An Exploratory Study of Problem-Based Learning in Virtual Worlds

Spyros Vosinakis
Dept. of Product and Systems Design Engineering
University of the Aegean
Hermoupolis, Syros, Greece
E-mail: spyrosv@aegean.gr

Panayiotis Koutsabasis
Dept. of Product and Systems Design Engineering
University of the Aegean
Hermoupolis, Syros, Greece
E-mail: kgp@aegean.gr

Panagiotis Zaharias
Computer Science Dept.
University of Cyprus
Nicosia, Cyprus
E-mail: zaharias@cs.ucy.ac.cy

***Abstract*—Research on the educational value of Virtual Worlds (VWs) has revealed their potential as future learning platforms. However, further studies are needed in order to assess their effectiveness in constructivist and collaborative learning paradigms. Problem-based learning (PBL) is an educational approach, in which students learn by addressing problems and reflecting on their experiences. The paper investigates the suitability of VWs as a platform for hosting PBL activities and explores their strengths and difficulties in terms of collaboration support and learning effectiveness. We have set up an educational VW, developed a number of in-world supporting tools, and ran a complete PBL activity in the area of User Interface Design. We performed a thorough summative evaluation of the learning activity using questionnaires, in-world observation, dialogue analysis, tutors' assessment of the process and outcome, and follow up interviews. The results revealed several findings about collaboration and PBL via VWs, and led to a series of recommendations about supporting tools and functionality issues.**

Keywords-Virtual Worlds;Problem-based Learning; Computer Supported Collaborative Learning

I. INTRODUCTION

Virtual Worlds (VWs) are computer-generated 3D environments, in which multiple users navigate, interact and communicate having a form of embodied representation [1]. Being a highly engaging medium that supports synchronous and asynchronous collaboration and user immersion in realistic or imaginary environments, VWs quickly captured the attention of the educational learning community as a prospective learning environment [2-4]. A number of environments, prototypes and case studies have been setup in order to draw results on the use Virtual Reality in education in the last two decades [4-7]. Although the studies vary in terms of system configuration and types of educational activities tested within the 3D environment, the early results have shown that VWs have significant potential as a complementary educational medium [8,9]. Nowadays, a number of universities and high-schools are using Virtual Worlds as part of their curricula.[1]

[1] http://virtualworldwatch.net

The majority of educational institutions that employ VWs for learning are primarily using the medium for resource sharing and teleconferencing. The common activities that take place within the environment are text or voice-based communication, document storage and exchange, group discussions and presentations, e.g. [10-12]. In these cases, traditional classroom activities are being transferred in the shared 3D space and the exploitation of the VW is restricted to tasks already supported by typical synchronous and asynchronous distance learning platforms. However, VWs have the distinctive characteristic that they can afford real-time simulations of custom environments, in which groups of users can actively participate. Therefore, they can be used for setting up interactive educational environments that visualize concrete or abstract objects and processes. In such places learners can gain knowledge by experimenting with the content and receiving immediate visual feedback about the effects of their actions. Furthermore, these experiential activities can happen in a shared space, in which learners will also be engaged in collaboration and discourse with fellows.

One learning approach that is following this principle of active and collaborative knowledge construction is Problem-based Learning (PBL). In PBL students learn by addressing ill-defined and open-ended problems and reflecting on their experiences, thus developing problem-solving strategies and building domain knowledge in a self-directed manner [13]. This approach has several advantages, as students are actively gaining transferable skills by investigating, explaining and resolving meaningful problems and the individual or group participation in problem-solving activities is highly motivating for them. However, there are only a few documented cases in which VWs have been used for collaborative PBL activities.

The aim of our work is to explore meaningful ways to set up and facilitate collaborative PBL activities in VWs and to evaluate their suitability and effectiveness as a learning platform. In this paper, we present a study in the field of User Interface Design; our goal was to engage students in a PBL activity through their collaborative experimentation with user interface prototypes, and we studied their experience, performance and outcome. We set up an educational environment on top of an existing VW platform, built a number of supporting tools for collaboration and prototyping, and designed a complete activity based on the principles of PBL. We performed an extensive evaluation of a full-day learning activity, in which we combined various methods for collecting and analyzing data in order to draw assumptions about collaboration, learning and usability. The evaluation results shed some light on the strengths and weaknesses of VWs as potential PBL platforms.

II. RELATED WORK

A. Problem-Based Learning

Problem-based learning as a learning and teaching practice has been widely adopted during the last 20 years in both traditional and online educational settings [14]. PBL incubate experiential and social learning and calls for an active rather than passive approach to learning that leads to the development of critical thinking skills. When it comes to teaching and the development of educational modules and courses, the main premise of PBL is that problems can be the stimulus and focus for the student/learner activities [15].

Problem based learning situations are directly related to the basic tenets of constructivism. Typical PBL contexts require learners to work in small groups to investigate a real-life problem. Most of the times there is an instructor who acts like a moderator and there is access to a wealth of resources that help learners find a solution to the problem. According to Boud and Feletti, [15] it is about a process of acquiring knowledge and skills through a staged sequence of problems: Clarification of the problem, identification of the needs to address the problem, individual learning/study and application of the newly acquired skills in order to solve the problem, are the main typical stages in a PBL situation.

Literature documents that collaboration and interaction are some of the critical factors for PBL success in both traditional and online learning settings. Regarding the online learning settings several studies have attempted to implement PBL. Donnelly [16] integrated online PBL techniques with face to face learning. It was found that group activities were the most important parameter for the success of the process. Dennis [17] compared a face to face with online PBL settings. Results showed that the groups did not differ in learning performance but the online group spent more time for learning activities. Ozdemir [18] reported that students in a collaborative PBL environment outperformed those who were in an individual PBL environment as regards the development of critical thinking. An [19] suggested that only online courses with collaboration characteristics should make use of PBL.

B. PBL in Virtual Worlds

PBL has already been characterized as one of the most appropriate learning methods in virtual worlds, especially in Second Life [20]. VWs as 3D persistent learning environments provide great opportunities for both synchronous and asynchronous learning. Typically instructors and educators can prepare learning materials as immersive tutorials and develop interactive learning scenarios. Typically students/learners are invited to interact with the world and become active participants in these scenarios, usually in small groups. Such scenarios can take the form of avatar-driven scenarios or information driven scenarios [20]:

- Avatar driven scenarios are the ones that require students to interact with an intelligent avatar of chatbot. These avatars inform students about the main issues and prompt the students to make decisions. Many times instructors can manipulate the chatbot so as to guide the story behind a PBL scenario.
- Information driven scenarios are the scenarios in which learning is led by the students in a more "free" and exploratory way.

Not much have been written about how can PBL and other constructivist learning methods be realized in VWs. [21] used Second Life[2] (SL) to implement a collaborative problem-based learning activity following a constructivist approach. The tutor intervened in the process by using scaffolding techniques in order to help students to achieve their goals. Jamaludin et al. [22] also used scaffolding techniques in their study and they found that collaborative learning in a virtual world became more effective.

Girvan and Savage [23] proposed Communal Constructivism as a potentially appropriate pedagogy for use in Second Life. According to Communal Constructivism learners try to build knowledge not only with a focus on themselves but for other future learners as well.

In [24], the suitability of SL for problem-based learning is demonstrated through the mapping of learning activities on to PBL goals as they have been stated in the framework of [13]. They used a machinima based assessment technique where the students worked in groups to create short video clips from their activities in SL. According to the findings it is supported that development of wider transferable skills can be realized effectively through virtual worlds such as SL. In another related study, [25] reported findings from a case study with a strong PBL approach where students were tasked to create learning experiences within SL for external clients. Main emphasis was placed on the process of how students formed groups and created the interactive learning experiences by using the affordances of SL. It was found that SL can contribute to PBL as a pedagogical approach in several ways such as supporting the roles of tutors and students, facilitating their relationships, enhancing students' motivation and ownership of the project, as well as easing the assessment activities by the tutors.

Collaboration and group interaction was a common denominator in the aforementioned studies. However much of the relevant research is still conceptual and information about empirical evaluation with regard to specific methods and practices is lacking. In this study we put much emphasis on the evaluation of collaborative learning activities according to the PBL philosophy and we ground our approach on CSCL (Computer-Supported Collaborative Learning) evaluation methods.

C. Evaluation of Collaborative Activities in Virtual Worlds

The assessment of computer supported collaborative learning activities in general is a research problem in its own right [26]. The process involves interaction analysis of the

[2] http://secondlife.com

participating teams that aims to clarify what types of collaborative interactions have occurred and what educational benefits have taken place [27]. Interaction analysis can be based on various qualitative and quantitative data collection methods and tools, like: automated monitoring of participant actions, participants' experiences and perceived learning outcomes and instructors' assessments, and must take into account the specific problem at hand. In [28] the evaluation of collaborative learning is described as "*placing strong emphasis on the situated nature of collaboration and the impact of certain situational factors (with a few or as little as possible a priori expectations)*".

The evaluation of collaborative learning activities is a complex issue that involves intertwined dimensions of collaboration, interaction and learning. In [29] a principled framework for the study and analysis of group interaction and scaffolding is presented that that proposes the qualitative inquiry of dimensions about 'task performance', 'group functioning', 'social support' and 'help services'. The approach has been applied in e-learning course situations with large numbers of participants, and it can be extended to cover the particular issues of problem-based learning interventions.

Also, in [30] a generic empirical framework for interaction analysis is proposed that refers to computer supported collaborative learning (CSCL) environments that support a problem-solving approach to learning. The framework is based on the life-cycle of (i) observation, in which raw data are collected by observing and recording the users' actions; (ii) abstraction, in which data are processed and transformed into high-level analysis indicators; and (iii) intervention, in which indicators are interpreted and different forms of feedback are presented. This work provides a tested process for the set up of the CSCL environment and its evaluation placing emphasis on PBL situations; however does not propose a specific set of calculated indicators for process analysis.

D. *The Scope of Our Research*

This study aims to extend previous research on assessing the effectiveness of VWs as educational platforms and on using them in novel learning paradigms. Our goals were to discover the extent in which VWs can support PBL activities, to evaluate the learning results of their use, and to unveil critical problems related to student collaboration and learning. We set up a complete activity in the problem area of User Interface Design, following the PBL learning cycle presented in [13] and we designed and implemented a number of tools to support collaborative and problem-specific tasks in the environment. Students were able to construct functional prototypes using the in-world tools and could instantly test and evaluate their solution.

We have set up a qualitative, mixed method to summative evaluation that adopts and refines the general framework proposed by [30] for the case of our PBL situation, i.e. user interface design. Furthermore, we adopted the interaction analysis indicators proposed by [29] and extended them to allow for problem-based CSCL situations in virtual environments. More specifically, we make use of the first three dimensions of interaction analysis identified, excluding the fourth dimension about help services, since virtual environments are new platforms that currently pose usability issues, which can be overcome by immediate technical support. In compensation, we have added the dimension of 'learning performance and outcome' that investigates issues relevant to problem-based learning.

III. METHODOLOGY

A. *Configuration of the Virtual World*

The VW implementation has been based entirely on open source software. The world server was installed in a standalone PC using the OpenSimulator platform,[3] and the FreeSwitch server[4] has been set up and connected to the environment to provide voice communication support. We have created a small island and built a number of interior and exterior places for group collaboration and whole class activities. We implemented four additional collaboration tools in the LSL Scripting language. On the client side, the Hippo OpenSim Viewer[5] was running on PCs with standard keyboard and mouse equipment plus an additional headset with microphone for voice communication. No significant decrease in efficiency or loss of quality has been detected during the whole experiment.

Figure 1. Screenshot of the environment

The main reasons for setting up our world in the OpenSimulator (OS) platform instead of the more popular world of SL were:

1. *Visualization and functionality*: there are no differences in graphics quality (both platforms use the same client) and OS supports most of the functionality of SL.

2. *Cost*: Besides the cost for owing private land, SL places a charge for every image uploaded. In our study the students had to upload a lot of images to construct the user interface prototype. A limitless number of images can be uploaded in OS at no cost.

3. *Data Recording*: Using OS we managed to record all voice sessions directly from the server. This would not be possible in SL – we would be able to record only public discussions in close range.

[3]http://www.opensimulator.org
[4]http://www.freeswitch.org
[5] http://mjm-labs.com/viewer

B. Building the Supporting Tools

Group educational activities in VWs have strong requirements concerning the communication and collaboration of remote students and teachers. For our study in the area of user interface design we have identified the following tasks in group-based PBL activities:

- In the early stages, students discuss about the problem, write down facts and reveal aspects for which further knowledge may be required.
- Then, they assign roles to group members, search for and share resources, and formulate, present and explain their ideas.
- Finally, they collaboratively assemble a final solution, refine it and present it to the class to be further evaluated.

To support these tasks, the educational environment should provide the appropriate means for text and voice chat, and allow students generate and share public and private documents to exchange ideas and coordinate their activities. Also, students should be able to easily take notes during group discussions and chat sessions and share them with others. Groups should be able to collect and organize their common resources within the VW in order to use them for reference during their problem solving activities. Finally, the world should contain the building blocks to collaboratively construct a working prototype and to enhance it with further explanations about the design choices.

The platform we have employed for our study provided inherent support only for part of these tasks. It allows for text and voice chat between users, but there is no support for offline messaging. Concerning resource management, one can only add geometric objects to the environment, whilst any other document type can only be placed in an object's contents. However, security reasons restrict other users besides the object owner to view its contents. Finally the construction of a working user interface prototype requires a lot of programming effort using the VW's scripting language, which was outside the scope of our learning session. We have therefore implemented a number of additional tools that were available to students during the study in order to overcome these obstacles and to enhance the collaboration affordances of the environment. The implemented tools were:

- *Resource*: an object that links to external web resources
- *Comment Recorder*: a tool to record and playback user messages
- *Annotation*: an object that contains a written message
- *InterfaceElement*: an object with scripted behavior that can be used as a user interface component in the working prototype

The aforementioned objects were provided to each student on initialization and they could insert multiple copies of them inside the environment. Fig.2 presents a screenshot of the four tools.

The "Resource" object is the equivalent of a hyperlink. It has the form of an open book and it opens a web resource in the default browser upon mouse click. It can be used by the teacher(s) in order to provide some initial resources to the students (guidelines, design patterns, templates, etc.) to aid them during their tasks, and by the student groups in order to share and organize the resources they found in their self-directed learning activities.

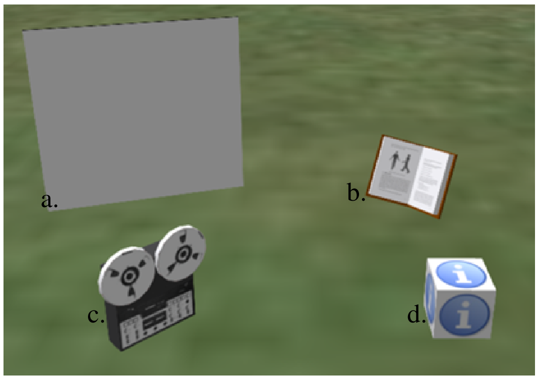

Figure 2. The supporting tools of the environment. a. Interface Element, b. Resource, c. Comment Recorder, d. Annotation

The "Annotation" object allows students to post annotations within the environment. If any user clicks on it, a text message is opened and may be saved in his/her inventory for later use. In the context of the PBL activities, annotations may be used for the asynchronous collaboration between group members (e.g. in the form of comments, notes about things to be done, role descriptions, etc.) or they may be attached to the user interface prototype as further notes or explanations of design choices.

The "Comment Recorder" object can record and playback user messages on demand by sending special commands to the text communication channel. It can be used to take notes from conversations during the early collaboration stages and also as a tool to record viewer comments during the final evaluation stage.

Finally, the "Interface Element" object is the principal design element of the user interface prototype. Its look and behavior can be configured using a simple set of commands and, depending on its configuration it can:

- show or hide in the environment as a result of an external event,
- operate as a button that will generate a batch of events if pressed, which may affect the status of other interface elements or itself
- contain a number of images (faces) that may change dynamically its appearance as a result of an external event, and
- operate as a container that forwards events to its contents

Students can combine and configure copies of the "Interface Element" object in order to design buttons, windows and image containers during the final stages of the learning activity and collaboratively construct an interactive user interface prototype.

C. Participants

The participants of the study were ten students (3 male, 7 female) of the University of the Aegean, from the departments of Product and Systems Design Engineering (8) and Information and Communication Systems Engineering (2), who volunteered to participate. Three (3) of them were at their 4th year of study and seven (7) at their 5th year. All participants had considerable experience in user interface design courses, since that they had all attended the courses of: human-computer interaction, interaction design and multimedia design. However, they had limited experience in collaborative, PBL situations, mediated by VWs. Naturally, each student possessed varying skills in this respect: e.g. some were good at sketching on paper, others at image editing and drawing programs, others at the use of usability guidelines, etc. All participants were proficient users of computers, but only three of them had some experiences with VWs, mainly as users of multiplayer online games like World of Warcraft and Second Life.

The participants were allocated in three equivalent groups in terms of their experience in VWs and their user interface design skills. Each group possessed one experienced user of VWs as well as users with skills of sketching and applying guidelines. Each participant was allocated several seats away from his/her team mates in the laboratory, to make use of the audio and text chat, thus simulating a remote collaborative work situation. The team mates performed all collaborative activities through the VW and they were not allowed to communicate face-to-face during the activity (apart from the breaks!).

D. Description of the learning intervention

The intervention has been designed as an optional exercise in the context of the course of 'Advanced User Interfaces'. The teaching team comprised of the authors themselves, who also provided technical support and facilitated the collaboration and learning activities during the whole intervention. The PBL activity was given to the participants in the following statement of a 'design brief': "*Design the user interface of a multimedia kiosk system for browsing available rooms to let in the island of Syros. The intended users are tourists (Greeks and foreigners), who can access the system from the harbour of Syros. You should take into account usability guidelines for multimedia presentations and information seeking. You should design the 5-7 most basic screens of the system, in wireframes*". In addition, the participants were presented with an abstract work plan that included tasks that they could choose to follow with indicative times for completion.

The learning goals of this intervention were: a) to discover the usability and accessibility requirements of touch screen interfaces, b) to understand the differences in the design of such interfaces compared to other, more conventional cases, and c) to apply this knowledge in a specific practical context. Following the principles of the PBL approach, the learning session has been applied as follows:

1. The students were given an introductory session in order to gain the necessary skills to properly navigate inside the VW, interact with its contents, and communicate with their fellow students.

2. The four additional tools that were built for the PBL session were presented to the students. Emphasis was placed on the usage and set up of the "Interface Element" objects, accompanied by specific use cases.

3. Students worked in groups inside their private space, where they analyzed the problem, shared ideas and gathered resources.

4. Each group assigned roles and/or tasks to its members. They proposed and argued about concepts, designed the appearance of the user interface elements using in-world and external tools, and collaboratively constructed their prototype as a proposed solution

5. Once the group agreed on the final prototype, they attached explanatory annotations to justify their design choices and presented it to the whole class (Fig.3)

6. Students and teachers were then free to test each interface prototype themselves and leave comments and suggestions concerning the appropriateness of the solution.

Figure 3. Group presentation inside the VW

The proposed activity engaged participants in a problem-based learning situation:

- They were confronted with a problem that does not have a single correct answer;

- They had to work in groups to identify what they need to learn in order to solve the problem;

- They also had to engage in self-directed learning and then apply their new knowledge to the problem and reflect on what they learned and the effectiveness of the strategies employed.

- The instructors acted to facilitate the learning process rather than to provide knowledge about the activity or tasks at hand.

E. *Data Collection and Analysis Method*

We have constructed a mixed method for interaction analysis of problem-based CSCL in VWs, which collects data from:

- Automated monitoring of student behaviour: video capturing of various stages of the activity within the VW; logfile analysis about the use (time to build, deleted elements, etc.) of the tools; and observation of the state of the VW during and after the exercise.
- Dialogue analysis: Voice chat was recorded for most of the exercise (the collaboration tasks, not the final presentation). We performed an analysis of utterances following the taxonomy of [31] who classify utterances in the categories of: procedure; task status; reference; internal state; and acknowledgement.
- Students' self-reporting: a questionnaire investigated several aspects of the PBL experience, as well as the follow-up discussion.
- Tutors' evaluation of learning performance and outcome: based on observations of the activity (tutors were inside the world, flying among work places, and observing and talking to students).

The method for interaction analysis explores the following dimensions of PBL: (a) 'Task performance', (b) 'Group functioning', (c) 'Social support', and (d) 'Learning performance and outcome'. Each dimension includes a number of interaction analysis indicators identified in related work [29,30] and were adapted to address important issues of PBL in VWs. Each indicator is investigated with at least two data collection methods, in order to cross-examine the results.

IV. RESULTS

A. *Task Performance*

With respect to the problem-solving capabilities demonstrated and related actions taken, we observed that students devoted a large portion of their available time to discuss about the design problem. These were intertwined with intervals of self-directed learning, which occurred either from 'assignments' or 'requests' by other team mates (e.g. "will you find photos and content about hotels?") or from individual initiative (e.g. "I can find some text to write about Syros history"). This was also identified by the dialogue analysis (Fig. 4): most of discussion was about the procedure and task coordination (38.7%) and acknowledgements (24.0%), while less time was devoted to discuss about the task status (6.2%) and to refer to virtual objects and tools (11.0%).

Self-evaluation of individual and group performance was quite similar for all participants. The average self-rating of their individual performance regarding the use of the system was: 7 (1: Bad – 10: Excellent) (st.dev.: 1.1). That was pretty much their rating about their team's performance, i.e.: an average of: 7.1 (st.dev.: 1.3). Their responses varied more, when they were asked about their performance with respect to the task of user interface design: they rated their individual performance with an average of 6 (st.dev.: 1.8) and their team's performance with an average of 5.9 (st.dev.: 1.9). Given that we closely observed the process, we consider these as rather misbalanced self-assessments: in fact, students faced many difficulties in using the VW, and the fact that they finally achieved to make use of the tools encouraged them to rate their performance rather highly than appropriate. On the other hand, the final outcome of the process was interesting from many aspects. Students have underestimated their performance in this respect because they needed more time for improvements.

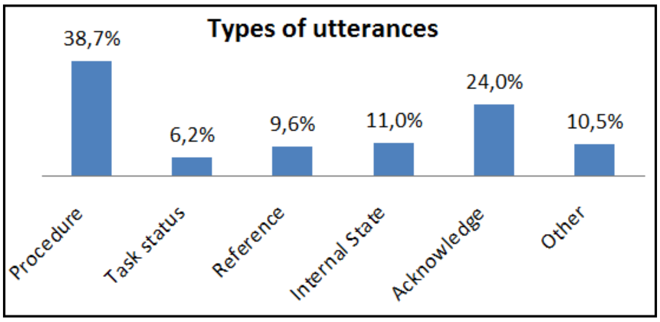

Figure 4. Types of utterances

B. *Group Functioning*

With regard to active participation, we observed (mainly from dialogue analysis and self-reporting) that all participants were actively involved in the collaboration and conversations, especially in the first phases of the collaborative activity. However, there were 2 students (team 2 and team 3) that gradually decreased their contributions. These students found it hard to make use of the tools and document their design contributions, therefore, they preferred to simply use voice or text chat. They reported that the experiment lasted too long, and they were tired by the process, despite that they enjoyed the experience overall.

All teams exhibited active interaction skills with respect to monitoring the progress of group work; this was evident especially from dialogue analysis: a rather large number of utterances were questions about how to proceed with the activity and specific tasks (14.1%), while there were also a large number of acknowledgements (24.0%) of group work. Each team used a different style of coordination of the work. Team 1 demonstrated a totally balanced coordination scheme without someone taking up a leading role. The other two teams quickly established a leader (in both cases the person who had more experience with the use of the VW) and allocated roles during the collaboration: the main roles were those of the 'visual designer', who also sketched the layout of the screens and the 'content designer' who located and edited content (mainly images and text). All participants reported that the result of their work was a collaborative product and that the environment contributed to their collaboration.

C. *Social Support*

With respect to social support, the results of the study are concerned with: members' commitment; level of peer involvement; peer contribution to mutual trust; motivational and emotional support; and contribution to conflict resolution. All participants and teams performed very well with respect to all these issues: they were all highly motivated students, who were acquainted to each other. More specifically, they rated their commitment towards the achievement of their goal at an average of 7.5 (1: Poor – 10: Excellent), and the main reason for this rating not being higher was that some of the participants got carried away with exploring the VW: when they had to wait for other team mates, they kept exploring the world, by flying around, keeping an eye on other teams' work progress and playing with their appearance. Also, some of them found the questions about contributing to mutual trust and emotional support rather odd, since that they considered these for granted. Regarding conflict resolution, there were disagreements about aspects of the design, which were expressed, discussed and quickly resolved. These were attributed to the nature of the task and to that they felt quite free to express them.

D. Learning Performance

Regarding the learning performance and outcomes, the main result was that all three teams achieved the goal of the exercise (i.e. to provide the design of the user interface of an information kiosk), at a fairly satisfactory level. All teams demonstrated interesting designs that took related guidelines and content into account. However they all reported that they would need more time to elaborate more their design solutions.

The participants reported that they gradually developed their knowledge about the activity at hand to a considerable extent (an average of 6; 1: Bad – 10: Excellent; st. dev.: 1.2). They also reported that they devoted about half of the time in self-directed learning: an average of 4.4 (1: None – 10: All; st.dev.:2.3). Also, when asked in which situations they best contributed to the team as with respect to whether they followed the agreed plan, they admitted that their contributions were more suitable when they stick to the plan (an average of 7.2; 1: Alone – 10: "I stick to the plan"; st. dev.:1.9).

Regarding the issue of developing problem-solving skills, students first reported on a number of problems faced: most students reported difficulties in using the VW, and a few found it difficult to document their design choices and their opinions with some of the tools provided. Then they reported on their ability to overcome these, an average of 5.2 (1: Bad – 10: Excellent; std. dev.: 2.4). The main reason for not performing better in this respect was that they had limited experience with previous use of VWs. However, we note that the final outcome of the activity, i.e. the user interface design was quite satisfactory for all teams.

V. DISCUSSION

In this section we discuss the more general aspects of the results of this study on the basis of the follow-up discussion in terms of identified problems, positives and recommendations, and our experiences with the set up and use of the VW.

The learning intervention lasted for a total time of 6.5 hours, which was about 1.5 hour more than initially estimated. The first 2 hours were devoted to the tutorial about the use of the VW. Then, a total of 3.5 hours were devoted to the activity of user interface design, presentations and follow-up; a total of 1 hour was allocated to the breaks. Participants were asked how much time they would need to carry out the user interface task in a 'face to face' situation and deliver at the same quality: some of them answered about the same time (3.5 hours), others said about an hour less. This is a quite interesting result considering other time consuming activities in face to face situations like for example time arrangements.

The main problems identified are as follows: (a) *Collaboration without voice is a problem*: at a couple of times, voice chat was unavailable (due to temporary problems of the voice server), and participants felt quite restricted in their communication. (b) *Focus on the VW environment, not on the task*: some users reported that their attention was more on the difficulties of using the environment, rather than on the user interface design task per se. (c) *Hard to perform organizational tasks*: the teams discussed and planned their activities, but they did not manage to keep track of their decisions. Despite that there were available tools in this respect, some of them found it hard to use them. (d) *The roles of participants were not mapped to their appearance*: this was also due to that some intentionally developed eccentric appearances over time. (e) *'More 2D functions':* e.g. the possibility to embed applications from their desktop environment to the VW. (f) *Familiarity with the environment*: this was perhaps the most important constraint for this study: none was proficient with the use of a VW, despite some had limited expertise. They faced problems with the use of the VW and they felt that if they were more familiar the final result would be much better.

The main positive aspects of the experience were identified as follows: (a) *Shared space*: This was perhaps the most important and recognized advantage of the system. Participants felt engaged with the shared space and motivated to work towards their common goal. (b) *Persistence*: Also, they highlighted that they could log off or postpone some of their activities in the world (especially when they performed self-directed learning) and that seeing the world as they had left it was extremely convenient to mentally focus fast on their task and continue from the point they had left. (c) *The VW promotes problem-based collaboration*: It was fairly easy to discuss about the task since that they had all material uploaded on the shared space. Also it was easy to compare design ideas and comment on others' work. (d) *It was fun*. Despite the long time in the lab, they were immersed in the VW; about half of the participants refused to eat in the lunch break! (e) *Engaging and immersive environment*: The VW kept them occupied all the time. Even when they had to wait for team mates, they performed various activities like: worked on their appearance, flying and exploring the world, creating objects in the VW, while one participant built a house to host their final presentation. (f) *Awareness of others' work, activity and progress* is also a positive issue, mainly as a motivating factor to one's own work.

All teams made use of the tools provided in the environment to document on the design process (Table 1). The main recommendations to the specific VW and tools are as follows: (a) *Shared whiteboard for sketching*. Some participants sketched on paper and scanned the images inside the VW. Others, used image design tools outside the world, mainly Photoshop. (b) *Tools for organization and coordination of team work;* some form of a shared agenda and direct visibility of roles (e.g. as part of their appearance) would be an asset. (c) *Tools for collaborative writing in the world*. (d) *More privacy*. Some reported that they needed to chat directly to their team mates, without others hearing.

Table 1: What tools of the VW contributed to the development of your knowledge about the problem?
(Bad 1 2 3 4 5 6 7 8 9 10 Excellent)

	Average	Median	Mode	St.Dev.
Resources	5,5	7	7	2,9
Annotations	6	6	6	1,6
Comment listener	4,1	5,5	0	3,7
Interactive objects	6,7	7	7	1,4
Chat (text)	7,5	8	9	1,9
Voice Chat	9	10	10	0,5

VI. CONCLUSIONS

In this paper we presented the design and evaluation of a problem-based learning activity in a popular Virtual World platform in order to investigate strengths and difficulties of Multi-user Virtual Environments as collaborative learning spaces. The evaluation results were quite encouraging, as the learning session that we studied managed to capture the attention of students, to trigger self-directed learning activities, and to foster collaboration and discourse between them. The study also highlighted a number of problems that were mostly related to activity awareness, resource sharing and coordination issues. Some of these obstacles are based on inherent deficiencies of the specific platform that we used and have been tackled in other multi-user virtual environments (e.g. the use of a shared whiteboard), while others are still open issues. Further research is needed towards the design and evaluation of novel metaphors, tools and paradigms for student collaboration in learning activities in order to overcome these difficulties and to improve the effectiveness of Virtual Worlds as learning environments.

REFERENCES

[1] R.A. Bartle, Designing Virtual Worlds, USA: New Riders, 2003.

[2] J. Hedberg and S. Alexander, “Virtual Reality in Education: Defining Researchable Issues,” Educational Media International, vol. 31, Dec. 1994, pp. 214-220.

[3] C. Cheal, “Second Life: hype or hyperlearning?,” On the Horizon, vol. 15, 2007, pp. 204-210.

[4] M. Dickey, “Brave new (interactive) worlds: A review of the design affordances and constraints of two 3D virtual worlds as interactive learning environments,” Interactive Learning Environments, vol. 13, Apr. 2005, pp. 121-137.

[5] M. Bricken, “Virtual reality learning environments: potentials and challenges,” ACM SIGGRAPH Computer Graphics, vol. 25, Jul. 1991, pp. 178-184.

[6] C. Dede, “The evolution of constructivist learning environments: Immersion in distributed, virtual worlds,” Constructivist learning environments: Case studies in instructional design, 1996, p. 165–175.

[7] M. Roussos, A. Johnson, T. Moher, J. Leigh, C. Vasilakis, and C. Barnes, “Learning and Building Together in an Immersive Virtual World,” Presence: Teleoperators & Virtual Environments, vol. 8, Jun. 1999, pp. 247-263.

[8] M.W. Bell, S. Smith-robbins, and G. Withnail, “Researching Learning in Virtual Worlds,” Human-Computer Interaction, 2010, pp. 177-191.

[9] T. Yu, “Learning in the virtual world: The pedagogical potentials of massively multiplayer online role playing games,” International Education Studies, vol. 2, 2009, pp. 32-38.

[10] C. Bouras, E. Giannaka, and T. Tsiatsos, “Virtual collaboration spaces: the EVE community,” 2003 Symposium on Applications and the Internet, 2003. Proceedings, 2003, pp. 48-55.

[11] A. De Lucia, R. Francese, I. Passero, and G. Tortora, “Development and evaluation of a virtual campus on Second Life: The case of SecondDMI,” Computers & Education, vol. 52, Jan. 2009, pp. 220-233.

[12] T. Monahan, G. Mcardle, and M. Bertolotto, “Virtual reality for collaborative e-learning,” Computers & Education, vol. 50, May. 2008, pp. 1339-1353.

[13] C.E. Hmelo-Silver, “Problem-Based Learning: What and How Do Students Learn?,” Educational Psychology Review, vol. 16, Sep. 2004, pp. 235-266.

[14] J. Pearson, “Investigating ICT using problem-based learning in face-to-face and online learning environments,” Computers & Education, vol. 47, 2006, pp. 56–73.

[15] D. Boud and G. I. Feletti, “Introduction,” in D. Boud, & G. Feletti (Eds.), The challenge of problem-based learning, London: Kogan Page, 1991, pp. 13–20.

[16] R. Donnelly, “Blended problem-based learning for teacher education: Lessons learnt learning. Media and Technology,” vol. 31(2), 2006, pp. 93-116.

[17] J. K. Dennis, “Problem-based learning in online vs. face-to-face. Education for Health,” vol. 16(2), 2003, pp. 198–209.

[18] S. Ozdemir, “The effects of individual and collaborative problem-based learning using an online asynchronized learning tool on critical thinking abilities, academic achievements, and attitudes toward internet use,” Phd dissertation. Ankara: Gazi University Graduate School of Educational Sciences, 2005.

[19] Y.J. An, “Collaborative problem-based learning in online environments,” Phd dissertation. Indiana, USA: Department of Instructional Systems Technology, Indiana University, 2006.

[20] S. Bignell and V. Parson, “Best practice in Virtual Worlds teaching: A guide to using problem-based learning in Second Life,” Online archive available at http://previewpsych.org/BPD2.0.pdf [accessed Oct. 2010]

[21] I. Vrellis, N.M. Papachristos, J. Bellou, N. Avouris, and T.A. Mikropoulos, “Designing a Collaborative Learning Activity in Second Life An exploratory study in physics,” Proceedings of the 10th IEEE International Conference on Advanced Learning Technologies, Sousse, Tunisia, 2010.

[22] A. Jamaludin, Y.S. Chee and C.M.L. Ho, “Fostering argumentative knowledge construction through enactive role play in Second Life,” Computers & Education, vol. 53(2), 2009, pp. 317-329.

[23] C. Girvan and T. Savage, “Identifying an appropriate pedagogy for virtual worlds: A communal constructivism case study,” Computers & Education, vol. 55(1), 2010, pp. 342-349.

[24] E. Brown, M. Gordon, and M. Hobbs, “Second Life as a holistic learning environment for problem-based learning and transferable skills,” Assessment, 2008, pp. 39-48.

[25] J. Good, K. Howland, and L. Thackray, “Problem-based learning spanning real and virtual words: a case study in Second Life,” Alt-J, vol. 16, Sep. 2008, pp. 163-172.

[26] A. Dimitrakopoulou and B. Lars, “State of the art of interaction analysis for Metacognitive Support & Diagnosis,” Analysis, vol. 1, 2006.

[27] P. Dillenbourg, D. Schneider, and P. Synteta, “Virtual learning environments,” Information & Communication Technologies in Education, 2002, pp. 3-18.

[28] J. Strijbos and F. Fischer, “Methodological challenges for collaborative learning research,” Learning and Instruction, vol. 17, 2007, pp. 389-393.

[29] T. Daradoumis, a Martinezmones, and F. Xhafa, “A layered framework for evaluating on-line collaborative learning interactions,” International Journal of Human-Computer Studies, vol. 64, Jul. 2006, pp. 622-635.

[30] C. Bravo, M. Redondo, M. Verdejo, and M. Ortega, “A framework for process–solution analysis in collaborative learning environments,” International Journal of Human-Computer Studies, vol. 66, Nov. 2008, pp. 812-832.

[31] S.R. Fussell, R.E. Kraut, and J. Siegel, “Coordination of Communication: Effects of Shared Visual Context on Collaborative Work,” Proceedings of the 2000 ACM conference on Computer supported cooperative work, ACM, 2000, pp. 21-30.