Mixed-reality Adaptive 3D Multi-user Online Communities of Practice in Academic Education

Tackling Students Motivation and Teachers' Self-efficacy

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1 RESEARCH PROBLEM

1.1 Introduction

Learning in 3D multi-user online virtual environments (3DMUVEs) is not a new paradigm, but one that continues to be approached in the context of new learning paradigms (social learning, game-based learning, gamification of learning, flipped classroom), IC&T technologies (mashup of services, webGL/X3DOM, Restful services, big data analysis) and devices (mobile devices, VR devices).

Several research works have proved the efficiency of learning in such environments for understanding abstract concepts, training for difficult or dangerous systems, for collaborative learning and interactive training. Typical implementations that illustrate MUVEs are based on the general-purpose platforms such as Second Life (SL), OpenSimulator (OS) (OpenSimulator, 2015), free and open-source variant of SL, ActiveWorlds (AW), OpenWonderland, Cloud Party. SL and OS use dedicated client viewers (such as Second Life, Firestorm, Singularity).

An important step forward was the integration of Second Life with the traditional online Learning Management Systems (LMS), by means of proprietary mashup solutions such as SLOODLE (Simulation Linked Object Oriented Dynamic Learning Environment) or integration of Unity3D based applications with SCORM (Shareable Content Object Reference Model) - compliant LMS by means of the SCORM API.

Recent research addresses a new generation of online 3D virtual worlds, i.e. accessed in web browsers, which are based on Unity3D (Jibe) or OpenSimulator (realExtend). These environments are under development and even they are open-source the implementation of a 3D simulator requires technical skills and administration fees.

Despite of the existing research work (de Freitas, 2008; Aldrich, 2009; Savin-Baden, 2010) and commercial implementations (Design Digitally, 2015) on educational MUVEs we argue that these environments are not fully exploited on a large scale in educational settings for supporting a full range of university activities and inter-university communication.

The usage of 3D virtual worlds as virtual universities (Moldoveanu et al., 2014) as a form of distant-learning, rises questions regarding the educational and learning benefits beyond using a mix of advanced technologies for providing previews of the academic environment or video-conferences facilities. Several problems must be addressed, e.g. modelling and render of large buildings, space orientation, provisioning of real-time information and live course organizations.

The University Politehnica of Bucharest (UPB) comprises a number of 15 faculties with Bachelor and Master of Science programms in Engineering Sciences. UPB also cooperates in Erasmus programs or with non-EU universities, and develops international research projects (UPB, 2015).

In 2010 the Department of Computer Graphics and Virtual Reality from the Faculty of Computers started a project named "3DUPB" (3DUPB, 2014) with the objective to implement a virtual clone of the UPB as a Massive Multiplayers Online (MMO) space and integrated services, using the OS platform. Several research work addressed technical challenges for implementing the platform (Moldoveanu et al., 2014).

1.2 The Research Problem

In the present research the general purpose 3D MUVEs are re-discussed in the context of mixing a virtual online 3D campus with real time activities within communities of practice and with the following research questions: a) what kind of instructional design is suitable and how this can be implemented in a 3D online environment and also connected with the traditional LMS; b) how students can be motivated and engaged during learning in a 3D MUVE; c) how teachers can use 3D MUVE for teaching in a more creative and challenging way, overcoming the first use reluctance; d) how to evaluate the learning benefit and the efficacy in a 3D online campus environment with modern analytical tools.

Open Simulator platform will be considered due to its openness and free of charge characteristics.

Apart from making use of game-based learning, in our research we study and implement Gamification (Deterding et al., 2011) and Learning Analytics (Horizon Report, 2014) concepts for supporting a more creative and adaptive instructional design, stimulate instrinsic and extrinsic motivation of both students and teachers, measure performance and usage indicators. Elements from the Role Playing Games (RPG) can also be used to design the usage of the environment.

One research hypothesis is that the gamification will improve engagement and motivation (intrinsic and extrinsic) by stimulating course attendance; on-time accomplishment of assignments and projects; overall performance of the students, seen also as a measure of teachers' self-efficacy.

Another research hypothesis is that the gamification along with Leaning Analytics instruments will provide indicators and insights on students' learning preferences and outcome, and also on the usage of the 3D environment.

The "3DUPB" virtual clone of the UPB is being used as a test bed for conducting experimentations and case studies.

2 OUTLINE OF OBJECTIVES

Our research is being conducted with the following guiding objectives:

- to define the research hypothesis;
- to understand expectations and define requirements of a 3D online learning environment (LE) for academic education, designed to support different communities of practice consisting of collaborative learning activities (LACT) e.g. courses, laboratories, showcase and assessment of projects;
- to perform a 3D graphic design and modelling of several educational spaces and learning objects (LOBJ), with possible adaptations for rendering on devices with limited resources (smartphones, tablet PCs);
- to integrate and experiment different technologies to develop a mixed-reality collaborative learning experience;
- to implement the fundamental behaviour of the LE and LOBJ: space orientation and navigation, learning activities, content, owner and rights, events, groups and friends;
- to implement an intelligent behaviour of the LE, i.e. a gamification of the LACT and LOBJ, with the objective to stimulate motivation and enhance in-world engagement, both of students and teachers;
- to perform abstraction of several functionalities of the LE, e.g. authentication, management of the learning content, actvities and events, customization and extensibility of the environment (prototyping from a functional point of view);
- to trace activities, events, and the usage of the environment with the objective to communicate with the university's Moodle LMS and further implement an adaptive behaviour and deliver of the educational content (Horizon Report, 2015);
- to define several indicators/metrics (e.g. course participation rate, average time spend in the LE) and the corresponding evaluation methods;
- to test the LE in an offline mode (with synthetically generated users) in at least 2 development stages;
- to experiment and conduct case studies in online mode (with a group of students and teachers from the Faculty of Computers and also with visitors from a faculty with non-technical profile) in at least 2 development stages;
- to collect data in an external database (possibly in the cloud), to implement different visualizations to display the indicators inside the LE;
- to evaluate learning achievements/outcome by comparison with average performance of a group of students before using the LE;
- to interpret and discuss the findings, in correspondence with the initial research questions;
- to make a survey-based evaluation of the engagement experience and usability of the LE for two categories of users (teachers and students);
- to define recommendations, methodology or/and good practices regarding the implementation of 3D online learning environments using mixed-reality (MR), gamification and adaptive content

and behaviour;
- to summarize the research conclusions (results, limitations, perspectives).
- to publish partial and final research results.

The main domain of application will be for computer graphic courses but by means of a generalization will also support other kinds of courses.

Other adjacent objectives:
- demonstration of the environment with the help of a machinima;
- creation of a Google+ blog to collect from students and teachers suggestions or problems encountered while experimenting the LE.

3 STATE OF THE ART

3.1 The Background Research

To have a multi-disciplinary approach of the thesis's tasks the following research was performed:
- studies regarding modern approaches for teaching and learning, i.e. experiential, constructive or blended-learning, flipped-classroom, mobile-learning; personal learning environments, game-based-learning;
- studies regarding traditional online learning environments (LMS/CMS);
- studies regarding the existing 3D MUVEs, comparisons of Second Life and OpenSimulator (OS), state-of-the art educational implementations;
- Mixed Reality (Augmented Virtuality/ Augmented Reality) (Azuma, 2001; Milgram and Kishino, 1994) technologies in educational applications;
- experimental developments of mobile AR and VR simulations in OpenSimulator (Ştefan and Moldoveanu, 2013; Gheorghiu and Ştefan, 2014; Ştefan and Gheorghiu, 2014), evaluation of educational impact of these technologies.

Several advantages but also drawbacks of OS where identified.

3.2 Mixed-reality and Gamified Communities of Practice

In order to create *communities of practice* (Wenger, 1998) in a larger 3D educational environment we leveraged the extensibility as one of the most important features of the "3DUPB" virtual campus, i.e. dynamic integration of other virtual spaces and new functionalities.

For our research an experimental LE with three regions with distinct functionalities were designed for further integration as subspaces in the "3DUPB" virtual campus: i) a virtual laboratory (VLAB) which models a Computer Graphics laboratory; ii) a pure virtual meeting space (MSP) for private meetings, showcase projects, peer review and teacher evaluation, a catalog for students' marks; iii) a pure virtual space, named "privileged space" (PRS), for inter-university communication. Also an open space is designed as a lounge/meeting space for socialization.

The graphical design also includes spatial orientation indicators, visual clues for the LOBJs, HUDs (heads-up displays), a teleport hub. Different HUDs were designed for specific functionalities, as scripts can be attached to them: in-world guidance tool, announcement panels, attendance counter, leader boards, an analytical dashboard.

The educational content is created and loaded by the in-world participants using special LOBJs, i.e. teachers can load Power Points (image by image), students can load presentations of their course work and can customize certain objects of the LE.

In order to be monitored, the activities and events in the LE are defined as functional components and managed from a specialized interface.

Peer review and teacher evaluation is a difficult task to be performed in-world. A solution is provided to write on a dedicated LOBJ.

3.2.1 Bots and Avatars

Avatars (humanoid agents controlled by users) will be created for teachers, students, visitors and the master administrator. Bots (intelligent agents controlled by the system) for master teacher (the one conducting the classroom) and a virtual guide will be used. In OS the bots can have different utilizations, e.g. group invitations (which is not possible in SL), non-player character (NPC) in a role-playing simulation. The NPCs will be scripted with *AI logic* to perform specific tasks. An authentication mechanism will associate also a role to each user logged in the LE.

All the avatars will be augmented with labels containing extended identification information. The appearance of avatar will be customized by each user with preference regarding the hair, clothes a.o. The most skilful students can add different attachments or make use of the AO (animation override) HUD of the client viewer, to change their poses and better express their in-world personality.

3.2.2 The Mixed-reality

The VLAB, MSP and PRS will contain LOBJ that manage media information. The i*n-world video streaming and communication tools* (e.g. voice calls) will provide a mixed-reality (MR) experience and video-conference facility. The MR paradigm applied in-world supports delivering of collaborative real-time (synchronized) courses but also on demand recorded lessons.

VLAB and MSP will contain gamification components for teachers and students, while PRS is accessed only by students with recognised participation and learning effort.

Real-time video streaming was experimented with free solutions, such as VLC (VideoLan media player) or Google Hangouts, to broadcast the video signal to a group of clients connected simultaneously. The VLC streaming server and player was preferred against others (manycam, ustream, Justin.tv) because the solution can be generalized for mobile devices. Students are encouraged to participate according with the Bring Your Own Device (BYOD) concept.

For an enterprise-wide solution (several universities campus with hundreds of participants) the Microsoft Lync server and client (Lync, 2015) was studied and proposed.

The MR is also ensured by connecting the educational simulator with the faculty LMS.

3.2.3 The Learning Gamification Rules

The gamification will be associated to *learning activities* (e.g. course attendance), *learning objects* (e.g. a video library) and to a more complex process or behaviour (teleport to a privileged region) and will target both intrinsic and extrinsic motivation.

The gamification objects are publicly visible by all in-world attendants.

The rewards are offered in reward points, prizes and exposure on a leader board. For special cases can be offered virtual money for acquiring in-world books or other educational materials. The reward points are given proportionally as follows: course attendance – 4 points; correct answers to the quizzes – 2 points; partial assignments and projects – 4 points.

The scores are calculated by a gamification engine (GE) and will be stored in an external database along with the user's identification number and further employed to establish and display the achievements. The gamification engine will make use of OS region modules by means of which the simulator's functionality can be extended.

Certain parameters of the GE can be further modified.

Students with certain performance levels can demand recorded lessons or other benefits (learning materials, participation in workshops). These are intended to stimulate the extrinsic motivation.

The most performant students will be rewarded with the possibility to be teleported into the PRS, and meet instructors/teachers and students from other universities, thus stimulating the intrinsic motivation. The design of the PRS may include a graphical environment enriched with some particle effects several TV sets for communication with the outside world (i.e. other educational grids).

We also found useful to create a motivational system for teachers to help them overcome the initial reluctance in managing learning in a 3D virtual environment and also to provide them with useful information regarding students' activities and participation (see paragraph 3.2.4). The most performant students' name will be displayed along with teacher's name.

The gamification components must be carefully designed to be motivating and engaging but not too distracting.

3.2.4 Learning Analytics

Besides the quantitative analysis provided by the in-world gamification, Learning Analytics (LA) instruments will be implemented for qualitative insights and significant facts regarding several aspects of the LE and students' performance, such as: a) course attendance; b) average time spent within the LE; c) knowledge transfer. Different 2D and 3D (immersive) visual representations will be experimented.

Table 1: Gamification versus Learning Analytics.

<table>
<tr><th colspan="2">Gamification</th><th>Learning Analytics</th></tr>
<tr><td rowspan="3">Qualitative measurement of performance and participation effort</td><td>Scores</td><td>Users' trace</td></tr>
<tr><td>Levels</td><td>Qualitative Insights</td></tr>
<tr><td>Achievements</td><td>Decision make dashboards</td></tr>
<tr><td colspan="2">Adaptive LE behaviour (e.g. teleport permissions)</td><td>Adaptive content recommandations or adaptive gamification (Monterrat et al., 2014)</td></tr>
</table>

Inside the MSP teachers can also access a private display with detailed information regarding a student's academic status. The master teacher can access a dashboard with course attendance statistics.

An in-world heat map visualization can be created to highlight the usage of different regions of the LE, visible by researchers and the LE administrator.

Machine learning algorithms will be employed to implement the *adaptive content recommendations* functionality.

4 METHODOLOGY

The adopted methodology will be the traditional research methodology of generating a working hypothesis and evaluate it after development and experimentation, but customized for the specific e-learning domain (Holotescu and Knight, 2002). The *Design Based Research* (DBR) methodology is mentioned in several papers (Barab and Squire, 2004; Joseph, 2004) as adequate for implementing design-based e-learning systems.

DBR, as conceived by Ann Brown (1992), was introduced with the expectation that researchers would systemically adjust various aspects of the designed context so that each adjustment served as a type of experimentation that allowed the researchers to test and generate theory in naturalistic contexts" (Barab and Squire, 2004). In practice, DBR borrows principles from Agile/SCRUM project management methodology consisting in incremental cycles of development and user validation. In our case the validation made by teachers and users is of crucial importance in order to avoid the rejection or abandon of the system.

In our research we will design, implement, and adjust functionalities in iterations comprising offline testing and real life case studies which will take into consideration undergraduate students from two universities and different academic years.

4.1 Research Surveys

During the research period several surveys will be conducted with the following objectives:

- Pre-experiment evaluation of students' and teachers' expectations for a designed 3D online LE;
- Post-experiment evaluations of the 3D online LE;
- Post-experiment evaluation of the engagement experience and usability of the 3D online LE.

Students and teachers will be informed of the research objectives and stage by means of surveys and the G+ blog. It is expected that they will became more interested to use the LE if will be informed that some of the data collected in-world about their activity will be directly connected to their academic status.

4.2 Bloom's Cognitive Taxonomy

The instructional design of the LACT and LOBJ will leverage the original Benjamin Bloom's cognitive taxonomy (Bloom, 1956) as these are more general that those updated later by different researchers. The correspondence with the instructional design based on learning affordances specific to a 3D LE is illustrated in Table 1.

Table 2: Bloom's taxonomy in the 3D LE.

Bloom's cognitive levels	Correspondence with the instructional design in a 3D LE
Knowledge	Courses and educational materials
Comprehension	Discussions, short quizzes
Application	Course work
Analysis	Design-based Projects
Synthesis	Implementation Projects
Evaluation	Final projects

An important cognitive dimension will be provided by the 3D LE under the form of "tacit knowledge" (Polanyi, 1958) by means of experiential, collaborative and social learning. This kind of knowledge will be evaluated with LA instruments.

4.3 Design and Implementation Methodology

The 3D design is being done with objects prototyped in UML (Figure 1) and Google SketchUp and modelled using specialized DCC programs (Autodesk 3dsMax or Blender); terrain terraforming and heightmaps; objects imported from repositories under Creative Common Licence (Google 3D warehouse, Opensim Kitely market); content created with in-world building tools; user-created content (students and teachers).

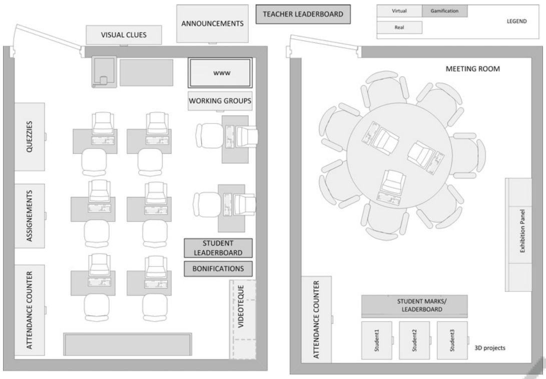

Figure 1: The experimental gamified infrastructure and the legend of the colours: with gray, elements of the real classroom; with pink, pure virtual representations; with orange, the gamified areas.

COLLADA DAE format is used for the imported 3D objects (Figure 2).

Figure 2: The virtual laboratory simulator.

The entire LE or selected objects can be exported as archives for backup and re-use.

4.4 Technologies

The following technologies are being used to create functionalities inside the OS simulated LE: scripting language for SL and OS (LSL, OSSL) for server and client, modern software architectures and paradigms (RESTful services, NoSQL programming), statistical algorithms, Machine Learning.

The service-based approach is being used to bridge the simulator with other systems and services, in a bidirectional way.

5 EXPECTED OUTCOME

The expected research outcome is summarized in Table 3:

Table 3: The expected research outcome.

Results
Original design and implementation of an experimental 3D online learning environment comprising Mixed-Reality and Adaptive Communities of Practice based on the OpenSimulator platform
Original gamification engine and 3D components for a 3D online LE, for quantitative students' and teachers performance, and adaptive behaviour of the LE.
Relevant data from experiments and case studies
Visual Learning Analytics instruments to highlight qualitative indicators regarding environment's usage preferences and predictive functionalities
Relevant research surveys
Findings regarding the engagement and motivation in relation with the gamified LE
Findings regarding the learning outcome in relation with the usage of the LE
Findings regarding the usability and acceptance of the LE by teachers and students
Recommendations, methodology or/and good practices regarding 3D online adaptive LE
Publications in peer-reviewed conferences and journals
The PhD. Thesis and Final Defence

6 STAGE OF THE RESEARCH

At the time of the present Doctoral Consortium paper submittance the LA instruments are to be implemented and the case studies with students and teachers to be defined and conducted. The Final Defence is scheduled for September 2015.

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