious Gaming for language learning; in Section 4, the Pictorial REAP.PT module is described in terms of its architecture, categories of exercises and game plan; Section 5 focuses on the description of features that can still be added to Pictorial REAP.PT, as well as the evaluation method to be followed, and a few conclusions.

2 REAP.PT

REAder-specific Practice PorTuguese (REAP.PT) is the result of porting REAP – originally built for English – to Portuguese. The porting effort required the integration of new linguistic tools and resources, as well as the indispensable adaptations for this topologically different language [3]. Interaction with the system is done via a Web browser. When a student logs into the system for the first time, s/he is presented with a series of questions that allow the system to determine her/his proficiency level. Based on this level, the student will be assigned a word list that contains the words s/he is supposed to learn. This is where the individualized learning comes into play, since each student will have her/his own list of words to learn. The list of words is derived from the

Portuguese Academic Word List (P-AWL) [4], a word list inspired in the English AWL and built specifically to be used in the REAP.PT tutoring system.

Another major characteristic of the system is the use of topics of interest. The student can choose from a number of topics, such as music, sport or history, and s/he can also accord them a certain level of interest (ranging from "not interested" to "very interested"). When the system chooses which documents are to be shown to the student, priority is given to certain documents based on the manifestations of interest in those topics. After defining her/his interests, the student can start an individual reading. In the document chosen by the system, target words are highlighted in blue. The student is given a certain amount of time to read the text, during which s/he can use the dictionary or the speech synthesiser to help her/him. Having finished reading the text, the student is presented with questions focused on the target words included in the text. These questions are automatically generated by another module of the system [5]. Current developments of REAP.PT also include automatic generation of syntactic and semantic exercises, and an oral comprehension module.

As described before, the current interface and exercises available to the student are completely text-based. In this paper we propose taking advantage of serious games in order to make both the interface and the exercises more appealing to the student.

3 Serious Gaming for Language Learning

It is known that video games have an intrinsic motivation appeal that makes them a valid tool for learning [6] [7] [8]. Serious Games emerged as digital games and equipment with an agenda of educational design and beyond entertainment. As Kurt Squire said, "e-Learning designers struggle to compel users who have paid thousands of dollars to complete an online course. Yet, game players routinely spend dozens, if not hundreds and thousands of hours mastering complex skills in digital worlds that are time-consuming, challenging, and difficult to master" [9]. Video games also allow players to be placed in rich environments, otherwise inaccessible, giving them increased motivation.

A study involving 100 students showed that the right combination of both interactivity and media-richness results in an increase in knowledge acquisition, sustainability and topic interest [10], making video games a trustworthy environment for learning.

Although Serious Games can have a broad range of purposes and areas of application – such as healthcare, military and education [11] – we will focus on language learning. Recent projects show that most of the time, Serious Games are used to learn specific parts of a language, or to prepare someone for a certain situation, be it a person in a vacation trip or a soldier going to war. The next paragraphs describe some of the Serious Games recently developed for language learning.

Polyglot Cubed[2] is an educational game designed to aid in foreign language learning [12]. Its purpose it not to provide all the resources required to learn a language in full, but instead to teach a few common vocabulary words for a situation where they will be useful. The game encourages a trial and error approach, and because of that does not require any prior knowledge of the language being learned. It is currently available for Mandarin Chinese and Cape Verdean Creole.

Global Conflicts[3] is a series of educational games used for teaching history, citizenship, geography and media courses. While not directly developed to teach a second language, it is an interesting example that can be used for that purpose, even at an advanced level. In one of these games the user plays the role of a freelancing journalist that has to write an article about the Palestinian Conflict, on site, by gaining the confidence of locals — Non-playable Characters (NPC's) — and have them provide him with quotes. A research project in two Danish high schools with 51 students using a playable prototype showed that over half of the students felt they had learned more from the game course than from normal history courses, and one third of the students felt they had learned as much as they usually do from a normal course [13].

Mingoville[4], an online learning environment featuring English lessons for children, has currently more than one million users [14]. Users are represented on screen by a Flamingo (hence the name), and can move freely in a world populated by other user's Flamingos, with whom they can speak to through text. Various games and learning activities are scattered throughout the world; these include exercises in spelling, speaking, reading and writing, sing-along karaoke songs and missions for vocabulary learning, each featuring a theme with a list of words that the user must learn. The game also features an illustrated dictionary with translations for 32 languages.

Tactical Language & Culture Training Systems[5] (TLTS) are courses that use virtual-world simulations to help people acquire communicative skills in foreign languages and cultures. Several titles have already been developed. Tactical Iraqi, Tactical Pashto, and Tactical French are in widespread use by U.S. marines and soldiers, and increasingly by military service members in other countries [15]. Heavy emphasis is given to spoken vocabulary and pronunciation, while grammar and written language is covered only when required. Also with significance in these courses is the cultural education. Users can learn norms of politeness and etiquette, as well as non-verbal gestures that are critical for successful communication. TLTS has two main components that interact with the user [16]. One of them is the Mission Skill Builder (MSB), which provides learning resources in the form of lessons. Another, the Mission Practice Environment (MPE), consists in the 3D simulations of social situations. Both of these components share and use a pool of resources of a common set of services and databases. These include a Language Model, featuring a natural language parser and a speech recognizer.

[2] `http://www.polyglotgame.com` (last accessed on June 2011).
[3] `http://www.globalconflicts.eu` (last accessed on June 2011).
[4] `http://www.mingoville.com` (last accessed on June 2011).
[5] `http://www.alelo.com/tactical_language.html` (last accessed on June 2011).

In short, the use of Serious Games for language learning has been increasing in recent years, and there are already some successful systems in widespread use. Thus, these systems served as inspiration for some of the aspects of our approach.

4 Our Approach

To create a 3D serious game for Portuguese learning we developed a new exercise module to be integrated in REAP.PT. The creation of this module was not a straightforward process. Decisions were made about which technology to chose to provide a graphical interface, as well as on the types of exercises that would best suit the student's needs. Another major decision point was on whether and how to surround these exercises with a gaming environment, so that all the advantages of the systems discussed in Section 3 could be explored. This section provides an insight on those decisions.

4.1 Game Plan

Much care has to be taken when developing a game in order for it to be successful regarding the user's enjoyment. Even more so when that game is intended for learning purposes. [17] discusses some heuristics that make things fun to learn, in particular when applied to instructional games. Those heuristics, along with the Serious Games review, were used as a base during the creation of this game plan and helped define many of its aspects, such as the importance of goals and of progression in keeping the user engaged; the need for appropriate performance and informative feedback; among others that are discussed in detail throughout this section.

Progression and Point System. The game's main scenario is the office. When starting a new game, only a small room is available to the player (See Figure 1 for an example of one of the available rooms). This location has exercises the student has to complete. For each correctly finished exercise, the student receives points, and when enough points have been gathered, another area of the office is unlocked for exploration, where more exercises are available. This structure of progression was chosen in order to keep the student curious about what is coming next, giving him the motivation to finish the exercises.

Points earned for completing exercises serve two purposes. The first is to unlock new areas. The second is to compare scores with other players. For each room, students are able to check how they graded against the other students, both in terms of points and speed. This second aspect of the point system contributes as a second layer goal. If there was no higher score to achieve, students would have no desire to repeat exercises, yet repetition can play an important role in language learning. It also provides the student with a sense of accomplishment, which, once again, keeps him motivated. Point attribution takes into consideration the exercise base point value, the number of errors made during its execution and the time taken to finish it.

Fig. 1. One of the rooms available

Challenge. Each division has a fixed number of exercises, which become increasingly more difficult as new areas are unlocked, but it is not required that all of them be finished before access is given to a new room. Since points are dependent on the student's efficiency, students that score higher need to complete fewer exercises, and students that score lower must complete almost every exercise. Low scoring students can proceed without completing all the exercises so that frustration does not build up from being unable to finish an exercise, causing her/him to quit. Hints are also available, which can help in a number of ways. One of them is in finding objects whose name the student still has not learned during a certain exercise. It is important to note that some of the hints are already given "for free" depending on the difficulty setting chosen by the student.

One of the essential characteristics of a good game, as discussed by [17], is the existence of a challenge. Winning can not be a certainty. Otherwise, the student would have less reason to give her/his full attention to the exercise. Because of this, it was decided that when an exercise is failed the student loses some of his score and may have to repeat a previous exercise.

Feedback. Feedback plays an important role in any game. [17] identified feedback as being necessary to both keep the player engaged and to instruct her/him. Keeping the player engaged can be accomplished by always providing feedback on how close s/he is to her/his goal. Applied to this game plan, the feedback is provided at different levels; the first one consists in giving the player information about how many points s/he still has to obtain in order to unlock the next division; the second one, inside exercises, is achieved by showing the student whether s/he is moving towards the exercise goal or away from it. Perhaps s/he picked the incorrect object or took the wrong turn. The student should be informed of this.

Instructing the player is done by giving constructive feedback when the exercise is not finished correctly. Instead of displaying a message such as "You have failed the exercise", it is many times more helpful to display something like "You did [A] and were supposed to do [B]". With the latter approach, students actually learn from their errors, and it was thus adopted when informing the player of her/his results.

4.2 TARGET Platform

This section provides a description of the technologies used in the development of this module. The chosen framework was the Transformative, Adaptive, Responsive and enGaging EnvironmenT (TARGET) Platform [18]. This serves as support for the TARGET Project[6], whose objective is to research, analyse and develop a new genre of Technology Enhanced Learning environment. In this environment, the learner goes through complex situations in the form of game scenarios. By completing these scenarios, knowledge is gradually acquired by the player.

The selection of the technology for the TARGET platform was made iteratively, during which two prototypes were developed in two different engines before going back to the analysis phase and finally choosing the Unity[7] game engine. This engine is one of the few that allows for the deployment of a web-based application – a crucial requirement in any REAP.PT module.

The TARGET platform was chosen based not only on its capabilities, but also on the similarities between the requirements of the work described in this paper and those in the TARGET Project. Also, [18] states that real development is necessary in order to be able to choose an appropriate platform. Since this was the case during TARGET's selection of technology, one can be confident in its capabilities based on the requirements of the project.

4.3 Architecture

Our system follows the TARGET platform's architecture, which is based on managers. It deploys a client-server application, and requires that the code running in both the client and the server side be the same. Because of this, these managers can be instantiated in both a client version and a server version. Our architecture – which can be seen on Figure 2 – makes use of some of the managers available in the TARGET platform, but adds new ones as well. All of them are are detailed below.

[6] `http://www.reachyourtarget.org/` (last accessed on June 2011).
[7] `http://unity3d.com` (last accessed on June 2011).

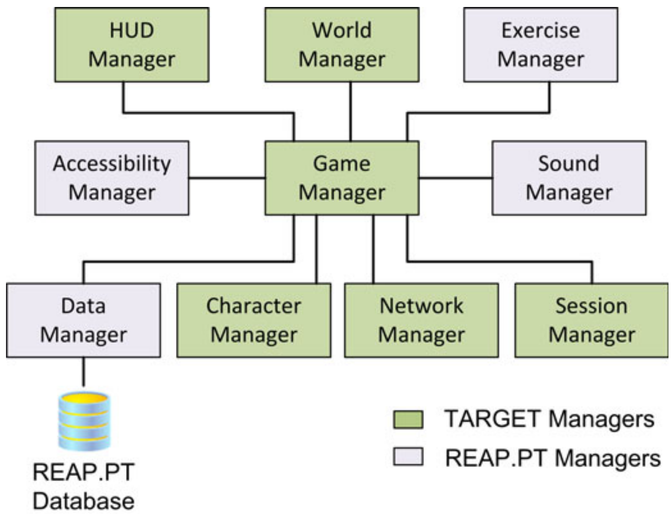

Fig. 2. Pictorial REAP.PT's Architecture

Game Manager is the main manager. It is responsible for loading the remaining managers. It also manages the game state, dealing with the progression aspect of the game and unlocking further exercises and divisions as necessary.

World Manager is responsible for defining the avatar's spawn point and moving it between different scenarios.

HUD Manager is used to provide most of the feedback given to the player, for instance, the number of exercises completed, the number of hints available, the current score and the current level. This manager also includes the menus used to navigate and configure the application.

Network and Session Manager are required to aid the communication between the client and the server application.

Sound Manager. Sound is also important to provide feedback. This is achieved with a Sound Manager, which allows different sounds to be played depending on the situation.

Exercise Manager. This manager contains the exercises in the application and it defines their different difficulty levels, as well as which hints can be used on each of them. The manager is also responsible for keeping track of the exercises completed.

Accessibility Manager provides access to the dictionary and the TTS functionality already in use on REAP.PT.

Data Manager is responsible for interacting with the REAP.PT Databases. It gets information on the student using the application, and stores her/his results. This manager also keeps the progress of the student updated, so that s/he can continue a previously started game.

Character Manager is responsible for keeping the student's score and time for every exercise completed, as well as any other information about the player, including her/his name, age, proficiency level and preferred difficulty level.

4.4 Exercise Description

Each exercise can be presented in two ways: (i) by asking the student to perform some sort of action; (ii) in a "describe the action" alternative, where the action is shown to the student, and s/he is asked to describe that particular action. This description can be provided either by choosing one of various options or by writing it. Apart from the differences between categories, each exercise also features different difficulty levels. Two categories of exercises are already implemented and described below. One more is planned to be developed in the near future.

Object Manipulation

This type of exercise consists in asking the students to change the position of various objects in the scene in order to comply with a specific spatial restriction. As an example, the avatar can be placed in an office and then be asked to put a document folder to the right of a computer monitor (see Figure 3). In order to correctly finish this exercise the student would have to move the document folder to the right of a computer monitor. The exercise is broken down in two steps, so that instructions and feedback can be given for each action.

Initially, the student has to find and click the documents. With this, we are certain that the student has found the right object, and can then fixate the camera in a new position where it will be possible to move the object. After that, the student has to pick and move the object. S/he does this by click and holding on the object and then moving the mouse until the object is placed in the intended position. To drop the object, s/he must stop holding the mouse button. The object will fall and the result will be displayed. If the answer is correct, a message appears giving information on the time taken to complete the exercise, the number of error committed and the number of points awarded. If, however, the answer is incorrect, a message appears informing the student of the position where s/he dropped the object, so that s/he can learn with the mistake.

Avatar Movement

In this category, the avatar is able of walking freely in the environment. The goal of each exercise involves performing movements with the avatar and go from one place to another. Directions appear on screen, such as "turn right", or "go down

Fig. 3. Exercise where the student has to move the documents to the right of the monitor

the stairs to the left", which the student must follow in order to reach her/his destination and complete the exercise. Similar attention to feedback has been given in this category, and the student is informed of errors with constructive messages.

These categories of exercises are presented in a gaming context, where the student is challenged to keep up with the increasing difficulty of the exercises, while, at the same time, s/he is rewarded with points for correctly finishing them. For this reason it is expected that the students will enjoy solving the exercises and become more motivated throughout the whole learning experience.

5 Conclusions and Future Work

The work described in this paper represents an evolution of REAP.PT towards a new direction, introducing exercises that use gaming aspects in order to further capture the student's interest. These are also the first non-text-based exercises, taking place in a 3D virtual environment. However, this is a work-in-progress and more features are being added to the preliminary version described in this paper.

To enrich the game, more categories of exercises are planned. "Object Interaction" is a new category involving interacting with objects. These exercises consist in asking the student to interact with the various objects that compose the scene independently. For example, the student can be asked to call an elevator in order to go to a certain floor, or to pick up a book from the correct shelf.

Another feature that will be added is a multiplayer component, which gives students a way to share their environment with other students. This would allow for the exercises to be taken in a competitive or cooperative manner, opening a variety of new ways to present the same exercises.

The current application features an office as the main scenario; however, it would be interesting to provide the student with more locations, not only to make it more fun, but also because it would allow for different expressions to be taught. Possible new locations are a mall, a street, a school or a farm.

This application will also be subject to an evaluation. The most appropriate way to do it consists in having real students interacting with the system. While this is a very time and resource-consuming method, it will provide the most accurate measure of quality. Aspects evaluated will include knowledge acquired by the student, knowledge sustainability – an important aspect of language learning –, and the student's opinion on the application itself, such as ease of use, interest and self-reported learning. The evaluation method will make use of two groups of students, having one of them using our system and the other using traditional exercises. A comparison of results will be made afterwards.

We believe that this new approach can offer satisfying results in language learning. Although we can not validate such claim before the evaluation, we expect that it will be ascertained by the user study. In case it is, our architecture will allow easier creation of future modules that feature similar requirements.

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Serious Games: Are They Part of the Solution in the Domain of Cognitive Rehabilitation?

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Abstract. Serious Games are in increasing use for serious purposes, such as health. Particularly in the field of cognitive rehabilitation, they can offer new solutions that are fun, user-friendly and goal-directed. In this study, a prototype rehabilitation platform is presented, aimed at intervening in executive functioning and other related cognitive functions in patients with Acquired Brain Injury. It was tested in three studies investigating patients' satisfaction and performance in a virtual environment using 2D computer-screen or 3D projection-screen approaches, and patients' satisfaction with the virtual reality (VR) program regarding its usability and role in motivation to participate in the rehabilitation process. Contributing to the final version of the program, results in our pilot-studies are promising, supporting the usability of the VR program and showing its relevance in subjects' motivation to participate in the rehabilitation process.

Keywords: Serious Games, Virtual Reality, Health Care, Cognitive Rehabilitation, Executive Dysfunction.

1 Introduction

Today we are witnessing social changes in perceptions and attitudes regarding deficiency and disability. These changes reflect a transposition of handicap conditions from the individual sphere, to which they were traditionally confined, to the public domain. Today's greater visibility of these phenomena, the professionalization of the services directed at them and the increase in demand for such services make the need for innovative practices even more pressing [1]. It is crucial that these practices promote equity in the access to the services, the success of interventions and the understanding of the mechanisms underlying intervention effects. The development of

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game design and technologies, as well as other technologies, like Virtual Reality (VR), has contributed to these purposes [2, 3, 4, 5]. For a long time, these resources were applied almost exclusively to domains such as the movie industry and games. Their main purposes were enjoyment, fun and entertainment [2]. With the democratization of their use, other areas can now benefit from their potential, particularly Health Care.

In this paper we discuss the possibility of using so-called Serious Games (SG) in the field of health, especially in rehabilitation. We introduce the Computer-Assisted Rehabilitation Program – Virtual Reality (CARP-VR) developed as an instance of SG tailored to the rehabilitation of executive functioning (EF) and other related cognitive functions in patients with Acquired Brain Injury (ABI). Finally, we present the preliminary testing of CARP-VR in three studies with ABI patients investigating patients' satisfaction and performance in a VE using two-dimensional (2D) computer-screen or three-dimensional (3D) (eyeglasses) projection-screen approaches, and patients' satisfaction with the VR program regarding its usability and role in motivation to participate in the rehabilitation process.

2 Serious Games: Is What Is Beautiful, Good?

SG can be defined as "a mental contest, played with a computer in accordance with specific rules, which uses entertainment to further government or corporate training, education, health, public policy, and strategic communication objectives" [6]. They are "games that engage the user, and contribute to the achievement of a defined purpose other than pure entertainment (whether or not the user is consciously aware of it)" [7]. Their characteristics and applicability to distinct areas led to an exponential growth of SG in the last decade [7].

In the domain of health we highlight their application to motor rehabilitation, including balance, upper limbs or wheelchair mobility, and cognitive rehabilitation, as in spatial capacity, visual perception, attention, memory or executive function. In this work we will focus on the field of cognitive rehabilitation [8, 9, 10, 11, 12].

Cognitive rehabilitation, as part of neuropsychological rehabilitation, can improve competences or minimize deficits. It refers to the "(…) therapeutic process of increasing or improving an individual's capacity to process and use incoming information so as to allow increased functioning in everyday life." [13].

Cognitive rehabilitation can have the goal of intervening on: (1) disability, seeking to stimulate and improve altered functions by direct action on these functions (restoration), (2) promoting the use of alternative mechanisms or of preserved skills (compensation), or (3) using different strategies to help minimize problems resulting from the dysfunction (replacement) [14].

When functionality and problem-solving abilities are significantly impaired due to dysfunction at the level of memory and executive functions (EF), cognitive rehabilitation becomes particularly important. EF refers to cognitive capacities involved in initiating, planning, sequencing, organizing, and regulating behavior [15], indispensable to the most basic tasks of daily life such as independent mobility or supermarket shopping. In fact, at the cognitive level, impaired memory and executive dysfunction are two of the most pervasive and disabling consequences of brain damage [16, 17, 18, 19, 20].

SG may allow goal-directed exercises, performance monitoring, immediate feedback and customization. The environment, level of difficulty and speed of progression are part of the parameters that can be dynamically adapted to the real needs of each subject, their abilities and performance [7, 10]. Also, SG are compatible with other technologies, like VR, with its characteristics of presence, involvement and interaction [6, 9, 21]. These are important advantages of SG over traditional rehabilitation tools. The already mentioned potential of SG in different areas has stimulated the creation of multidisciplinary teams involved in the design, development, testing and implementation of rehabilitation programs. However, the balance between "science", "engineering" and "entertainment" or, in other words, between "engineers", "artists" and "scientists" is complex. Their diverse backgrounds provide them with different perspectives on the process [22]. This can be a difficulty – for example, if too much importance is placed on technology in detriment of the ends towards which it is intended – or an asset, with collaboration giving rise to new questions and solutions on old problems. Authors such as Bermùdez i Badia showed the importance of answering the question of what matters most, whether to improve the way therapy is made available or its working principles [22]. Very sophisticated and technologically advanced interventions do not always mean better interventions. The opposite also seems true.

In the field of rehabilitation, the motivation that gaming factors provide is a crucial dimension, as rehabilitation is a long, repetitive, dull and intense process, with often slow progress and, in some cases, personal unawareness of deficits [23]. However, the design of more effective rehabilitation tools cannot fall exclusively on the promotion of motivation. Theoretically supported designs of exercises / tasks for innovative rehabilitation of different cognitive functions are also crucial. Additionally, it is important to understand the mechanisms underlying recovery, for example in the case of restoration [24].

Reconciliation of these multiple objectives will certainly be part of all interventions in the future, which can bring significant progress to rehabilitation in the years to come. This progress is also due, in part, to the rapid evolution that other areas, like the field of neuroimaging, have also undergone [25, 26]. These considerations highlight the importance of strong principles guiding the process of developing any intervention/rehabilitation tool. Among them, evaluation should be considered a requirement crucial to the process, not a superfluous dimension [27]. Also important is the involvement, since the program's conception, of those for whom it is intended [28, 29]. Only this way can such technologies', and each specific program's effectiveness and efficiency in rehabilitating be ensured, and satisfaction with their use granted [30].

3 Our Contribution: Attempting to Take Part of the Solution

Our team is working on the design, development and implementation of CARP-VR (Computer Assisted Rehabilitation Program-Virtual Reality). The CARP-VR rehabilitation system is an interactive virtual environment simulator of real-life contexts in which patients perform various activities that are based on daily situations. Rehabilitation sessions are composed from a sequence of levels that the patient has to complete successfully in order to progress to the next level. The success in a level depends on the fulfilment of a predefined list of tasks.

3.1 CARP-VR Architecture

The CARP-VR rehabilitation system is built into two distinct applications (Fig. 1): the CARP-VR Editor is the back-office interface, where the therapist defines the simulation environment and required tasks for each level. This therapist's working station also includes the results manager to allow the study of individual performance in the training sessions. The CARP-VR Player is the interactive virtual environment navigator. It allows the patient to train the execution of the specified task events and registers all actions and progress in the system's database.

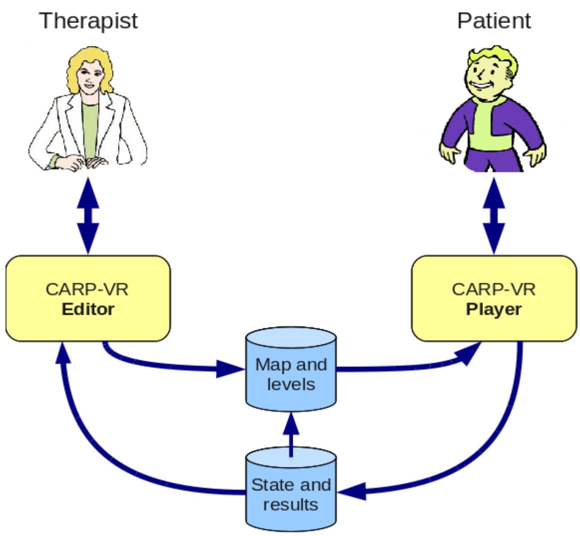

Fig. 1. The CARP-VR Rehabilitation System Architecture

3.2 CARP-VR Player

The Player is the CARP-VR rehabilitation system's main application. It is built in the C# programming language and uses the NeoAxis Game Engine for the simulation and visualization of the 3D virtual environments [32]. NeoAxis is a proprietary game engine, free for non-commercial use, that offers a fully integrated development environment for interactive simulation applications. NeoAxis was developed over the OGRE graphics engine, which is one of the most popular and complete open-source graphics rendering engines [33]. The functionalities delivered by the OGRE graphics engine allow the use of a wide set of geometric formats and visualization and iteration devices in the developed CARP-VR player [33]. The functionalities provided by the NeoAxis games engine provided a physically-based simulation of the virtual objects and a more direct specification of the desired rehabilitation events [32].

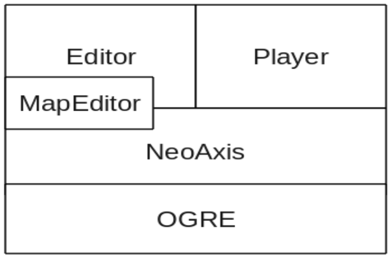

Fig. 2. The development stack for the CARP-VR Editor and Player

3.3 CARP-VR Editor

The CARP-VR Editor is the set of tools used by the therapist. It is used to prepare and test the rehabilitation sessions before they take place, to monitor patients' behaviour in real time during the rehabilitation sessions and to access and analyse the results registered after each rehabilitation session. Like the CARP-VR Player, this Editor uses the NeoAxis game engine, version 0.9, from the NeoAxis Group,, but it also takes advantage of the NeoAxis map editor [32]. This extra module, included in the NeoAxis integrated development environment, allows a fast and friendly preparation of the different required simulation scenarios and levels [32].

Rehabilitation session results are accessed from the therapist's working station using some database interface modules, developed using the .Net framework and the SQL queering language. For each patient, results can be obtained in either an accumulated way or for each independent rehabilitation session.

3.4 Database

The CARP-VR rehabilitation system's database stores the definition for the simulated environments, the behaviour of movable simulated entities, the guidelines for the rehabilitation sessions, the state of rehabilitation and specific data for each participant, and the results produced in each realised rehabilitation session. As figure 2 shows, this database is organized in two different sets.

All the virtual environments used in rehabilitation are described in typical 3D scene files, in the native Ogre3D or in any other format supported by the OGRE graphics engine. All the data related to each patient and the results from each rehabilitation session are stored in a relational database, implemented by a MySQL database management system [34].

Due to the high number of different required rehabilitation environments and levels, the rehabilitation environments can be completed and adjusted for each level in real time, according to multiple level specifications also stored in this relational database.

3.5 Rehabilitation Environments

A virtual environment of a home has been developed and has been employed as a training and assessment environment, used by every patient before starting the rehabilitation program. It aims to prepare patients to use the VR Program itself, including how to navigate in the virtual environment and the kind of tasks that can be performed there. In the Training Environment, the patients can explore three different scenarios: Scenario 1: storage room; Scenario 2: kitchen (Fig. 3(a)); Scenario 3: bedroom. In these scenarios the subjects need to solve different tasks of increasing complexity but low level of demand, because it is a training environment. The skills required are: recognition (to select the products asked for), sorting (to select the products asked for in a specified order) and problem solving (to select the products asked for in order to perform a certain task), respectively.

(*a*) (b)

Fig. 3. The Training Environment (*a*) and the Supermarket (*b*

Results presented in this paper were produced using this training environment and the rehabilitation environment of a typical supermarket and the surrounding parking lot (Fig. 3(b)). The tasks included in this environment have growing levels of complexity and demand according to patient's performances, and the program's gaming components include the growing number of sections to visit, products to acquire, and problems to solve. Parameters that can change, generating the different levels, are: Products' list (visible or not); List format (Auditory or Visual); Instructions (Yes/No - Y/N); Delayed start (Y/N); Repetition (Y/N); Error allowed (Y/N); Corrections (Y/N); Number of items to be purchased; Number of sections; Products' prices (Y/N); Supermarket map display (Y/N); Alarm (Y/N); Magic words – for the training of self-instruction, according to the Goal Management Training [18]; Time limit (Y/N); Temporal assessment; and Special Requirements (involving problem solving). These are articulated as to increase the difficulty of the tasks throughout the program [31]. Other rehabilitation environments (e.g., a citizen shop) are under development for future use.

4 Usability Testing

Usability can be defined as "the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use" [30]. Usability, an essential condition for the acceptance of the product by the user, should be tested throughout the development process, even during the interface design [28, 29]. Thus we conducted tests with the population that CARP-VR targets. The results (presented in study 3, below, for ABI patients), as well as those obtained in the new tests that are in course, are considered and integrated (in terms of environments and exercises) in the program under development.

4.1 Study 1

Goal. To test the usability of the Training Environment (see section 3, above), in the 2D visualization mode [6, 7].

Participants. Eight subjects with ABI, 6 males (75.0%) and 2 females (25.0%), mean age of 30.5 years old (SD=7.4), mean education of 10 years (SD=4.0), were recruited.

Procedure. We tested the time spent in the tasks in each scenario (Scenario 1: storage room - recognition; Scenario 2: kitchen - sorting; Scenario 3: bedroom - problem solving. Two evaluations were conducted four days apart (Test 1 vs Test 2). The virtual environments were visualized in a 2D computer screen.

Results and Discussion. We observed improvements in all participants within the time needed (on average) to perform the requested tasks. From the first to a second test, time reduction varied between 27% and 75%. The number of errors decreased as well. The study also shows the potential of VR technology in terms of subjects' motivation for the task. We observed a strong involvement in carrying out tasks. An after-task questionnaire survey further displayed the patients' desire to continue that kind of tasks.

Table 1. Time participants (P1 to P8) spent in the tasks by scenario

	Scenario 1		Scenario 2		Scenario 3				
	Test 1 (min)	Test 2 (min)	Test 1 (min)	Test 2 (min)	Test 1 (min)	Test 2 (min)	M Test 1	M Test 2	Time improvement
P1	6.53	1.57	5.35	0.47	1.23	1.22	4.37	1.09	75%
P2	1.24	2.54	5.14	0.40	3.22	2.21	3.20	1.72	46%
P3	6.00	2.54	17.30	5.05	7.00	2.06	10.10	3.47	66%
P4	2.19	1.15	3.40	1.26	1.57	1.14	2.39	1.18	51%
P5	1.33	0.38	0.49	1.14	2.10	0.44	1.31	0.65	50%
P6	7.45	2.40	4.44	5.26	3.32	2.40	5.07	3.35	34%
P7	3.38	4.55	3.20	4.31	7.00	1.33	4.68	3.40	27%
P8	1.26	0.50	1.05	0.55	0.33	0.37	0.88	0.47	47%

4.2 Study 2

Goal. To compare subjects' performances and satisfaction with the same training environment of study 1 (see section 4.1, above), in two visualization modes, 2D and 3D.

Participants. Seven male subjects with ABI, mean age of 28.6 years old (SD=8.1), mean education of 10 years (SD=1.5), were recruited.

Procedure. We tested the time spent in the tasks in each scenario (Scenario 1: storage room - recognition; Scenario 2: dining room - sorting; Scenario 3: bedroom - problem solving). Two evaluations were conducted four days apart (Test 1 vs Test 2). The virtual environments were visualized in a 3D projection screen (eyeglasses).

Table 2. Time participants (P1 to P8) spent in the tasks by scenario and by visualization mode

	Scenario 1		Scenario 2		Scenario 3				
	2D (min)	3D (min)	2D (min)	3D (min)	2D (min)	3D (min)	M Test 1	M Test 2	Comparison M2D *vs* M3D
P1	2.85	3.70	4.65	5.18	6.08	2.12	4.53	3.67	Improved 19%
P2	1.12	3.60	0.92	0.80	2.22	0.73	1.42	1.71	Worsen 21%
P3	2.48	0.93	4.17	6.50	1.50	2.45	2.72	3.29	Worsen 21%
P4	1.65	2.02	1.42	1.02	5.67	1.37	2.91	1.47	Improved 50%
P5	6.00	5.42	17.50	2.08	7.00	2.05	10.17	3.18	Improved 69%
P6	2.48	3.20	1.17	1.07	2.43	1.63	2.03	1.97	Improved 3%
P7	2.07	2.95	2.35	2.33	1.50	1.55	1.97	2.28	Worsen 15%

Results and Discussion. Comparing with the 2D visualization mode, no significant improvement was observed in the 3D visualization mode in what concerns the necessary time to complete the tasks. However, the number of errors was lower for the 3D than for the 2D visualization mode. Regarding the VR technology potential concerning motivation towards the rehabilitation tasks, we observed good involvement of the subjects when browsing the VEs and performing the tasks in both visualization modes (2D and 3D). Also, they all gave equivalent positive answers to the questionnaire on satisfaction with the use of both visualization modes. The main difficulties in both modes seemed related to the simultaneous use of the mouse and the keyboard to navigate, because these are poorly fit to the physical disabilities that most subjects had. The main advantage that can be pointed out to the visualization in 3D was the dimension of objects and environments coming from the projection system; Interestingly, although subjects did not report a strong sense of immersion in the 3D visualization mode, the interest they expressed in taking part in future studies was higher for 3D than for 2D.

4.3 Study 3

Goal. To test the Training Program (assessment and rehabilitation phases), through the application of a usability test (System Usability Scale - SUS, Digital Equipment Corporation, 1986).

Participants. Nine subjects with ABI, 5 males (55.6%) and 4 females (44.4%), mean age of 28.1 years old (SD=5.4), mean education of 9 years (SD=4.1), were recruited.

Procedure. In this pilot test of the initial prototype, participants experimented one of the program's levels – to shop in the supermarket using a shopping list. They needed to navigate in the supermarket and acquire the specified products by clicking on them. Additionally, they were asked to identify the specified products.

Results and Discussion. The analysis revealed that all participants obtained scores above 40 (possible range varying between 0 and 80 in the SUS, due to the exclusion of items 5 and 6). These results above the scale's midpoint lend support to the usability of the program. The sample mean is 58.1% (SD=14.1%), which is a satisfactory result. Nevertheless the findings should be interpreted with caution, particularly with regard to the influence of item 4 on the global score ("I think that I would need the support of a technical person to be able to use this system"). The answer to this item may not always correspond to32 patients' real capacities, but to their personal perceptions of deficits. Given the pathologies in question, some lack of correspondence with reality is expected in this population. There may be either an ability overestimation or underestimation. The first one may occur as a result of self-awareness deficit; the second one may be due to generalization of the difficulties from some areas to others, almost as a form of learned helplessness. Closely related to this item's content is item 10 ("I needed to learn a lot of things before I could get going with this system"), in which assessment of the program seems to be very dependent on perceived self-efficacy. These two items correspond to the "Learnability factor" and the other eight to the "Usability factor" [35]. Thus, the "Learnability factor" is likely more susceptible to the influence of subjects' pathologies (although further analyses of these two factors as separate scales are needed). Non response to item 7 (i.e., rate of 3 in this item) ("I would imagine that most people would learn to use this system very quickly") was explained by subjects feeling that they cannot answer it, given the diversity of deficits each patient has. One extra item was added to the scale with the aim of assessing the role (relevance) of the VR program on motivation to participate in the rehabilitation process. In this item, respondents indicate the degree of relevance of the VR program to this end on a 5-point Likert scale (1 - nothing important; 5 - very important). All participants obtained scores above 3 (midpoint of the scale). This suggests that subjects recognize the relevance of the VR program on motivation to participate in the rehabilitation process.

5 Conclusion

In this paper we briefly contextualized the importance of SG in several domains, namely the area of health, and cognitive rehabilitation in particular. We introduced one of the issues that have recently been discussed in the literature and in our team: The balance between technologically advanced, "beautiful" tools still requiring considerable financial support to be implemented *versus* less expensive solutions which may nevertheless contribute to improvements in intervention and the scientific study of recovery mechanisms. Both require systematic research to become part of the rehabilitation process in a sustained manner.

Reflecting this concern, we presented the CARP-VR as an SG tailored to cognitive rehabilitation that did not involve expensive technological solutions and includes exercises that are theoretically grounded in the fields of Cognitive Psychology and Neuropsychology. The clinical experience of those involved in its design was also important for its conception and making. The program has been tested throughout its development process. Results in our pilot-studies with ABI patients are promising, supporting the usability of the VR program and showing its relevance in subjects' motivation to participate in the rehabilitation process, which also reflects their satisfaction with it.

Usability tests with other program levels and with a more advanced version of the program (that includes improvements resulting from the previous tests) are currently in progress. With the progression of the project we hope to contribute to the implementation of the SG to the cognitive rehabilitation field, promoting independence and functionality of ABI patients, thus improving their quality of life.

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A Cloud Observational Learning System of Art Education via E-Learning in Taiwan

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Abstract. This study tried to apply observational learning of social learning theory in the curriculum of art education in an elementary school. Art creation skills are complicated and difficult to memorize, and thus this study expected to utilize computer to assist in the instruction. In order to solve the problems such as long creation process, massive information, complicated computing, and the difficulty to learn from others' works, this study developed a cloud education system to assist instruction. This course was taught on two groups by two teachers. The group using the cloud education system was the on-line observational learning group, and the other group was the general observational learning group. For students' evaluation, this study used "Measurement of Children's Painting Expression Ability" designed by Guo (1994) to be the evaluation instrument; higher score represents stronger painting performance ability, and vice versa. 61 pieces of work collected by the researcher were analyzed and scored by two teachers, and a statistical analysis was conducted based on the results.

Image expression ability, color expression ability, space expression ability, and aesthetic expression ability were all significantly different between the two groups; that is, the scores of the on-line observational learning group were better than those of the general observational group. But there was no significant difference in completeness expression ability, showing that these two groups were equal in this ability. Besides, after the instruction was finished, this study used a questionnaire to survey students and conducted a teacher interview on their satisfaction with the system. The results showed that students were highly satisfied with the functions of high-speed computing, repeated play, fine work quotation, work observation and learning of this system, and teachers had a high evaluation about using this system to teach.

Keywords: Cloud Education, Observational Learning, Art education.

1 Introduction

Observational learning in the field of social learning theory refers to the behavior or attitude learned by observing others' behaviors. [1] Lots of people regard observational learning as imitation. The difference lies in that the behavioral change is caused by observing models in observational learning rather than copying their behaviors.

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Observational learning usually occurs in the childhood, and the authority is very influential. Social learning theory has already demonstrated the effects of observational learning.

Observational learning or copy painting learning is an art teaching method, which is to study someone's work, understand the creative mentality of the author, and finally re-create the work in one's own way. The historical background, the creator's style characteristic, the motive for creation and the creator's inner thoughts of the imitated work can be understood through imitation learning. The drawing skill, formation, composition, colour, material selection and presentation techniques of the imitated work can also be understood through imitation learning, and it is also helpful for future creations.

Art teaching mainly focuses on observational learning. However, due to the great amount of students, teachers often cannot focus on individual students and understand his/her observational learning process; most of time they concern about the learning result of the student. Therefore, it is a major difficulty to understand and record a student's observational learning process in elementary school art teaching.

Along with the improving information technology, drawing can no longer be only processed on paper or fabric; applying computer graphics has already become the common method of art creation. Computer graphics can present the various strokes, textures, and colours of traditional drawings. Applying computer graphics in art teaching has been broadly accepted by the public and most teachers, and is even being used.

In this study, we attempted to apply blended learning in teaching and to develop an observational learning system to assist the students in observational learning. We combined observational learning and traditional classroom teaching and expect to receive better learning effects. Applying practical theory in art teaching is not an easy task. Therefore, we hope to understand the student's observational learning process through this observational learning system. The teachers can add some short-term tasks to the observational learning process to allow the students to more easily understand the concept of drawing and enhance the effectiveness of elementary school art teaching through "Learning by Doing".

2 Observational Learning

Observational learning is also called vicarious learning and social learning. This theory holds that humans mostly learn through observing and imitating models' behaviors in social contact. When learners learn through observation, they do not have to react externally or experience the reinforcement, and they just learn by observing others' behaviors in certain setting and their acceptance of reinforcement. Bandura (1977) identified that there are 4 processes in observational learning: (1) Attention process: In order to learn by observation, learners need to pay attention to the important characteristics of models' behaviors and then perceive them correctly. Numerous models always exist in everyone's surroundings, but learners are able to perform in-depth observation and absorb related knowledge only by paying attention to them. The type and quantity of observation experience are adjusted during the attention process including learners' characteristics, characteristics presented by the models, and the structural characteristics of interpersonal relationship. (2) Retention process: This process is to keep models' behaviors in the memory by impression and language and then encode them. In the future, if they need to perform these behaviors, these data kept in the memory can help them to perform. (3) Motor reproduction process: This process is to transform the information kept as the impression and language in the memory into the actual behavior [2]. That is the implementation process of behavior. This implementation is divided into the cognitive combination of reaction, the first performance of reaction, the monitoring of reaction and attentive practice according to information feedback, and so forth. (4) Motivation process: People do not perform all learned behaviors; therefore, this theory distinguished the acquisition and performance of behaviors. If models' behaviors lead to valuable results, then they will reinforce the observers' tendency to perform the same behaviors; if these behaviors lead to punishment or no payment, they will restrain or reduce their tendency to perform them. Direct reinforcement, alternative reinforcement and self-reinforcement have motivating functions for performing the behaviors they learned. Couzijn (1995) and Braaksma (2002) found that observational learning is indeed an effective learning tool for students when learning to write informative or persuasive texts [3] [4].

Observational learning is also a significant method of art education. Numerous expression techniques exist in painting; for a beginner, it is difficult to learn painting only by painting still life (sketch and hand painting). Even though one can make it, he or she must spend much time and effort. Observation takes much shorter time to learn the techniques accumulated by predecessors. Some regard that practicing painting still life more can replace or cancel observational learning.

The main method of observational learning is to learn predecessors' expression technique, detail treatment, and creation concept, etc. Some technique application, shaping treatment, composition method, creative ideas and colour matching of art learning will be learned through observational learning. Zimmerman and Dialessi (1973) found that observing models had beneficial effects on creative idea generation [5]. However, we need to note that it is possible that observational learning can make us learn the good parts and also the bad parts. It is not necessarily that everyone's works are perfect. Hence, when we imitate predecessors' works, first we have to choose better works to imitate. Nevertheless, one piece of work is not necessarily perfect in each aspect; for instance, the technique is good but the coloring is bad. In this situation, we need to consider carefully about how to make the selection and only absorb the good parts.

The merits of each style can be understood through observation excellent works of these styles. Each piece of work has its own shape, expression, technique, feeling and understanding, and therefore we can constantly improve our observation method, comprehension method, and expression technique during observation to enhance our aesthetic conception. People can trace the artist's working sequence, colours and mediums, surfaces and tools, as he/she creates a new painting [6] .

During the process of observational learning, we have to clearly understand the purpose of learning; we do not just emphasize on whether the observation is close to the original one. Observational learning asks us to read and study predecessors' works conscientiously, realize painters' exquisite artistic conception profoundly, and comprehend how they paint shapes using lines and planes. In observational predecessors' works, we should simultaneously learn and understand how to paint shapes according to our own understanding in order to achieve the optimization of shapes.

3 Cloud Computing

The basic concept of cloud computing can be traced back to 1960s. John McCarthy opined that computation may someday be organized as a public utility. Cloud computing is to integrate massive systematic resources and provide computing resources for users by providing services, and they can access information they need by any equipment anywhere. Cloud computing uses shared infrastructure; hence even if more IT resources are added, the management cost will not change significantly, and this reason has made cloud computing become a hot trend of IT structure currently.

Details are abstracted from consumers, who no longer have need for expertise in, or control over, the technology infrastructure "in the cloud" that supports them [7] [8]. This also let cloud computing become a new supplement, consumption, and delivery model for IT services based on the Internet, and it typically involves over-the-Internet provision of dynamically scalable and often virtualized resources [9]. The services of cloud computing system often are used through browsers or other web programs. Its software and data are stored in the web server, and this also allowed users not to be worried about data destruction or losing.

The basic concept of the cloud computing is a huge operation over the network handled the program will automatically split into many smaller sub-programs, and then from multiple servers by searching an extensive system, the computer analysis will be followed back to the use of the results persons. Through this technology, service providers can remotely within a few seconds to reach deal with billions of dollars or even tens of millions of information reach.

Cloud computing is divided into three levels:

- SaaS (Software as a Service): Manufacturers to break the monopoly the past, everyone has the freedom to sway creativity, providing a wide range of software services. Participants: software developers around the world.
- PaaS (Platform as a Service) : Create a program development platform and operating system platforms, so developers can write programs and services through the Internet, consumers can also run the program above. Participants: Google, Microsoft, Apple, Yahoo!;
- IaaS (Infrastructure as a Service) : The infrastructure (such as IT systems, databases, etc.) to integrate, like the hotel, as separated into different rooms for corporate hire. Participants: British industry, IBM, Dell, Sun, HP, Amazon.

From the perspective of education, the major purpose of cloud education is providing a safe, stable and easy-to-expand cloud computing platform. It makes it easy to put the courses needing large amount of resources computer in the platform for educational institutions and allows students to learn independently outside the classroom, set the learning schedule by themselves, and perform self-study. Through the platform of cloud education, teachers will be more flexible to design the courses, conduct on-line interactive instructions, and keep on improving teaching materials by the cooperative results. The virtualization and automatic techniques of cloud computing will benefit MIS personnel by enabling them to optimize the application of resources, reduce the cost, and improve the efficiency.

4 Painting Expression Ability

For art education, the creation process is far more important than the final work. When students fully concentrate on painting, they can know themselves more and fully exert their imagination during the creation process; even if teachers do not like the final works, they have to encourage them and give them confidence which can enable them to keep on creating freely. Hence, creations should be evaluated according to their individual value. Evaluating students' works enables teachers to better understand their growth, intentions for creation and lives outside of art.

What is the suitable method to evaluate students' painting works? Are evaluation methods, grading or tests suitable? It depends on teachers' instructional goals. Eisner (1972) analyzed students' painting works based on three dimensions [10]: (1) skills included the handling and control of material, form invention, symbol creation, and space, etc.[10]; (2) aesthetic and expression included aesthetic order and expression, the aesthetics of form depiction and the aesthetics they created; and (3) imagination included the results of wisdom they showed in the works. Chen (1995) who studied the guidelines to evaluate children's works held that teachers should examine the materiality of works and the details by color, line and shape because all details could enrich the content and completeness of works [11]. The next steps were to examine the clues of works by theme, meaning, mind and emotion, and to track the background material in order to capture the metaphor in works (Chen and Chen, 1995). Yunghans (1981) regarded the criteria of work evaluation include the straightforwardness and purity of expression, the method of problem solving, the period focusing on the creation, and the increase of and attention to details [12] [13]. The evaluation criteria of Lark-Horovitz, et al (1973) were personality, skill, knowledge, persistence, and growth showed in the works such as concept, form, cognition, skill, etc [14]. Getzels studied evaluators' attitude in the evaluation process, and the criteria were "overall beauty", "skill" and "originality". He invited 4 groups of people with different identities to evaluate. The first group was art critics; the second group was formed by art education teachers; the third group was formed by mathematical doctors, and the fourth group was formed by graduate students; the latter two groups were called "outsider evaluation". The results showed that evaluators who were not art professionals cared more about skills and art professionals emphasized overall beauty and originality more.

There are plenty of researches on children's painting expression ability, and this study used "Measurement of Children's Painting Expression Ability" designed by Guo (1994) to be the evaluation instrument. Higher children's scores represented better painting expression ability, and vice versa [15]. The content of the evaluation showed as follows:

- Image expression ability: It refers to the ability to show the completeness level of objective images, the correctness level of contour depiction and precision level of depiction in painting.
- Color expression ability: It refers to the ability to show color change, color mixing skill, and warm and cold colors in painting.
- Space expression ability: It includes the ability to show brightness and darkness, farness and nearness, overlapping, three dimension of space in painting.

- Aesthetic expression ability: It includes the ability to show consistence and harmony of key and secondary tones in painting.
- Completeness ability: It refers to the ability to finish the complete painting and demonstrate individualized beauty in painting.

5 Methodology

The purposes of this study were to build up a cloud education system to satisfy the high-speed computing needs of observational learning system and massive storage, to investigate the learning performance of observational learning of art education in the elementary school assisted by this system, and finally to investigate students' satisfaction with this system. Subjects were the on-line observational learning group who used the cloud education system and the other group served as the general observational learning group. Based on the purposes, this study constructed the following research process and framework. There were three main phases. The first phase included a pre-test and sampling categorization; the second phase was teaching and experiment treatment, and final phase included a post-test and teaching evaluation survey.

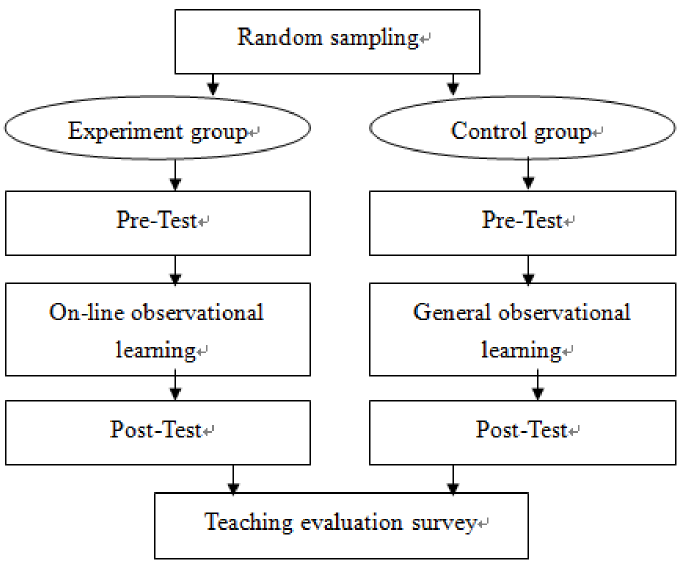

Fig. 1. Research framework

High definition paintings contain huge amount of information and large file size. In order to record the changes of works, the system needs a huge space. Besides, in order to observe others' works, these works need to be transmitted to PC through the internet. By the computing of computer, the works under observation could be played for learners to conduct observational learning. Transmitting and restructuring works by the internet contain great amount of information and need a very high speed computing. If the researcher used the common method of application program to design it, this process would become very slow. When the students attended the class and used the internet simultaneously, the observational learning would not work.

Therefore, this study designed and developed a system to be the research tool. This study utilized cloud computing and Web to design an observational learning system. The basic data format was XML, and the researcher designed the system by cloud computing and network tapping technique. The framework of the system showed in the following figure. What learners would feel was a simple drawing board, and when they were on line, they could attend the on-line art instruction. The system did not need to record data in each PC, and all creation processes were recorded in the internet, emphasizing the concept of cloud computing.

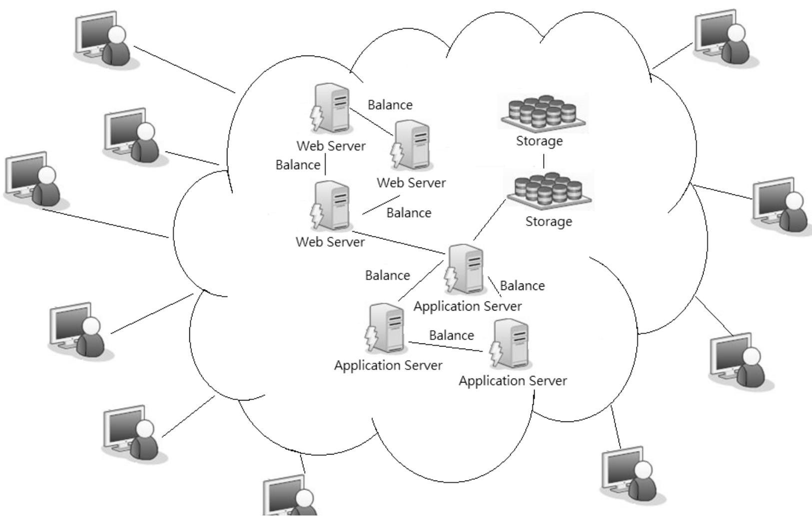

Fig. 2. System architecture of cloud education system

All data were stored in the cloud. Learners could observe others' paintings and understand these creators' skills such as shaping, composition, coloring, etc. anytime. These paintings could be played repeatedly and paused at any time and any frame so that learners could grasp all skills which creators used profoundly. Teachers also could know all of learners' details and characteristics in performing observational learning and strengthen the teaching.

This questionnaire was to understand the experiences and feelings of the experiment group. The researcher designed the questionnaire, and it contained 8 questions including narrative and evaluative questions, according to Likert Scale the researcher divided the levels into highly satisfied (5 points), satisfied (4 points), OK (3 points), dissatisfied (2 points), and highly dissatisfied (1 point).

Fig. 3. Play the painting processes

6 Results and Discussion

6.1 System Design

For the development of the system, this study used cloud computing to design, and the creation process of each work could be played on line. No matter how long the creation process was, it only took 31 seconds on average to load the file and play the work. Moreover, all files were saved in the web server which conformed to the concept of cloud computing; even if the work was not finished, it could be quoted again to finish it. The huge amount of information was not saved in PC, so they would not be lost, and all paintings could be quoted.

For the designing principle of instructional content, 88% students were satisfied with it of this website. This indicated that the arrangement and planning of chapter and session of this system were generally accepted by these users. The results of this study showed that there was no significant difference among different gender and class, and this showed that users in this study generally held the same opinion about the instructional design of this study. It was found out that the content planning of this study currently was professional in the research of instructional content.

For the designing principle of instructional design, 94% students were most satisfied with this dimension. This indicated that the instructional design of the curriculum of this study was professional. The research of instructional design showed that multimedia applications such as image, sound, animation, professional image processing...etc. used in this system were favored by the users; moreover, they were highly satisfied with the features of learning anytime and anywhere. This was the advantage of e-Learning over traditional learning methods.

For the designing principle of learning guidance, 82% students were generally satisfied with it of the website of this system. This indicated that learning guidance of the curriculum was carefully designed in this system. It was found out in the research of learning guidance that operation instruction, related link guide, search function...etc. used in this curriculum were recognized by the users. Generally speaking, when they used e-Learning materials usually there was no teacher to guide and interact with them, and they might not know where to start. When they face massive learning data, they need a more complete function of learning guidance which can assist them in using e-Learning.

For the designing principle of instructional media, 90% students were generally satisfied with it of the website of this system. This showed that the application of image and text, the aesthetics of color, and layout editing of this system were professional. The results of this study indicated that there was no significant difference among different gender and class, and this showed that users generally held the same opinion about the instructional media in this system.

For the designing principle of interface compatibility, 83% students were generally satisfied with it of the website of this system; however, the satisfaction level was the lowest among instructional content, instructional design, learning guidance, instructional media and interface compatibility. This indicated that the techniques applied in the system operation were fine; however, it still could be improved. It was found out in the research of interface compatibility that this e-Learning system made the users feel convenient and reliable in using it, and this is a very critical factor for e-Learning to be popularized. The goal of e-Learning is to eliminate the distance in learning: to make teaching materials accessible to users and allow them to use these materials in different settings.

The possible difficulties that students might encounter: 42.1% was lack of learning motivation, 29.7% was having no time to learn, 21.4% was lack of ability to use computer, 20.3% was that equipment was outdated, 18.1% was insufficient courses, the least was not being used to this instructional method (4.8%). This showed that students thought that they were able to learn via e-Learning system; however, if they learned mainly by e-Learning, the major difficulties they would have was lack of practical motive and time planning.

6.2 Learning Performance

For learning performance, this study used learning performance evaluation and data from the satisfaction questionnaire survey done after the on-line observational learning course to understand the performance of on-line observational learning course. From the statistical analysis, students' five abilities of painting expression could be obtained as follows:

The average score of image expression ability was 2.97, meaning that most children were able to show the completeness of image, correctness of contour, and precise depiction of objects in painting. The average score of color expression ability was 2.72, and most children were able to show color change, color mixing skill, and aesthetic level in painting. The average score of expression ability of space treatment was 2.74, and most children were able to show light and shadow, the arrangement of farness and nearness and overlapping. The average score of aesthetic expression ability was 2.64, and most children were able to show the aesthetic level of consistence and organization. The average score of completeness ability was 3.40, and most children were able to complete the whole painting, concentrate on it and complete the individualized work within a certain period.

The average scores of these testees' 5 expression abilities of painting from high to low separately were completeness, image, space treatment, color, and aesthetic expression abilities. We also have run the one-way ANOVA and found that there were significant differences of "image expression ability", "color expression ability", "space expression ability", and "aesthetic expression ability" between the two groups (as shown in Table 1). The results indicated that the on-line observational learning group performed better than the control group in image expression, color expression, space expression and aesthetic expression. But for completeness expression ability, data obtained from the test of painting expression ability showed that there was no significant difference between the two groups. Hence, the completeness expression abilities of these two groups were at the same level.

Table 1. The ability Comparison of significant difference between two groups

Item		Mean	Sd	F	P
image expression ability	Experiment Group	3.4121	.9354	4.6601	.000*
	Control Group	2.3333	.7360		
color expression ability	Experiment Group	3.3045	.9211	7.1231	.000*
	Control Group	2.3433	.7244		
space expression ability	Experiment Group	3.0182	.9475	8.6432	.000*
	Control Group	2.4346	.6410		
aesthetic ability	Experiment Group	2.9182	.9133	4.3173	.001*
	Control Group	2.3122	.8122		
completeness expression ability	Experiment Group	2.9941	0.9177	1.9871	0.68
	Control Group	2.9012	1.0321		

$^*p<0.05$, $^{**}p<0.01$

After collecting and analyzing the data from the questionnaires, the following conclusions were obtained based on the analysis of the satisfaction. According to Neilsen (1994), he found out the intermediate value of Likert Scale was 3.9, and all questions were above this level. In this study, the experiment group had the highest satisfaction score about "the course can be played repeatedly" (4.6 points). The second highest score was "easy operation" (4.2 points); the third highest score was "course quotation and works can be amended fast and conveniently (4.1 points), and the lowest score was "this course can help you in learning art" (4 points). All of these were above the level, describing the users' positive attitude toward this system for art learning. About the window and operation of the system, the satisfaction level was above 4 points, and it was clear that users did not have problems in the operation and it was easy and convenient to use. As a whole, the scores were all above 3.9, and it showed that this system was recognized by these users.

Summarizing the results, the on-line observational learning system had positive effects on art learning of students in the elementary school. For the effects of learning performance, the results of academic tests showed that the experiment group's learning performance was better than that of the control group and there was a significant difference; that is, the learning performance of the experiment group receiving on-line observational learning was better than that of the control group receiving general observational learning. In other words, with the assistance of this system the experiment group's learning performance was better than that of the control group. In addition, the attitude survey of the students in the experiment group showed that almost all children enjoyed using the system although its operation and content design were not perfect.

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The Use of Integrative Framework to Support the Development of Competences

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Abstract. In corporate environments, there is a growing interest in deploying more effective solutions in supporting competence development, namely to address the identified need of developing soft-skills (eg: negotiation, leadership) and complex competences (eg: sense-making and cross-cultural communication). The "learning by doing" has gained prominence, in particular when considering the use of serious games as the delivery platform for the educational content. However, the adoption of serious games alone is not a guarantee for effective learning and consequently, the aim of this paper is to present the integrative framework that combines together five key developments in education research, namely Knowledge Ecology, Social Learning Communities, Threshold Concepts, Experience Management and Cognitive Management. Based on the integrative framework, the paper proceeds to present the TARGET componentized platform.

Keywords: Serious Games, Competence Development, Threshold Concepts, Cognitive Load, Social Learning, Knowledge Ecology.

1 Introduction

This was recently illustrated in an article by Richard Barker:

No, management is not a profession. Some business skills can't be taught in a classroom. They have to be learned through experience.

Barker 2010 [4]

The above comment does not refer only to the challenges faced by business schools and the those institutions teaching management, but may be applied to other learning domains that are relevant to different industrial sectors, as demonstrated by the study by Nair et al [24], where employers indicated there to be a shortfall in some competences deemed essential for a graduate engineer to have in their repertoire, such

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as ‘capacity to analyze and solve problems’ and ‘ability to develop new and innovative ideas, directions, opportunities or improvements’. However, it has been argued that the solution relies on the industry, research institutes and universities need to cooperate with one another [36].

With the fast pace of technology and the shrinking of geographical distances due to globalization, the “war for talent” is fiercer than ever before. This has led to increasing acceptance by organizations, as a key business strategy, of the need to retain and re-train their existing staff through some kind of tailored competence development that reduces the lead-time for a learner to achieve target productivity: the “time-to-competence" (TTC). The need for rapid competence development is compounded by shorter cycles concerning the knowledge to be acquired and mastered. Aldrich in [1] draws an interesting parallel of e-learning industry with the fast-food industry, where the focus is in reducing costs, increase efficiency and minimizing the time spent by a customer in eating. Unfortunately, in maximizing the process efficiency of fast-food, the nutritious and health value of a meal has been neglected and similar claims are made concerning e-learning, where the focus is on maximizing the efficiency of delivery of content, but not necessarily achieving the TTC. Finally, the fabric of society has been shaped by technology, resulting in the emergence of the “digital natives” [30] who due to their familiarity with multiple technological stimuli and social interactivity, have become more demanding on how the facilitation of learning should be carried out. This paper presents the Integrative Framework used in the Transformative, Adaptive, Responsive and enGaging EnvironmenT (TARGET) project [31], which shapes the associated componentized platform.

2 Integrative Framework

Today, the main route to short TTC is a bespoke (hand-crafted) face-to-face or blended course, which tends to be resource-intensive (expensive to create and deliver). There is a need of methods and tools to effectively and economically address dynamic competence development rapidly, with flexible learning contexts of varying complexity and longevity. One challenge is that each learner is a unique individual, with different cognitive abilities, emotional intelligence, personality, knowledge, and experience. Thus, it is not feasible to develop a single solution tailored to all learners, but rather it is necessary to support mass-individualization. The problems are exacerbated by the need to retain the capacity to handle unpredicted events, meaning that at least some of the learners/managers in an organization need to attain novel ways of understanding and the ability to think with different perspectives.

In order to address these problems, the TARGET project [31] has taken the approach of building an integrative framework (Figure 1) that brings together five key development areas of education research, namely Knowledge Ecology, Threshold Concepts, Experience Management, Cognitive Management, Social Learning Communities, each of which will be described in the subsequent subsections.

2.1 Knowledge Ecology

As we are living in a knowledge society, knowledge-management is increasingly important, especially from an organizational point of view. Traditionally, the term

Fig. 1. Integrative Framework

knowledge management is applied to any method of gathering, organizing, refining and disseminating the knowledge present in an organization. However, the scope of knowledge management has changed, extending the traditional content perspective to a broader vision that also includes the individual's knowledge. As an outcome of this trend, successful knowledge management nowadays tries to make knowledge potentials of organizations and the individuals as transparent and holistic as possible. Besides, the explication and detection of knowledge potentials has also the possible impact as a remedy against brain-drain in organizations and in knowledge societies.

The term knowledge Ecology (or Ecosystem of knowledge) has been used within the field of knowledge management to highlight parallels between ecological ideas and the dynamics and properties of the knowledge environment within organizations. The metaphor also highlights the fact that knowledge within organizations is dynamic, which implies a lifecycle beginning with the creation of new knowledge and its recognition (in the sense of altering prior knowledge to incorporate new, hence re-conceptualizing, re-thinking), which evolves and matures over time. Elements of these ecologies have life cycles that mimic natural life cycles [7][16]. According to [29], the concepts of knowledge ecologies and ecosystems help to bridge the gap between the static data repositories of traditional knowledge management and future, more useful repositories that embody the dynamic, adaptive behaviour of natural systems. Recently the distinction between tacit and explicit knowledge has also become popular within organizational knowledge management approaches. Tacit knowledge is regarded as not yet explicated knowledge and is seen as individual knowledge. The major difference of tacit to explicit knowledge is the lack of conscious awareness of the individual about the tacit knowledge he or she has. Implicit knowledge also mostly results from the accumulated experience of several episodes rather than that of a single event. Thereby it is hard for yourself to explicate the tacit knowledge you own. However, to address these problems, the Knowledge Ecology is concerned primarily with the transmission and acquisition of dynamically changing knowledge connected to and embedded in shareable processes.

2.2 Experience Management

Management disciplines involve a combination of skills. Hard skills are often described as science and require technical training. Whereas soft skills relate to working with and managing people. Soft skills, often described as an art, are critical for project management success. These skills are typically acquired through experience [4] and consequently experiences are key to human understanding. It is not primarily a matter of remembering general concepts or applying abstract rules. Rather, humans think and understand best when they can imagine (simulate) an experience. The simulation is preparation for performing necessary and preferred actions in order to accomplish goals.

Serious games are strong contenders to support competence development and have potential advantages over more traditional learning methods and on-the-job training because they offer tailored experiences, in which participants learn through a grammar of doing and being [32]. These include tolerance to and encouragement of risk within a safe environment, thus promoting and encouraging experimentation and better understanding instead of passive learning [18]. In addition serious games increase motivation, provide ego gratification, encourage creativity, socialization and above all are fun. Serious games also support a situated context for learning in a virtual world as when you learn by playing a game, you apply that learning immediately in the game and move on to learning new skills [15]. Game scenarios and characters in the game that reflect the real world will enable a near-transfer of knowledge. Evidence is growing for the increased efficiency of serious games over more traditional learning methods [9]. Serious games have already been adopted in numerous sectors like Manufacturing, Sales, Human Resource, Finance, Energy, and also Project Management. Some example like IBM’s INNOV8 2.0, Sharkworld Game and SimuLearn’s Virtual Leader already give a glimpse of how serious games can leverage the power of computer game by engaging the learners in tasks and experience situations which would otherwise be impossible and/or undesirable for cost, time, logistical and safety reasons.

In TARGET, serious games offer learners an opportunity to experience realistic project situations, which are highly motivating and engaging learning experiences that contribute to long-term knowledge retention. Using serious games, a learner is able to go through a multitude of experiences, each one introducing different situations generated dynamically to suit the learning purposes. This is one way serious games can offer the advantages of both experiential learning and situated learning, which is learning by doing and acting in real life situations [19].

2.3 Cognitive Management

According to Cognitive Load Theory (CLT), learners have a working memory with very limited capacity. Learning is dependent on three kinds of cognitive load: the intellectual demands of the learning content (intrinsic cognitive load), cognitive demands that interfere with learning (extraneous cognitive load) and, finally, deep processing that leads to the development and/or integration of schemas in long-term memory (germane cognitive load) [3].

Early CLT research focused on design techniques to reduce extraneous cognitive load so that available cognitive resources could be fully devoted to learning. Recently CLT research has focused on the identification of techniques to optimize cognitive load by decreasing intrinsic load and bolstering germane load [3]. In part, this switch of focus is an attempt to make CLT more relevant to complex learning. In complex learning, students must learn to deal with materials incorporating an enormous number of interacting elements. Even after all sources of extraneous cognitive load have been removed, element interactivity of learning material can still be too high to allow effective learning. Therefore, new instructional methods are needed to reduce intrinsic cognitive load and/or bolster germane load.

One approach has aimed at the reducing intrinsic cognitive load. For example [28] studied the effects of sequencing in the context of CLT and found that understanding of complex material was greater when isolated elements were processed prior to the presentation of the full information with all the interacting elements. Another key development in CLT research is based on the idea that instructional design effectiveness depends, in part, on the learner's experience in the domain being taught. According to the expertise reversal effect, instructional techniques that are effective for novices (e.g. instructional guidance) can lose their effectiveness and even have negative consequences for learning when used with more experienced learners [3]. The implication for instructional design is that materials should be tailored to the learner's level of expertise. Within computer-based environments, this requires a dynamic assessment of individual learners' expertise and adaptation of the instruction, in real-time, to changes in the student's performance and/or cognitive load [3].

Some researchers within the CLT framework interested in e-learning have focused on effective expertise measurement. Expertise assessment usually includes some or all of the following: performance, mental load and mental effort. The latter refers to the cognitive capacity that is allocated to accommodate the task demands. To date, most studies have used self-report rating scales to measure mental effort [26] although there has been some research into other methods e.g. psychophysiological measures [33]. One strand of research has addressed the challenge of measuring performance in complex tasks, for example [17] "rapid assessment test". Finally, some work has addressed the challenge of how to combine mental effort and performance measures.

2.4 Threshold Concepts

The Threshold Concept (TC) Framework focuses on identifying those aspects of a discipline that are essential to a grasp of the discipline, that are likely to be difficult and once overcome will transform the learner's view of that discipline. This means the learner will now begin to think as does a practitioner of their discipline, e.g., thinks as a manager, thinks as an innovator. It arose from a study of the teaching of economics but has now been taken up by educational researchers and teachers across a wide range of disciplines [12]. "Difficulty in understanding TC may leave the learner in a state of liminality (Latin limen "threshold"), a suspended state in which understanding approximates to a kind of mimicry or lack of authenticity" [23]. The originators of the framework, Meyer and Land, characterize the TC as:

- **Transformative**: once a TC is understood, a significant shift appears in the student's perception of the subject;
- **Integrative**: once learned, TCs are likely to bring together and relate different aspects of the subject that previously did not appear to the learner;
- **Irreversible**: given their transformative potential, a TC is also likely to be irreversible, difficult to unlearn;
- **Bounded**: a TC will probably delineate a particular conceptual space, serving a specific and limited purpose;
- **Discursive**: Meyer and Land suggest that the crossing of a threshold will incorporate an enhanced and extended use of language;
- **Troublesome**: TCs are likely to be troublesome for the learner.

The framework draws on Perkins' discussions of how knowledge may be troublesome e.g. alien, incoherent or counter-intuitive [27]. In grasping a TC a student moves from an apparent 'common sense' understanding to an understanding which may conflict with perceptions that have previously seemed self-evidently true. [10] suggests some influences that TCs can have in the design of a university course curriculum: first, they enable teachers to focus on what is fundamental to grasp of the taught subject, a 'less is more' approach to curriculum design; once identified, the tutor becomes aware of the areas where students might encounter problems; then, they might need recursiveness in order to be mastered; they also require listening from tutor's side in order to hear what the students' misunderstandings and un-certainties are in order to engage with them [10]. Cousin characterized in 2009 the TC framework as a transactional curriculum enquiry [11]. This would require a partner-ship between the discipline's experts, educational re-searchers and learners in which curriculum inquiry and curriculum design are seen as feeding into each other rather than as sequential activities.

Recentlty it has been suggested that a two contemporary and powerful conceptual frameworks, TCs and variation theory share a key pedagogic principal and share a central common focus [22] warranting further examination. Variation theory of learning is associated with a much more formalized approach rooted in phenomenography [20]. It states that a key feature of learning involves experiencing that phenomenon in a new light [21]. Marton argues that "there is no learning without discernment and there is no discernment without variation". Therefore, in order for students to discern the object of learning, they must experience how they vary. The key elements that are relevant here may be summarized as its four pat-terns of variation:

- contrast - experience something else to compare it with;
- generalization - experience varying appearance of an object;
- separation - experience a certain aspect of something by means of varying it while other aspects remain invariant
- fusion - experience several critical aspects simultaneously.

The work of Bernhard's group [8] on applying variation theory to a circuit analysis problems in which a TC is embedded and the study by [13] on how a TC in engineering comes into view when approached from two very different engineering contexts suggests Meyer and colleagues suggested further examination is justified. Problem-based learning has also been suggested for facilitating a learner's traverse across the liminal space. Other recent studies of Meyer and colleagues [23] show how meta-learning can help at overcoming TCs and its importance in identifying transformation. To sum up, all these studies show positive results over the improvement of the learning process by integrating TCs. In this context, we consider that TCs are indispensable for an efficient, beyond the current state-of-the-art, learning environment.

2.6 Social Learning Communities

The concept of 'Social Learning Communities' is increasing considered to provide a valuable addition to how organizations utilize and develop their learning and knowledge assets. Learning social communities is the term applied in the TARGET context to describe a wide range of possible social constellations of collaboration within and among organizations. The modern workspace is characterized by increasing diversity and variety in the way learning communities are formed and operate, and this diversity is seen as a necessary repertoire to meet the speed of the new economy [25]. Learning social communities previously referred to groups that were co-located, homogeneous in background and education, and with relatively stable functions. As such, these groups are designed for the purpose of bringing new people into an existing environment of knowledge and practice. Here, the focus for the participants is on belonging. Increasingly, these stable and predictable organizational forms are augmented with different possible collaborative possibilities. The traditional team, such as found in communities of practice, with their guild resemblance, now is at one end of a gamut. This is complemented with networks of varying density and regularity towards the other end of the gamut. These learning communities are looser, more unstable, yet able to move quickly and adapt to changing situations. Their lack of formality is precisely their strength and attraction. At this end of the gamut, the focus is on connecting. Increasingly, these groups migrate to the web, creating collaborative forms beyond the scope of a group or a hierarchy. Different types of 'digital habitats' emerge [34][35]. Both varieties, the traditionally oriented and the future oriented share the common purpose of providing the means and environment for participation and the environment for transferring participation into reification. By this is meant the translation of an experience into a "collective anchor", that may be a certain method, a way of doing things, a way of thinking, a prototype, a perspective or a way of seeing the world. A common trait to be observed in these collaborative constellations is that the learning taking place is of a definite constructive and social nature.

At the same time as organizations have become more complex in their structure and functionality, the role of learning as a part of the added valued and competitive advantage has become increasingly important. The various ad hoc collaborative constructions may all contribute to this end. However, understanding and charting the changed landscape of the organization is a necessary complementation of understanding and charting the learning process. Such an approach to organizations may be found in the increasing body of literature that perceives organizations as 'complex evolving systems'. In this perspective, organizations are co-evolving within a social ecosystem, thereby changing the focus from the organization as the centre of attention to the social ecosystem. A major characteristic of these collaborative constellations is that they tend to emerge upon the initiative of individuals, and on the side of the ways of the organization they are a part of. Lack of control and predictability of development are salient features [34]. Consequently, an important characteristic of these collaborate constellations is that they are difficult to govern or to rule, if applying a traditional organizational approach. Instead, the focus regarding learning communities should be turned from controlling to facilitating the activities of the individuals and the community they take part in [34][35].

3 TARGET Platform Overview

The TARGET project aims to develop an innovative TEL platform that provides learners with a responsive environment that addresses personalized rapid competence development and sharing of experiences.

3.1 The Duality of Individual and Social Learning

The approach taken in TARGET reflects upon James Baldwin's paradox [5] "in order to be social you have to be individual and in order to be individual you have to be social", thereby treating learning as a non-linear process moving away from a dichotomy of individual and social aspects of learning, whilst emphasizing dialogue and transformation (e.g. Threshold Concepts Framework [13]. This duality is captured in the block diagram of Figure 2. In TARGET, the learning process draws heavily from Problem Based Learning (PBL) [6] and Action Learning (AL) [14], resulting in the use of digital interactive Stories that provide situated rich contexts where a learner is required to apply and develop competences to achieve successful outcomes.

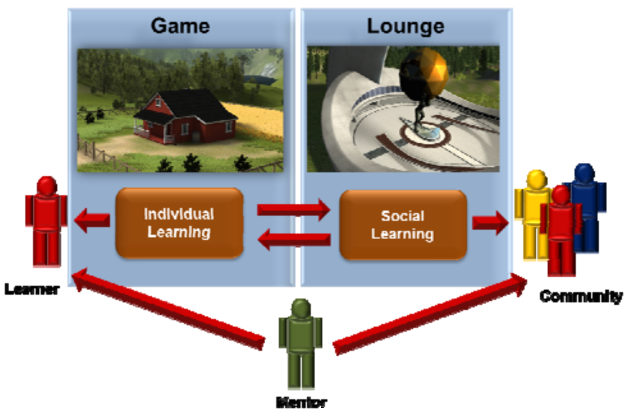

Fig. 2. Individual and social learning supported by TARGET componentized platform

The situated contexts captured by Stories represent a scoped business environment where multiple characters are defined with specific roles and responsibilities. Since the paradigm of emergent storytelling is adopted, some of the characters are strategically controlled by Non-Player Characters (NPC) to ensure the Story unfolds with the aim of developing the associated competences, so for example with conflict management, the NPC will control the anti-protagonist to oppose the learner's goals. However, taking aside these strategic characters assumed by NPCs, the learner may choose which one of the remainder characters to assume in the Story. In the cases where there is more than a single character available for the learner to choose, then it is possible to have multiple learners engaged in the same Story. The fact that a few learners may simultaneously engage with the same Story does not change that learning continues to be individual irrespective of the possibility of learners exhibiting behaviours out-of-character, communicating with one another.

As evidenced in social constructivism, peer-to-peer learning is essential for facilitating the externalization of the tacit experience acquired by learners whilst engaged in the Stories.

3.2 The TARGET Learning Process

The instantiation of the TARGET Learning Process, which is supported by a componentized platform, is illustrated in the diagram of Figure 3.

Fig. 3. Overview of the TARGET Learning Process

Each of the stages can be characterized as follows:

- **Curricula Design.** The TARGET Learning Process begins with the learner deciding on what competences to develop. This is done in one of two ways, either goal-oriented or self-directed learning. In the case of goal-oriented learning, the learner defines their current competence profile and their desired learning outcome in the form of outlining their target competence profile. The result of profiling leads to the creation of a learning plan based on custom stories tailored to the particular needs of the learner. Each story captures a business context, which may also involve defined characters with particular roles. The process of creating the learning plan is governed and shaped by a learning strategy that is chosen by the learner. In the case of self-directed learning, the learner builds their learning plan from the experiences of others within the community and these are stored in the knowledge ecosystem.

- **Briefing.** The learner is provided a background to a Story, which gives insight into the context, including the various characters available and their role in the Story. Some of the characters are available to the learner to be played by them, but in many cases the characters are only manipulated by NPCs.
- **Experience.** Whilst engaged with the Story, the system provides an environment where the learner engages with other characters (either controlled by another learner or a NPC) and the environment, enacting their decisions. These decisions will have an impact which will affect and change the situated context of the Story. By monitoring the actions of the learner and taking into account the desired learning outcomes, the TARGET platform makes changes to the Story if necessary. As examples, these changes may be modifying the personality of a NPC to be more confrontational or delaying tasks within a project.
- **Reflection.** The learner is presented with the assessment of their competence during the experience in the form of a timeline manner. The ability of looking back on their decisions by reviewing how the story unfolded whilst cross-referencing the assessment of their competence at each point in time, allows the learner to evaluate their performance leading to reflection.
- **Peer Learning.** The TARGET learning process supports the learner in externalizing the tacit knowledge acquired after their experience of a Story, thereby contributing to the creation of knowledge assets that are uploaded to the Knowledge Ecosystem. Once uploaded, the learning community plays an important role in the process with the support of recognized mentors as facilitators and in discussion with other learners. The social aspects address the need of an ability to deal with flux and instability, and to thrive in situations of flux.

Each of the five phases of the TARGET learning process is supported by a set of well-defined services embodied into components that are event driven, thus loosely decoupled from one another with some sharing functional dependencies. This means that the TARGET platform need not be entirely deployed as an integrated solution, but only subsets of the supported functionality. However, one needs to ensure that those components sharing functional dependencies are deployed together otherwise they may be operational at run-time but not work as required.

5 Conclusions

Actually, there is a need to effectively and economically address dynamic competence development rapidly, with flexible learning contexts of varying complexity and longevity. One challenge is that each learner is a unique individual, with different cognitive abilities, emotional intelligence, personality, knowledge, and experience.

In order to address these problems, we presented in this paper the integrative framework deployed in the TARGET project which brings together five key development areas of education research, namely Knowledge Ecology, Threshold Concepts, Experience Management, Cognitive Management, Social Learning Communities.

In fact, TARGET goes beyond current competence development platforms, by combining serious games with cognitive science, threshold concepts and learning communities, thereby offering users a platform where they may develop their competences through the fastest learning path and in condensed time. Much like flight simulator training offers pilots the opportunity to train for thousands of situations not even a lifelong career would ever present to them, a few months' use of TARGET can give project managers experience of thousands of situations marked by community recognized challenges. And since both allow the learner to experiment with different approaches and solutions without risking more than losing the simulation/game, this way of building experience normally leads to an even richer set of lessons learned.

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A SUNNY DAY: Ann and Ron's World an iPad Application for Children with Autism

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Abstract. As autism becomes a more widely-understood medical field, so do therapeutic implications. With the recent development of these methodologies in mind, "A SUNNY DAY" aids the therapeutic treatment of children with autism by providing simple and structured tasks while awarding children with praise in the form of an electronic iPad application. Every task in the game takes into consideration the emotional, social, and sensory disabilities autistic children struggle with and utilizes new teaching methods to remedy them. This paper includes the research prior to developing the application and the design and objectives of the application.

Keywords: Autism; autistic disorder; iPad; application; therapy; rehabilitation; game; a sunny day; interactive behavior training; text-to-speech; communication.

1 Introduction

The 1988 film, Rain Man, depicts the life of a person with the developmental disorder known as autism. Raymond Babbitt, played by Dustin Hoffman, had extraordinary mathematic capabilities that rival calculators, as well as a photographic memory. Although he has these gifts, he lacks social abilities to effectively communicate with others. Raymond's struggles are common to many individuals in the real world who also have autism.

Autism, also known as "Autistic Disorder," is a developmental disorder caused by a malfunction of the nervous system, with symptoms including defective social awareness, the inability to communicate effectively, and abnormal interests and behaviors. Although autism has been known to occur in approximately five in ten thousand people [5], there has been an increase in reported diagnoses of children and older people alike with milder forms of autism. Individuals with autism may cause mental and economic burdens for their families, as autism is a relatively new medical field which contains many mysteries yet to be solved.

"A SUNNY DAY" seeks to aid the therapy of autistic children. This iPad application is a product of the widespread goal of the Tencent Foundation and the Digital Media Lab of the Central Academy of Fine Arts in helping autistic children "live in sunshine," improving the lives of children with autism and their families and friends. This tool can help remedy effects of autism by challenging users with tasks,

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based on the corresponding research. Additionally, it educates families, friends, and caretakers of autism and aids in the therapy of their loved-ones. “A SUNNY DAY” utilizes technology not previously available or user-friendly to children with autism in order to provide effective means of education and therapy in the home without the presence of expensive medical or professional aid.

The purpose of this paper is to present the research conducted in discovering the best method to accomplish this goal. Through interviewing and investigation of existing therapeutic methodologies, we are able to establish our own based on technological advantages offered by the iPad and effectively change the manner in which autism is treated. Although games are previously thought to be purely for entertainment, through research and implementation of multiple therapeutic methodologies, it is possible for serious game technologies to act as a medical tool for children with autism.

We shall begin by discussing the discourse of the background investigation involved prior to the design stage. In the three stages of investigation, we will visit and interview institutions who work with autism in order to design a game correctly catered towards children with autism and help them improve learning skills. Section 3 will discuss the game concept and factors implemented pertaining to the research on autism followed by Section 4 which describes the test process with allowing children to play the game, and adjusting the game design to more effectively meet the needs of the children.

2 Initial Research

Prior to developing a therapeutic game for children with autism, it is imperative that we gain the appropriate knowledge of autism: what is it, how can it be treated, and how can we treat it in a single iPad application? We address these questions in the following three stages of investigation.

Our research will be conducted in three phases. The first stage of investigation will be directed towards learning about autism as a whole. We do this by interviewing hospitals, clinics, and other institutions related to the treatment of autism. Doing so will allow us to understand the basis for the game design and establish clear goals about the goals of the game. Stage 2 of the investigation will continue to closely interview clinics and observe current practices for the remedy and treatment of autism. These practices consist of several methods and training strategies which help children improve various skills. Studying current treatment methods will allow us to form our own treatment techniques while incorporating other existing techniques. Stage 3 of the investigation will continue to observe training methods and interviewing parents, teachers, and children in order to discover effective ways to incorporate training methods into an electronic application. We will focus on finding out what elements best captures the attention of a child with autism. The research of autism is vital to the game design. Every element of the game is designed to train children effectively in various areas and cannot digress in lieu of possible adverse affects.

2.1 Stage 1 of Investigation

Following the investigation with the Beijing Association for Rehabilitation of Autistic Children, Sixth Affiliated Hospital of Peking University, Capital Pediatrics Institution and Children's Hospital, and visiting with Professor Wang Yufeng, the Vice President of Sixth Affiliated Hospital of Peking University, Vice President of Beijing Association for Rehabilitation of Autistic Children, and the pediatric doctors of Children's Hospital affiliated to Capital Pediatrics Institution, we have discovered several findings regarding autism. Contrary to popular belief, autism is a developmental disorder, not a psychological disease. The difference between the two is that autism is inherent to the individual, while disease is caused by a more direct, external, biological agent. As forms of autism differ, it can also be caused by different physical, social, or mental factors. Additionally, autism changes with the maturing of both the body and minds of children. According to the Chinese Autism website [4], the occurrence curve for mental retardation is opposite to that of autism, with autism being significantly higher. This is largely due to the lack of related studies and diagnostic tools that differentiate the two. There are no commonly known guaranteed therapeutic correctional methods related to autism. With the release of the Apple iPad, we seek to introduce new correctional methods that incorporate this technology. The iPad is a simple means of interaction with an intuitive display and interface for children with autism. John Gruber, on his blog addressing autism applications, states that "A SUNNY DAY" has "results [that] are seemingly miraculous…the lack of indirection — fingers [are] touching screen elements directly, rather than pushing hardware buttons or manipulating an on-screen pointer using a mouse or trackpad" [7]. Indeed, the simplicity of a direct interface of the iPad proves to be, by far, the simplest form of interaction for children with autism.

2.2 Stage 2 of Investigation

The purpose of this investigation was to assess the viability of "A SUNNY DAY" in comparison with other rehabilitation methods. Upon interviewing teachers and parents, and the data derived from questionnaires, we have found that there were many types and subtypes of autism treatment, both orthodox and unorthodox. In order to produce an effective learning software for children with autism, it is imperative to implement teaching methods that are known to be effective. This is to avoid implementing education elements that are irrelevant and may possibly confuse the children.

According to popular discourse, autism is a biological defect and language is the foundation of the disorder. However, studies indicate that its core symptoms do not, in fact, stem from language problems [9]. Thus, methods which derive therapeutic processes from solutions based on language may not necessarily be helpful. The foundation of symptoms in autism is the social response, which incorporates language among other communication skills.

In addition, autism patients are susceptible to the connotation of respective cultures. A common definition of autism is the incapability of communicating within a certain culture. While it is true that the capacity to communicate on the premises of language may be lacking, it is the capability to communicate to the standards of the culture which is difficult. Of course, this does not imply that a child can be autistic in one culture and not another, but that certain cultures may contribute, to a certain extent, to the development of autism, as it is a social disorder and is relevant to social contexts and situations. Based on these assumptions and findings, we aim of "A SUNNY DAY" will target the core disorder of autism – the malfunction of social functions.

As case studies of current methods of autism therapy are vital in developing new teaching methods, we have examined therapy sessions in the Sunshine & Friendship Rehabilitation Center. In each session, there are four sections: the cognitive lesson, interactive behavior training, a game simulation to help provoke healthy learning habits, and sensory integration activities which stimulate the children's sensory capabilities. Of these lessons, the interactive behavior portion is to remedy the damage of social functions. The following is the methodology of one of these sessions.

Lesson name: Interactive Behavior Training
Duration: 45 min
Participants: 5 autistic children, 1 teacher, 5 accompanying parents
Training Methodology: Train and encourage healthy daily activities such as putting on clothes, brushing teeth, and eating breakfast. The importance of these tests is to teach children structural habits by encouraging step-by-step repetition.
Training Steps: Demonstrating the movements and actions involved in each activity while explaining them, having parents assisting the children to emulate the activity as instructed by the teacher, analyze the performance of the children and repeat the repeat the steps again, and finally, the issuance of reward to promote future positive behavior.

The methodology that the interactive behavior training incorporates is called "Treatment and Education of Autistic and Related Communication-Handicapped Children," also known as "TEACCH Therapy," which involves close interaction with children and teachers, and rewarding the positive responses of children.

We have made several conclusions after observing and analyzing these therapeutic sessions. People live in tangible, structural social environments; they are foundations of our future behaviors which are products of the responses we receive from the environment. We form cognitions around responses that are to be expected of the environment. Autistic children lack the ability to form cognitions and assumptions of their respective environments, requiring outside assistance in order to effectively do so. It is important to note that it is not impossible for autistic children to overcome the difficulties of forming a structured cognitive system – it is important to implement an effective learning environment which can consistently provide the environmental responses that autistic children require, when normal environments do not.

2.3 Stage 3 of Investigation

After referring to several autobiographies of people with autism, we have discerned that according to personal accounts of autism, these following factors are emotions people with autism feel, and the situations that cause these responses:

- The surrounding environment is usually filled with unintelligible and intolerable noises
- Feel pain and anxiety when touched
- Feel uncomfortable and do not know what to say around others
- Feel delighted and happy when they experience rhythm
- They will not know the meaning of the words they speak out if they do not repeat them
- Are confused when in crowded environments
- They attempt to stop this confusion by acting out

"A SUNNY DAY" contains several features which are sensitive to those feelings described in the above points. First, "A SUNNY DAY" contains background music which is soothing and has a predictable rhythm to induce a calming atmosphere for the player. Additionally, there are several alternatives for voices and music which can be adjusted. Second, the structured step-by-step process is easy for the player to understand without overwhelming or confusing him/her. Third, there are several forms of praise to reward players for completing tasks to encourage effective behaviors and increasing concentration. Fourth, there are a small number of tasks which have real life applications such as finding food and taking baths. These tasks are designed to exercise and improve multiple brain functions including concentration, imaging capacity, and communication skills. Colors implemented in the game are chosen as simple and obvious with strong contrast. Characters are easy-recognizable cartoon figures.

3 Game Concept

The basic interface of the game is simple, making it easy for players to choose the activity by simply touching the object that the player is most interested in. The title screen, shown in Fig. 1, shows a pleasant animated scene with the two main characters of the game, Ann and Ron. Selecting either one will utilize the corresponding character as the assistant who will help the player in achieving tasks. Voice assistance not only aids the player in completing tasks to avoid use of extensive texts for instruction, but it also helps with communication skills. Touching other objects such as the sun or clouds will trigger small animations. There are seven small games in total, five of which are correlated with basic daily life skills such as getting up, brushing teeth, eating, bathing, and going to sleep. These five games are determined by the time of day which include, daytime, school time, and night time. During school time, there are two games which stimulate the child's sense of perception, shapes, concentration, among other abilities

After a character has been selected from the main screen, the player will be prompted to select one out of three scenes: daytime, school time, or nighttime, as shown in Fig. 2. In the daytime, there are three tasks a player must complete: get up, brush teeth, and eat breakfast. During school time, the player must find food with an animal helper and complete a tangram puzzle. At nighttime, the player must take a bath and go to bed.

Fig. 1. "A SUNNY DAY" Title Screen

Fig. 2. Selecting the Time of Day

In the food-finding mini-game, the player has an option of picking a variety of different animals. Upon choosing an animal, it will rotate its eyes until it stops on an icon for a certain kind of food. The player is to remember the type of food chosen by the animal and select it. Upon successfully picking the right food item, the player will be rewarded with praise and a special animated sticker. This exercise will help the child with concentration and memory, familiarization with animals and foods, and develop more effective social communication skills from the interaction and eye contact with animals.

In the tangram puzzle game, the player is to utilize a series of shapes and as-semble them into a pattern outlined on the screen. Players complete the puzzle by touching the shapes and dragging them into the correct locations. They also have the ability to zoom in by touching the screen accordingly. There are four puzzles which players can repeat. This game contains simple shapes and colors that are easy for the player to distinguish. Skills that are involved include shape and color recognition, creative thinking skills, analytical skills, concentration, and memory.

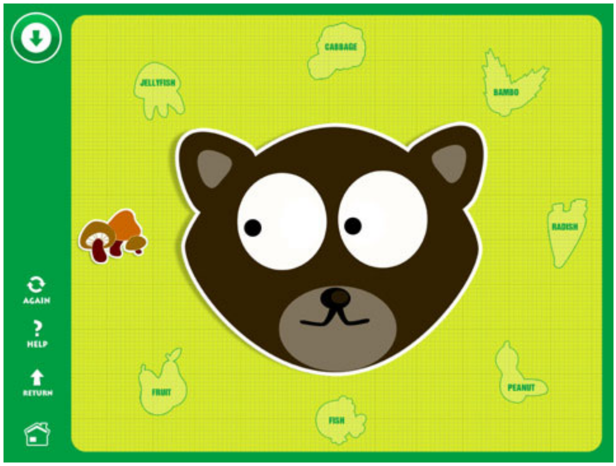

Fig. 3. Finding Food Mini-Game

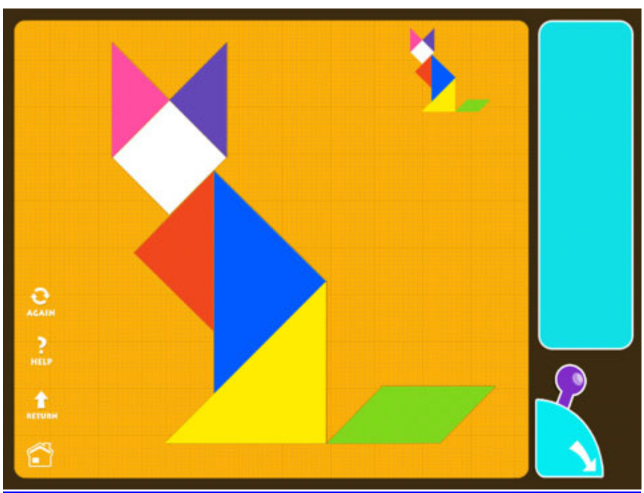

Fig. 4. Tangram Puzzle

Other games follow suit with similar format and styles. Each game seeks to remedy the problems children with autism struggle with in a structured fashion without the use of extensive medical and professional facilities. It also provides an entertaining environment for the children which encourages them to continue therapy, an element that may or may not be present in other therapeutic methods.

Fig. 5. Eating Breakfast and Taking Bath Mini-games

3.1 Comparison of Applications for Autism

Indeed, there are several existing electronic applications intended for children with autism. However, most applications exercise only one skill such as communication, social abilities, emotions, and language. Some applications train communication by associating text with images and sound to help the children memorize them in a fashion similar to flash cards such as iAssist, iComm, and MyVoice Commuication. Text-to-speech applications help children learn words by associating audio clips with text displayed on the screen.

"A SUNNY DAY" combines several types of training methods into one app. Real life situations require children to be able to utilize different types of skills. While one application can help with one skill, it is difficult for children to learn many things at once in the form of different applications. "A SUNNY DAY" avoids this by incorporating several skills into separate games which train every skill naturally without the need for excessive memorization or attention, but to the player's own enjoyment. Additionally, excessive text can have adverse effects on a child's attention span. The replacement of text with pictures, colors, and simple symbols creates a fun and simple atmosphere for the child.

While many existing iPad applications for children with autism have extensive features catered towards specific skills, they can be excessively complex and due to the variety of skills required for children to learn, purchasing the required applications and devices can be expensive and requires guidance from a teacher or parent. "A SUNNY DAY" is available to children free of charge, and parents or teachers only need to aid the child in purchasing the program without continual attention on helping the child learn how to use the application. This application utilizes the technological capacities of the iPad to maximize the simplicity of the user interface. It eliminates the use of text and instructions and allows the child to touch pictures they like, allowing the child to learn independently without aid from others. The tasks presented to the player are directly related to real-life activities and by training mental and social skills, they become more adept at daily tasks and schedules. The simplicity, fun characters, animations, and rewards create the feeling that they are playing a game, not learning.

In addition to learning mental and social skills, children are also taught, by repetition and the background story of the game and tasks, to perform tasks timely on a daily basis. "A SUNNY DAY" presents tasks which always occur on schedule and are attributed to specific times of the day. As the child plays through the tasks, they will discover that it is normal for other children (Ron and Ann) to participate in these activities and will want to do so as well. Helping the characters accomplish these tasks will encourage doing the same in real life by positive reinforcement from rewards and praise granted in the game. Ron and Ann serve as both assistants in helping the children accomplish tasks as well as role models by promoting positive behavior. "A SUNNY DAY" demonstrates to children that simple, daily tasks can be fun and rewarding.

4 Design Test

Following the development and completion of the game, several tests were conducted to assess the applicability and overall effectiveness of the game. The goal of these tests was to determine if the new methodologies implemented in the game were indeed effective in treating autism. The following steps were taken:

1. Allow a child with autism to play the game
2. Receive feedback from doctors, teachers, parents who observe effects of the game
3. Allow parents and teachers to play the game and receive feedback accordingly

Following the test, we discovered that children with autism retain the following difficulties when using the application:

- Difficulty in dealing with signals – can only deal with one signal at once.
- Visual stimuli are received more readily than audio stimuli.
- Effective communication of instructions is difficult – only hear parts of the instruction.

According to the suggestions proposed by doctors, teachers, and parents, the interface should be simpler and more distinctive to clarify objectives. Rewards should also be awarded more quickly after completing tasks. This is to more effectively associate success with tasks completed.

We have also discovered that the game is meant as an individual learning tool. With the participation of a parent, they can cause confusion and uncertainty in the child. The game itself provides minimal emotional and visual stimuli to avoid overwhelming the child. The presence of a parent can overwhelm the child's emotional capacity. Additionally, frequent contact with the parent can deter the child's concentration and thought processes. Much like the real world, feelings of success should be produced by the individual, not by an outside source because outside sources are unreliable and inconsistent. Changes to the game have been made accordingly as per the proposed suggestions.

5 Summary of Project

Due to the positive feedback we have received from individuals who have tested "A SUNNY DAY," we have concluded that it is indeed possible for games to have medical uses as well as entertainment purposes. Specifically, the entertainment aspect of games can be used as a means to increase the attention spans of players is widely beneficial in addition to the simplicity of the user interface. While the causes of autism cannot be treated easily biologically with medicines, technological advances in interface devices have indeed aided clinical therapeutic methods. “A SUNNY DAY” has successfully implemented multiple therapy methodologies in one, simple interface application for children to use as an alternative for more complex and expensive therapeutic methods with the aid of game technology. This new methodology using technology as leverage is valuable alternatives to often-times complex or expensive medical treatments when otherwise unobtainable vis-à-vis conventional means. We are hopeful for the future utilization of game-related technologies for other medical (and other fields of) applications.

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Ordsall Hall in Manchester: A Creative Game for Heritage Studies

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Abstract. The article describes the development of an educational game at the University of Salford to facilitate learning and discussion about on a Heritage Site in Manchester: Ordsall Hall. The building has been used as a basis for a series of games about gastronomy, religion, fashion and politics of the respective times with the aim of delivering information in a playful manner. The project investigates of how a popular games engine (UT2004) can be used to create Digital Heritage representations and how features that are popular and well known amongst dedicated gamers can be ported or modified to suit an interactive environment that corresponds to scientific standards. Three games have been developed that differ in regard to "ludicity", seriousness, depth of content implemented, and ease of use. This led to terminological considerations in regard to the notion of "Serious Games" and to a critical analysis of the terminologies used and strategic branding of games as "historic", "big fun", puzzle, "serious", "First Person Shooter" or "Creative".

Keywords: Serious Games, Creative Games, Games with a Purpose, Games Studies, Cyberspace.

1 Motivation

During the last few years a huge number of videogames have been designed with the intention in mind to promote heritage sites, tell about historic facts or to just advertise tourist attractions. Usually these applications are developed and disseminated with the objective of either being serious science, fun, pedagogically correct, politically instrumental, or helpful in developing A-level skills. The game about Ordsall Hall, a Tudor Manor in the Northwest of England, is an experiment in games design that is not based on an a priori objective like the ones mentioned before, but rather investigates how scientific and ludic approaches can coexist and how playfulness might inform knowledge rather than distract from it. The history of the building we chose to base our game on dates back to the mid 13th century, with some Roman remains and a significant medieval structure. The objective of the project was to investigate how computer game engine, i.e. software usually used for entertainment purposes, could provide serious information about a specific historic site.

M. Ma, M. Fradinho Oliveira, J. Madeiras Pereira (Eds.): SGDA 2011, LNCS 6944, pp. 139–145, 2011.

Fig. 1. Screenshot from the Creative Game about Ordsall Hall

Different methods were employed by three research groups to ascertain the advantages and disadvantages of interfaces, game engines, narratives and media focus used in each of the approaches.

The challenge of the confrontation of game-driven design versus content-driven design led to questions of ludic versus narrative implementations as described by Frasca [7], Aarseth [1], Juul [14] and others.

2 Serious, Educational or Creative?

The creation of 3-dimensional digital environments has been accompanied by a number of terms and notions which added particular flavours to the environments created. Jaron Lanier's "Virtual Reality" paved the way for a Californian New Age concept of an immersive space with unlimited possibilities beyond physics and real world constraints. Cyberspace was the fancier version of Virtual Reality promising to connect the human body to the digital domain with the promise to liberate users from spatial or temporal limitations of any kind.

The term "Serious Games" was introduced in the first decade of the 21st century to describe projects that use computer game technology for purposes not generally considered to be part of the mainstream games industry. It soon became apparent that the notion of Serious Games carries a number of problems when applied to game design for the Arts, Music, Social Sciences, Health, Architecture, and Urban Planning - but also also to the wider field of Warfare and Military Simulation. If one sticks to a scholarly understanding of what makes a game, as suggested by Huizinga [12] and Caillois [4], it remains a puzzle why a 3D-Environment that teaches soldiers combat skills should be called a "game". An analysis in the footsteps of Caillois would point out that "agôn" is replaced by unbalanced dominance, that "alea" is chance with a purpose, that "mimicry" is identity in disguise, and that "ilinx" comes in a form that might make us loose control, but without a chance to enjoy it. To call such an application a "Serious Game" seems to suggest that this game it is not even good fun. It became apparent that the so called Serious Games as defined by Henry Jenkins [13] at recent Games Developers Conferences and other symposia run into a tricky problem of terminology, when having to explain why a battlefield simulation involving the US Army is supposed to be serious whereas a battlefield simulation produced by a commercial company is referred to as non-serious [11]. We therefore suggested in 2004 to call a set of games "Creative Games" if the design, gameplay, application background or interface is based on innovative creativity rather than on conventional standards [9]. The games we are interested in might be creative, but not serious; they can be educational, but their pedagogical features alone would not classify them as creative.

3 Knowledge Space

The concept of computer-aided knowledge spaces is related to techniques of Mnemosyne, used by Greek orators (Simonides of Cheos) and philosophers as well as Renaissance scholars [18]. Storytellers used this form of mnemotechnique, that was called "loci" method to memorize complete speeches by orienting oneself in a fictional space. The orator imagined a building and learned every spatial detail and objects within the rooms until he was able to move about the building in his memory. As a preparation for the speech a multitude of items of different complexity and amount of detail could be placed in the memorized rooms, e.g. a pair of scissors for the barber, a boot for the shoemaker, etc. While delivering the speech the orator wandered from room to room and collected the hints to each point he wished to make.

In the case of the digital Ordsall Hall knowledge space, a number of objects were carefully selected to work as key objects for the historic references. The game cannot be regarded as realistic as it concentrates on certain objects and leaves out others. Erik Malcolm Champion stated in "Evaluating Cultural Learning in Virtual Environments" that "if we wish to understand how such ancient people as the Mayans of Lakam-Ha at Palenqué thought, believed and acted, we need non-realistic worlds" [3]. The objects chosen lead to stories or micro-narratives about various aspects of daily life in Tudor times and introduce architectonic, social, political or military background facts. The inter-disciplinary approach taken did however not intend to create a holistic picture that pretended to be a synthesis of the aspects visualized in the game, but drew from methods developed by Warburg and others to introduce asignificant cuts and unpredictable relations of objects, ideas and stories. [10], [15], [16], [17].

The arrangement of rooms, objects and interactive keypoints poses a number of questions that we tried to tackle from a heritage studies standpoint as well as from an artist's viewpoint:

1. How does the appearance of the rooms contribute to the meaning of the objects contained in these rooms?
2. How does the appearance of the learning subject in the virtual environment contribute to the learning process and the possible modes of acquiring knowledge?

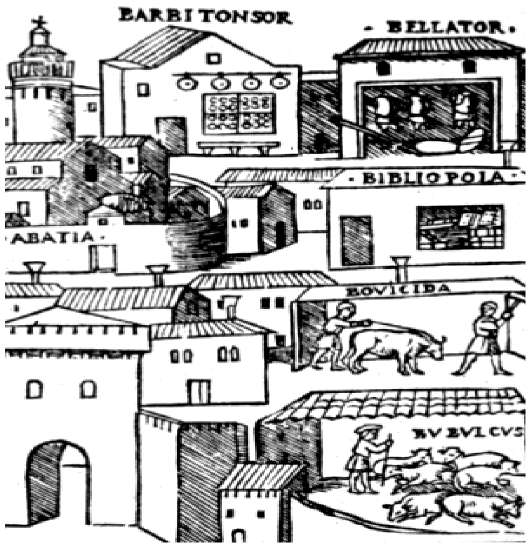

Fig. 2. Mnemotic system with abbey (Johannes Romberch: Congestorium Artificiose Memorie, Venice 1533)

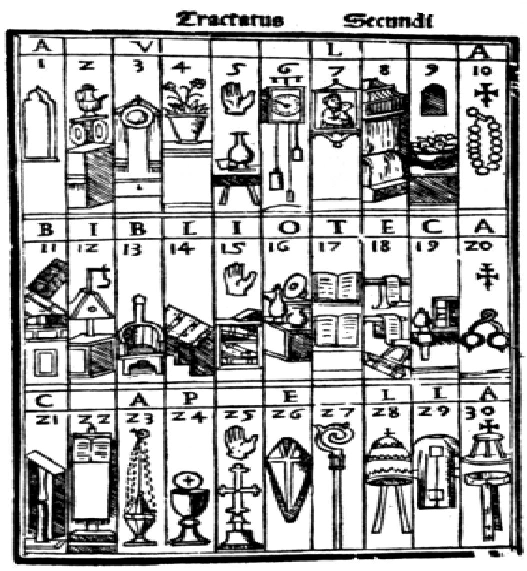

Fig. 3. Items used within the mnemotic system of Romberch

3. How do modes of movement contribute to emphasizing certain topics in the field of knowledge?
4. Is it essential for users to have a bird's eye view of the terrain they are exploring?

5. Is a visualisation-based approach, an activity-affording approach or a hermeneutically rich game design most appropriate for the intended use as a creative educational game? [3]

Based on a comparative study of three different implementations we arrived at observations that led us to the following tentative conclusions:

1. As suggested in an earlier publication [8] and in investigations into architectonic aspects of 3D-Design [2], [5] the appearance of the rooms significantly contributes to the experience of being immersed, actively watching, using, constructing or deconstructing a room. Different levels of abstraction of the main hall of the Tudor building taught us that a high degree of realism contributes to the seductiveness of the game. At the same time we observed that musical background can easily compensate for a lack of realism and still immerse the player in the gamescape.
2. The project teams experimented with first person view as opposed to behind view settings. It turned out that the most convincing implementation offered first person and non-first person views as an alternative that could be chosen by the player. The historic costume in which the player pawns were dressed made it possible to counterbalance gaming stereotypes. We observed that the interest and care taken in guiding a historically attired pawn through the gamescape added an enormous amount of pseudo-responsibility to the virtual environment. Philip Muwanga, the designer of one of the levels built for Ordsall Hall animated the guide/pawn to turn to the player and produce a polite bow at gamestart. The effect seems to have been that players identified themselves with the pawn much more than when only having seen the character from behind.


Fig. 4. and 5. Player pawn and real actors in historic costumes

3. To navigate the spaces of different content the users have to keep moving. They can walk, run, climb, jump, crouch, swim or fly according to the spatial situation. The Frankfurt-based cultural scientist Manfred Faßler has mentioned in his publication "CyberModerne" that the etymological root of the German word for experience (Erfahrung) stems from "fahren", i.e. "to move" [6]. We consider the process of actively exploring a quasi-spatial structure as the key mechanism for creating a semantic structure that is neither linear nor hierarchical. It is clear that the technology of a computer game is a helpful tool for the mediation of complex content. We also

consider the freedom of the user to go his or her own way in the virtual environment is an important feature that allows for individually shaped relational networks inside a complex field of knowledge.

4. Due to the low complexity of the building that provided the setting for the game, we decided not to have a map of the building displayed in the game. This helped to maintain suspense as the gameplayer found hidden doors, escape routes or traps. One of the implementations, "Victorian Escape", briefed the players to find a way out of the building. This referred to a real historic situation when the Catholic owners of the house had to flee from soldiers. A lack of control within the spatial layout helped to increase the gameplay excitement.

5. The approaches tested by students involved a hermeneutically enriched gametype, a visualisation-based game and an activity-affording game. The choice to implement one or the other was often influenced by personal preferences and educational background. Whereas the puzzle solving games obviously asked for facts to be remembered or to be guessed, the more realistic implementations favoured a "virtual sense of place" [3]. A viable situation seems to have been found by an implementation which attributes different modes of usage to various rooms. The garden containing bows, arrows and a target allowed for activity affording gameplay, whereas the Great Hall with information about objects and historical background information was obviously hermeneutically enriched and at the same time visually stimulating.

A question still to be investigated is whether Digital Heritage game design should prearrange areas of one of the three types of environments and lead the player into a preferred behaviour or whether game design should offer these possibilities side by side and at the same time. A current trend in complex commercial 3D environments - as shown in "Grand Theft Auto, San Andreas" or similar games - is to allow for deviant behaviour or individually chosen unorthodox behaviour in any given situation. The player is free to chase a car, listen to a song on the car stereo or just enjoy the beauty of the cityscape. This kind of freedom, which seems to work well in contemporary commercial applications, is opposed to the old concept of a stringent game narrative – or a main narrative with minigames, interrupting the large narration at a certain stage. The minigames have to be played only at a certain time and for a fixed period. Afterwards the story has to go on until it reaches its conclusion. It seems to us that games in the field of Digital Heritage could employ either of the two strategies. One can imagine a story being told about a building, a historic site or a person via the game. At the same time activity-based or visually-focused activities can be of high interest. We are obviously skirting the borderline between Educational Games and Creative Games when we try to make up our mind whether we want to tell a story or let the player play. The first approach is closer to narratology, the latter to ludology. Espen Aarseth discusses this dilemma in terms of "genre trouble" [1], and yet it is conceivable that a joyful way of balancing the demands of play and narrative can be discovered which is not at all troublesome. We hope that some of the experiments made with the Creative Game "Ordsall Hall" point in this direction.

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