# Game-Based Learning Using a 3D Virtual World in Computer Engineering Education

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*Abstract*—This paper presents an on-line three-dimensional virtual world learning environment that has been developed aiming to contribute to the improvement of Information Security issues awareness. This learning environment simulates a number of information security threat scenarios, presented to users as games, selected by users as the most interesting ones. The environment enables students to experience the risks, be educated about them and combine skills and knowledge to overcome them, without exposing themselves and their data to real risk. This paper provides insight and focuses on the learning process and the learning outcomes of using this three-dimensional virtual world learning environment into a formal university education process for computer engineering students.

*Keywords—game-based learning; virtual worlds; immersive learning*

## I. INTRODUCTION

It is the common belief that Internet has become an integral part of our daily lives; the clear majority of kids and students dedicate long hours surfing Internet, communicating with others, playing games and enjoying a wide range of opportunities that it offers. Although its use has brought many benefits to the field of communication, its wide use inevitably has been associated with negative impacts, such as disturbed privacy, hacking and identity thefts, cyber bullying etc. The increasing variety of threats and attacks has made protecting information a complex challenge; education is the safest way to enhance users' awareness regarding Information Security issues. To this direction, this paper presents the educational tool which has been developed and aims to contribute to the improvement of Information Security threats awareness.

This educational tool is an on-line three-dimensional virtual world learning environment where all users have the potential to experience several Information Security threat scenarios, presented to them as games. By participating into the games and navigating through the world, users experience the risks, get informed and educated about them and combine skills and knowledge to overcome them, without exposing themselves and their data into real danger. The main aims of this paper are to: introduce this educational tool, present the scenarios that have been developed so far, as well as the evaluation methods that have been followed and the results achieved. Also, this paper provides insight and focuses on the learning process and the learning outcomes of using this three-dimensional virtual world learning environment into a formal university education process for computer engineering students.

Many three dimensional Virtual Worlds (3DVW) are available nowadays, with a lot of them tailored to specific user needs mostly for socialization and leisure activities. Some of these 3DVW are serving purposes such as commercial facilitation (i.e. sales, marketing, customer support, etc.) and education enhancement (i.e. training simulations, virtual laboratories). These 3DVW provide to their users a highly immersive three dimensional graphical and interactive on-line environments which can be either a replica of an existing physical place or an imaginary place, or even places that are impossible to visit in real life due to restrictions (i.e. cost, safety, etc.). Recently it is recognized that the special characteristics and the possibilities these 3DVW offer to the users make them a powerful technological tool towards enhancing the learning experience.

Research in learning shows that deep learning is an active and constructive process [1] and it can be more effective when it comes through real-world learning styles; problem-based, cooperative, activity-led learning, etc., can boost student's critical thinking skills. Moreover, learning emerges in the interaction between an active constructive learner and a supportive and simulating learning environment [2]. In that sense, the 3DVW presented in this paper offers the appropriate infrastructure to provide learners with a full understanding of a situation using immersive experiences.

The development and usage of 3DVW environments for learning is an emerging field that challenges and enlarges the idea of learning environment [3]. Using such environments learners could freely wander through the learning environment,

explore it, obtain sense of purpose, act, make mistakes, collaborate and communicate with other learners. In a 3DVW the aim is to allow learners to feel immersed into the environment. Immersion is the feeling of "actually being there" and accompanied with the interaction with virtual objects can enhance learners' interest and engagement to the learning tasks and help them to develop a stronger conceptual understanding, depending on the content [4, 5].

Motivated by the ability of 3DVW to facilitate the learning processes and recognizing the need for educating people regarding Information Security (IS) issues, an educational tool has been developed, which deals with some of the most critical IS threats. Specifically, wandering through the implemented 3DVW learning environment, users interact with real-life IS threat scenarios, presented to them as games, gain first-hand experience of the different risks and threats, though in a safe and enjoyable manner.

A lot of effort has been given for the design of the platform. During the development phase, evaluation procedures have been performed, which contributed to significant improvements, not only to the system's functionality, but also to the scenarios' plots. This paper analyzes the evaluation methodology used and presents the results achieved through these evaluation procedures. However, the emphasis of the paper is on the educational aspects of this game-based learning activities and on the use of this 3DVW learning environment by Computer Engineering students. The main aim of this paper is to demonstrate that the implemented 3DVW educational tool is a valuable tool contributing to IS awareness. To achieve this goal, the paper is organized as follows: Section II describes the implemented 3DVW platform, Section III presents the evaluations' analysis results, whilst the educational outcomes by using the tool in formal education are presented at Section IV.

## II. THE 3-DIMENSIONAL VIRTUAL WORLD

To develop the 3DVW, an extensive research on available open-source and free virtual world platforms was conducted [6]. The OpenSimulator platform was selected coupled with the integrating functionality of the Moodle LMS through SLOODLE middleware. The OpenSimulator provides an embedded 3D Editor, scripting language and server, allowing the creation of engaging and fully interactive multiuser 3D environments from scratch. The SLOODLE middleware allows real-time data exchange and synchronization flow between the OpenSimulator and Moodle LMS, through scripted 3D objects which are placed in the 3DVW. Thus, tasks such as registration, course enrolment, avatars' performance tracking and recording are accomplished while being 'in-world', whereas the multimedia educational material on Moodle can be presented directly in the 3DVW.

In addition to the aforementioned platforms, a reasoning module was also developed in order to perform as personalized recommender system [7, 8]. This module assists the user during the simulations either by offering adapted learning content or guidance tips and hints on actions that should be taken. The reasoning module retrieves and analyses relevant user information such as user's profile and user's performance

history to provide personalized content and assistance in real-time.

The design of the 3D simulations was based on the results of a survey on user requirements that was conducted involving educators, students and practitioners in 5 countries [9]. A total of 666 responses were acquired. More specifically, 361 (54.2%) responses from school students, a sum of 49 (7.4%) responses from teachers (12) and academic professors (37), 194 (29.1%) responses from university students and 62 (9.3%) responses from practitioners. According to the results of the user requirements survey, the developed 3DVW simulates real-life Information Security threats, such as: Identity Theft, Phishing/Spam emails, Social Networking Security and Password Protection. These threats were voted as the most awareness-crucial for the end users and were implemented as scenario-based simulations for the games into the 3DVW.

The conceptual design of the simulations was based on the principles of experiential learning. The "*branching scenario*" approach was used as a form of storytelling. Therefore, all simulations put the user in a mission, motivating them to explore the 3DVW and look for important pieces of information which will be useful for the completion of the scenario tasks. The entire story and the scenarios are offered to the users as games. These games require critical thinking before reaching a decision.

While the scenario of each game unfolds, the 'in-world' educational material is presented as part of the plot. The non-completed tasks may either lead to situations where the user experiences the negative consequences, or simply prevent users from proceeding. In the end, all games provide educational feedback related to the simulated threat. Most of the simulations are single-player except for one, that is the Social Networking Security, which is a role-play game for a team of five trainees and one trainer. The 3DVW provides the feature to the designers to add new games into the environment, modify the games, or create sequences of games. Hereinafter four representative games that are available into the environment are presented.

### A. The Phishing/Spam Game

Analytically, the *Phishing/Spam* scenario has been designed as single-player simulation and aims to educate the user on phishing attacks. The user holds the role of investigator whose mission is to investigate, resolve and report the phishing attack incident which emptied the school bank account.

According to the scenario, the user must find evidence on what could have happened and through this quest they will get educated upon phishing attacks. During the analysis of the evidence and clues collected through their interaction with the virtual environment, the user must discover the attackers' lair and report everything they have succeed to found at the appropriate place, which is the Investigation Department.

This simulation foresees two "turning points" where the user's gained knowledge is tested through a quiz. Only when the user succeeds in the quiz can proceed to the subsequent "episode" of the story.

Fig. 1. Various games inside the 3DVW learning environment



Fig. 2. The welcome area of the 3DVW learning environment

### B. The Identity Theft Game

The second game deals with an *Identity Theft* scenario, a phenomenon which is rapidly increased with a lot of young people becoming victims. The person whose identity has been assumed may suffer adverse consequences if they are held responsible for the perpetrator's actions. Identity theft occurs when someone uses another's personally identifying information, like their name, identifying number, or credit card number, without their permission, to commit fraud or other crimes.

At the beginning of the game the user is located at the entrance of a shopping mall. The game's goal is to receive a free ticket for entrance to the premiere of a movie. The user visits the stores within the shopping mall and answer quiz questions; the number of questions they answer is related to the game credits they receive. The more credits they get the most likely is to see the movie. The educational target that is achieved through this scenario is that users should not share personal information on social networking sites.

### C. The Social Networking Security Game

The *Social Networking Security* is a role-play game for a team of trainees and one trainer and the educational target is that users should not trust and talk with strangers at the web. The plot of the game takes part at a room inside the world called "*The cafeteria*". The main aims of the game are: a) make as more friends as possible and b) identify the user who has fake profile. The roles of the participants are either assigned by the educator that moderates the game, or randomly while users are joining the game, or the educator could assume the role of the user with the fake profile who is trying to collect information from others users.

### D. The Password Protection Game

The main objective of the *Password Protection* scenario is to educate the user to create strong passwords on on-line portals and social networks.

The plot of the game is simple: users try to free some birds being kept locked within a tree. To enter the tree and unlock the door the user should select a strong password, which then they must remember and provide it in order to manage to free the birds. Guidelines regarding password length and complexity are presented to the users. The users must set an appropriate password to meet all the guidelines and still be able to remember it twice during the game, to achieve their goal.

### E. Other Areas of the Environment

As previously presented, the 3DVW consists of various virtual settings, each of which supports one game (sample screens from these games are shown in fig. 1). These areas include interactive 3D objects (i.e. doors, chairs and anything that the avatar can interact with), Non-Player Characters (also known as 'bots' that are computer-animated avatars either participating in the scenarios, or enriching the virtual world), mechanisms for text communication, easy navigation and orientation, avatar performance tracking, scoring, feedback, personalized assistance and knowledge assessment.

Besides the virtual areas of the simulations, a "Welcome Area" was also developed (shown in fig. 2) which is actually the landing point after logging in the 3DVW. This area consists of an auditorium and two meeting rooms for delivering live lectures and presentations in the 3DVW. It also includes an information room which provides information security hints, as well as tips on how to use the virtual world. There are also an avatar customization area and leisure areas. These places aim to facilitate users' further literacy and self-training on the topic while reinforcing their engagement in the virtual environment. Finally, specific 'teleporters' are established in this area in order to facilitate users' transportation to the various games inside the learning environment.

The 'in-world' textual content and the educational material of the 3DVW is produced and implemented in five languages: English, Greek, Croatian, Serbian and Bulgarian.

| Category | # of Participants |
|---|---|
| Primary and secondary schools | 9 |
| Primary and secondary school teachers | 33 |
| Primary school students (10-14 years) | 118 |
| Secondary school students (15-18 years) | 70 |
| Administrative/Enterprise Personnel | 61 |
| University students | 78 |
| University professors/researchers | 46 |
| **TOTAL Number of Participants** | **406** |

## III.    EVALUATION OF THE ENVIRONMENT

The evaluation of the learning environment is an important aspect in any system development; not only determines the degree of desired qualities of a system but also can identify weaknesses and generate suggestions for further development. Hence, before using the 3DVW as a formal education tool at universities, several evaluation procedures have taken place. In particular, the development of the 3DVW platform has been broken down into phases. Its alpha version has been tested by a team of 5 people with expertise at Software Quality and/or Information Security issues. Its beta version has been evaluated through a formative evaluation procedure which included: a) usability testing through the System Usability (SUS) standardized questionnaire b) spatial presence measure (the users' sense about how much they are immersed in the 3D environment), through the Presence standardized questionnaire and c) knowledge improvement test though a customized questionnaire. Taking into consideration the guidelines that resulted from the described testing sessions, the improved third version has been provided to various target groups for a summative evaluation procedure, where the participants had to complete the well-known UEQ (User Experience) questionnaire. All these evaluation procedures have significantly contributed to the system's functionality improvement and its outcomes are briefly discussed below.

The evaluation session of the alpha version of the 3DVW was held by four software engineers and one IS expert. During this session both technical and content issues were examined, such as network connection problems, speed of response of the virtual environment to user's interaction, possible lack of provided in-world information, feedback and guidance, etc. The aim of this work was to monitor significant malfunctions and technical issues which should be redesigned by the developers and/or the information security experts before the actual formative evaluation sessions and eventually the release of the final version of the virtual world. The results were in general quite positive; however, the evaluators identified a number of technical problems and usability issues which have been taken into account into the beta version of the platform.

The formative evaluation session took place at the Software Quality Laboratory of Hellenic Open University. During this evaluation procedure 32 participants were asked to fill in a demographics questionnaire and a pre-test questionnaire and then complete one scenario available in the 3DVW within 30 minutes. Then, they were asked to fill in the System Usability Scale (SUS) questionnaire [10] and the Presence questionnaire [11]. The former questionnaire was used to evaluate the system's usability and the later to refer to the participant's sense of being in a place and expresses either the a) psychological sense or b) the subjective experience [12, 13]. Finally, they filled in a post-test questionnaire (identical with the pre-test) to evaluate the gained educational value. The entire process (staring from the pre-questionnaires) lasted approximately 1 hour and 15 minutes per group [14].

The obtained evaluation results have been positively characterized and are presented at [14]. Regarding usability evaluation, the average SUS score was 67.3/100 which is acceptable and is comparable with usability scores achieved at similar systems. The presence perception of the participants was high and this indicates that the implemented system is performing well. Analyzing the evaluation results and taking into consideration the received feedback lead into improvements to the system's interface.

The summative evaluation procedure took place at 5 countries (i.e. Greece, Serbia, Croatia, Bulgaria and Cyprus and more than 400 people have participated into the pilot implementation sessions and evaluated the implemented 3-D VWLE via the UEQ questionnaire. Table 1 illustrates the total number of participants that were involved to the pilot testing per target group.

The UEQ is a well-known questionnaire which allows a quick assessment of the user experience of interactive products. The format of the questionnaire supports users to immediately express feelings, impressions, and attitudes that arise when they use a product. The scales of the questionnaire cover a comprehensive impression of user experience, i.e. measure both classical usability aspects (efficiency, perspicuity, dependability) and user experience aspects (originality, stimulation). The items have the form of a semantic differential, i.e. each item is represented by two terms with opposite meanings. The order of the terms is randomized per item, i.e. half of the items of a scale start with the positive term and the other half of the items start with the negative term. A seven-stage scale is used to reduce the central tendency bias for such types of items. The items are scaled from 1 to 7. Thus, 1 represents the most negative answer, 4 a neutral answer, and 7 the most positive answer.

The UEQ consists of 6 scales with 26 items:

- Attractiveness: Overall impression of the product. Do users like or dislike the product?

- Perspicuity: Is it easy to get familiar with the product? Is it easy to learn how to use the product?

- Efficiency: Can users solve their tasks without unnecessary effort?

- Dependability: Does the user feel in control of the interaction?

- Stimulation: Is it exciting and motivating to use the product?

- Novelty: Is the product innovative and creative? Does the product catch the interest of users?

TABLE II.     UEQ SCALES

| UEQ Scales | |
|---|---|
| *Category* | *Scale* |
| Attractiveness | 1.107 |
| Perspicuity | 0.646 |
| Efficiency | 0.641 |
| Dependability | 0.756 |
| Stimulation | 0.949 |
| Novelty | 0.591 |



Fig. 3.  Results achieved during the summative evaluation

Attractiveness is a pure valence dimension. Perspicuity, Efficiency and Dependability are pragmatic quality aspects (goal-directed), while Stimulation and Novelty are hedonic quality aspects (not goal-directed).

Table II and figure 3 illustrate the results obtained for the UEQ scales adding all the evaluated data at all partners' countries. The "attractiveness" score has achieved the highest score indicating that the participants' overall impression for the platform was very positive. Perspicuity, efficiency and novelty are the scales which had the lowest mean values all rated with neutral evaluation.

The evaluation results indicated that the participants were attracted by the platform and obtained good first impression of it. Most of the factors have been positively evaluated apart from (in some cases) the efficiency scale, mainly for the inexperienced at 3-D games participants. Neutral evaluation has also been received at the novelty scale mainly for the students' participants who have previous experience in 3-D games.

Overall, significant effort has been given to the evaluation of the platform; during all the evaluation procedures, critical issues have been addressed and taken into consideration for the released version of the educational tool. The software's final version has been used as an educational tool at the premises of University of Cyprus (UCY).

## IV.  USING THE VIRTUAL WORLD IN FORMAL EDUCATION

The 3DVW was used for the education of computer science students in information security awareness at the premises of UCY. In the UCY premises a total of 18 university students (ages 22-25) were engaged. The sessions were conducted in the context of two formal university courses, i.e. the students were scored positively in the particular course for their participation in the 3DVW game sessions. Since not all students could participate in the sessions due to practical and technical limitations concerning the 3DVW, the evaluation sessions were conducted in a voluntary basis and thus a negative score was not given to students that did not participate. The positive score was 2% on the overall score for the course.

The evaluation sessions were conducted as follows: in each session, a group of four (minimum) to five (maximum) students participated (this is the maximum allowed number of participants for the 3DVW learning scenarios within the platform), with the supervision of two experts from the UCY that were involved in the development of the 3DVW.
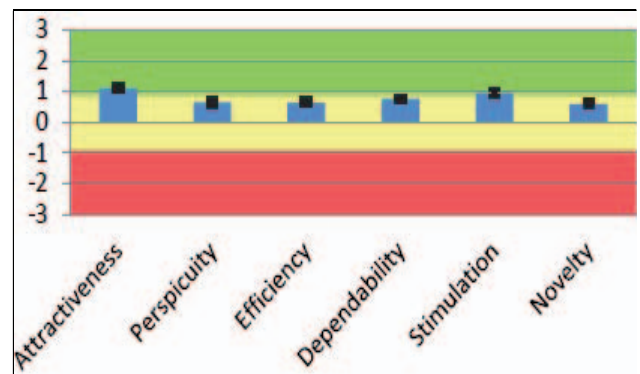
The experts were providing information and advice; however, they were not interfering with the students' tasks at all. Each learning session lasted for maximum two hours. After the end of the session, users were asked to fill in an evaluation questionnaire (in English).

The outcomes of the students' sessions regarding information security education were very positive. All students were able to successfully conduct the learning activities within the 3DVW scenarios. Among the student's feedback was that they "*... felt that the tool had a positive impact on their learning performance ...*", that "*... the tool has helped them to improve their knowledge on Information Security ...*" and that "*... they would eventually recommend the learning tool to others ...*".

More to the point, the majority of the students (~78%) felt comfortable using the 3DVW learning tool, while a small percentage (~11%) mentioned that in fact they did not. Additionally, a high percentage (~83%) of the students felt that the tool had a positive impact on their learning performance, with a small percentage (~11%) feeling that the tool had a rather negative impact. Positive impact on learning performance refers to that, through the particular scenarios of the 3DVW, students are more able, more motivated and able to learn faster about information security awareness, see examples and learn how to solve problems, than without using the tool.

In addition, 72% of the students felt that the tool has helped them very much to improve their knowledge on Information Security, 17% reported that the tool has helped them significantly, while the remaining 11% that the tool has helped them little (3 on a scale of 7) to improve their knowledge on Information Security. It is important to note that none of the participants has reported that the tool has not helped them to improve their knowledge on Information Security, which highlights the importance of the educational aspect of the 3DVW platform.

On the question whether they would recommend this learning tool to a colleague, 72% responded that they would strongly recommend it, 22% that they may recommend it, and 6% (1 participant) that they would not recommend it at all.

Table III presents useful statistics regarding the student evaluation results, including the mean, median, minimum, maximum and standard deviation for each question.

TABLE III.    STUDENTS EVALUATION RESULTS

| Items | N | Mean | Median | Min | Max | SD |
|---|---|---|---|---|---|---|
| Feel comfortable using the learning tool | 18 | 5.39 | 6 | 1 | 7 | 1.58 |
| The tool had a positive impact on user's learning performance | 18 | 5.44 | 6 | 1 | 7 | 1.69 |
| The tool has helped the user to improve his/her knowledge on IS | 18 | 5.44 | 6 | 3 | 7 | 1.34 |
| The user would recommend the learning tool to a colleague | 18 | 5.39 | 6 | 1 | 7 | 1.61 |

From the above it is evident that the tool can be used effectively as an educational tool on information security awareness, that it actively enables and promotes learning among university students and that it does so in a comfortable for the user manner. After the evaluation sessions, the students were asked (informally) whether this experience was worthwhile their time and effort, considering that it was a period close to exams and that they were about to receive an additional scoring of only 2% on their overall grade for the course. Their response was that it was worthwhile because, not only had they learned new and important things, they have done so in an entertaining manner as well. The students were glad they had participated in the evaluations.

## V. CONCLUSION AND FUTURE WORK

An on-line three-dimensional virtual world learning environment that has been developed aiming to contribute to the improvement of Information Security issues awareness is presented. The focus of this paper is on the learning process and the learning outcomes of using this three-dimensional virtual world learning environment into a formal university education process.

As a future work the focus will be to a) evaluate the educational value of each implemented scenario and b) design and develop additional scenarios. Also, it would be of great interest to investigate potential correlations between usability and immersion presence compared with the educational value.

## ACKNOWLEDGMENT

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