A Framework for Problem-Based Learning Activities in Virtual Worlds

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Abstract

Problem-based Learning (PBL) is an educational approach based on the principles of constructivism, in which students learn by addressing authentic problems reflecting on their experiences. Virtual Worlds (VWs) are a promising educational medium that has the affordances to support constructivist learning and may be used to extend PBL activities in a more experiential way. In this paper we propose a generic framework for designing PBL activities in VWs based on the principles of constructivism, the traditional and technology-enhanced approaches to PBL, and the educational affordances of VWs. The proposed framework has been applied in an HCI Design studio course and the results are presented.

Keywords: Virtual Reality, Virtual Worlds, Problem-Based Learning, Constructivism

1. Introduction

Problem-Based Learning (PBL) is an approach based on the principles of active and collaborative knowledge construction, which has shown to be quite effective compared to traditional instructional methods [Hmelo-Silver (2004)]. In PBL students learn by collaboratively addressing ill-defined and open-ended real-life problems, usually without prior knowledge about the problem domain. During the problem-solving process students identify their knowledge deficiencies, decide what they need to learn, propose solutions, evaluate them and reflect on their experiences, thus developing problem-solving strategies and building domain knowledge in a self-directed manner.

PLB has been used as a learning approach in many different disciplines and courses, but the utilization of technology as an educational aid is limited. In the recent years, Virtual Worlds (VWs) have stood out as a promising new educational medium, basically due to their unique affordances and their highly motivating nature, and they can offer valuable support to PBL activities. VWs are computer-generated 3D environments, in which multiple users navigate, interact and communicate having a form of embodied representations [Bartle (2003)]. They have been characterized by many researchers as suitable mediums for applying constructivist learning theories because of their unique ability to create, manipulate and share interactive 3D content in real-time. Some researchers consider PBL as the most appropriate learning method in VWs [Bignell et al (2010)].

The utilization of VWs for constructivist learning activities remains at an experimental level today, despite the fact that they are extensively being used in universities and high schools. The majority of educational institutions are primarily using the medium for resource sharing and teleconferencing. 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. There have been a number of studies that explore the use of VWs as constructivist learning environments, and especially some PBL approaches applied in VWs, e.g. [Brown et al (2008), Good et al (2008), Vosinakis et al (2011)], but there are stull no generic methods and guidelines on how to implement PBL activities.

The aim of this paper is to propose a generic framework for designing and implementing PBL activities in VWs. Based on the principles of constructivism and on the current theoretical and applied approaches to PBL, we discover and exploit the unique affordances of VWs in order to effectively support these activities in the new medium. The proposed framework aims to guide educators and researchers to the preparation of the environment and supporting tools, and to the application of learning activities within it. We have followed the proposed framework for the design of a postgraduate course in HCI Design that ran through the semester using a VW as a complementary medium. The results of the case study provide further insight into the applicability of the proposed platform and highlight practical issues and technical challenges that should be further studied.

2. Virtual Worlds as a Constructivist Learning Platform

VWs seem to be ideal candidates as constructivist learning environments. The sense of *presence* that users feel when immersed in a VW allows them to perceive it as a space they belong to, rather than a digital environment they are interacting with. Additionally, the *persistence* of VWs lets users reform the space and construct their own meaningful structures, while the *embodiment* of users as avatars allows them to interact with others in richer ways. The expressiveness of animated interactive 3D graphics can be used to present abstract or complex concepts that are difficult to comprehend in a textual form using *metaphors*, and help learners to interpret the environments or even construct their own interpretations and communicate them to their peers. Finally, the *real-time simulation* and *3D interaction* capabilities of VWs can be exploited to implement the appropriate tools and devices for experiential learning and problem solving.

A number of case studies have been presented in the last few years that involved PBL activities in VWs. [Brown et al (2008)] demonstrated the suitability of SL for problem-based learning through the mapping of learning activities on to PBL goals. The problems posed to the students were to create short video clips from their activities in the VW using the technique of machinima. [Good et al (2008)] reported findings from a case study with a PBL approach where students were tasked to create learning experiences within the VW 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 the VW. [Vrellis et al (2010)] used Second Life (SL) to implement a collaborative problem-based learning activity following a constructivist approach. The VW presented a simple physics experiment in a real-world context and pairs students had to collaboratively propose a solution to the problem using a calculator, two rulers and a shared whiteboard. The empirical results highlighted several advantages of VWs for constructivist learning, such as the persistence of the environment, the in-world object manipulation and the use of learning tools. In another case study, [Esteves et al (2009)] used VWs for PBL in computer programming. Students were asked to collaboratively implement interactive objects using LSL, i.e. the embedded scripting language of SL. The results of the study indicate that the learning environment had positive impact on motivation and was beneficial especially for novice students.

The aforementioned research works present encouraging results concerning the ability of VWs to support PBL activities. However, the case studies cannot be easily generalized and applied to other domains. Constructivist activities such as the use of tools to collaboratively experiment with various problem solutions have not been included and to the best of the authors' knowledge no guidelines or methods on how a VW can be extended and configured to host PBL activities have yet been proposed. This paper focuses on generic solutions for designing and implementing PBL activities in VWs. The main motivation of our work is to discover ways of further exploiting the affordances of VWs and using them as a learning medium that extends class activities in novel, rich and effective ways.

3. The Proposed Framework

In this section we present a framework for designing and implementing PBL activities in VWs. The first stage of the proposed approach is the *design of the learning environment*, in which the design team has to take decisions about the VW platform that is going to be used by the learning community, the interactive tools that will be developed to support the activities, and the construction and configuration of the in-world learning space that will host the process. The next stage is the *design of the PBL activities,* during which the designers have to decide about the way that the various activities will be organized and supported inside the VW. The final stage is the evaluation of the VW and learning activities.

3.1 Design of the Environment

The VW that will host the learning community and in which the PBL activities will take place should utilize a number of characteristics of VWs that have been considered important for collaborative constructivist learning. Therefore, the VW platform should at least support a) avatar customization, b) verbal and non-verbal forms of communication, c) user-generated content, d) public and private spaces and e) programming / scripting language.

Supporting Tools

A VW platform alone does not suffice as a constructivist learning environment. It has to be extended with the appropriate functionality to better support the students' needs. [Perkins (1991)] defines the following facets of learning environments that exist in the classrooms and can be further expanded and supported using technological means: *information banks*, *symbol pads*, *construction kits*, *phenomenaria* and *task managers*. An information bank within a VW could be a collection of related resources linked to active URLs, which the learning community may explore and update, if necessary. Respectively, symbol pads may be introduced in a VW in the form of personal or public message boards and drawing boards. These tools should help the learning community to quickly record or present their ideas and concepts in the form of notes, sketches and diagrams. The equivalent of construction kits in 3D would be a set of building blocks related to the problem domain (e.g. various molecule types and bonds in the case of chemistry), which learners could manipulate to construct new concepts. VWs can be ideal places for hosting phenomenaria as real time simulations in 3D. Custom rules can be assigned to 3D objects to define their real-time behavior, and thus, any phenomenon, be it deterministic or stochastic, can be simulated in the VW given that the processing power is enough to visualize it in real time. Finally, a VW may provide tools to support the task management and feedback processes, such as a board containing the action plan and the assigned roles to the students, and annotations or comments to be placed within the environment.

A collaborative learning community should be also supported with tools for group presentation and argumentation. The VW could include elements for communicating ideas to the group or to the whole class, such as interactive presentation boards, through which any student may upload her document(s) and present them publicly. Furthermore tools to post comments and annotations and to record discussions will facilitate student reflection and remote asynchronous group collaboration.

Finally, an interactive PBL whiteboard based on Barrow's model [Barrows(1992)] may be implemented as an in-world tool to support the process in a similar way to the traditional classroom approach. The board could contain the Facts, Ideas, Learning Issues and Action Plan of the problem solving process and the students will be able to insert and edit its contents to reflect the status of the project. The list of proposed VW supporting tools categorized by their function is presented in Table 1.

Table 1. *Supporting tools for PBL activities*

Generic learning tools	Resources
	Message boards
	Drawing boards
Constructivist learning	Building blocks
	Simulation objects
Collaboration	Annotations
	Discussion logs
	Presentation boards
PBL specific	PBL whiteboard

Learning Space

The design of the learning space is an important part of a VW configuration to host constructivist activities. According to the underlying theory of PBL, the problem presented to the students should be authentic, i.e. it should have the complexity and open-endedness of real-world problems. VWs may offer significant assistance to letting students be engaged in authentic tasks, not only by presenting them a real-world problem, but also by putting them in a realistic context. The interactive objects that will be implemented to support the constructivist problem-solving process may be presented in a realistic environment to place students in an experiential learning setting. We call this place a *simulation* place and its role is to be used by the group to construct and evaluate a problem solution and to present it to the rest of the class.

[Redfern et al (2002)] propose three types of places in collaborative virtual environments to support constructivist learning communities: a) Collaborative Zones, in which the groups share resources and collaborate, b) a Campus for informal interactions between the learning community, and c) Lecture rooms as a formal environment for lecturing. These places can be translated in the context of PBL as follows: there can be one *Group Collaboration* place, which can be used for resource sharing, group discussions and collaborative design of the solution and a *Class Meeting* place as a formal place for class presentations, discussions with the instructors, common resource sharing and announcements. The free spaces of the VW can be used as a place for informal student interactions, so there is no need for a specially designed campus environment.

Finally, given that constructivism supports the testing of ideas against alternative views and alternative contexts (Savery & Duffy), we also propose a *Personal* place for each user, in which he/she may copy and organize resources to aid their better understanding and reflection, and also propose alterations to existing solutions or construct new ones to present them to the group. Table 2 presents the proposed places to be included in a VW to support PBL activities and their access type. The design of each place and the interactive tools to be included depends on the problem domain and the typical tasks related to that domain.[Prasolova-Forland et al (2006)] present a number of possible place metaphors for educational VWs that can be used for the construction and configuration of the above-mentioned places.

Table 2. *Learning Places in the VW*

Places	**Access type**	**Activities**
Personal	Private	organize resources, try alternative solutions
Simulation	Group / Public	construct, present, evaluate problem solution
Collaboration	Group	share resources, meet, design problem solution
Class Meeting	Public	class discussions, public resources and announcements

3.2 Design of the Learning Activities

The next stage is to design and organize the learning process and the facilitator support. A generic process for PBL activities in the VW is presented in Figure 1.

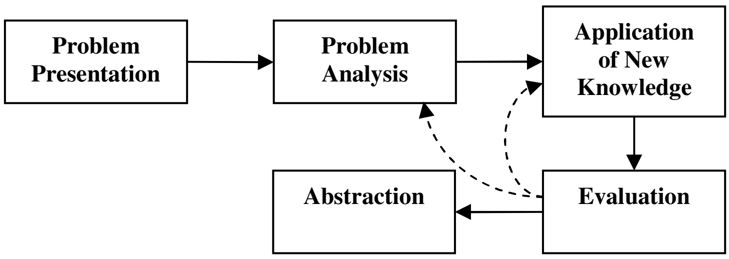

Figure 1. *The PBL process*

Problem presentation. Initially the problem is described to the students by the instructor(s). It may be presented in a more realistic context by constructing the simulation space so as to reflect the initial status of the problem. Short descriptions of the problem and the requested deliverables may be additionally provided by the instructors as annotations in the class meeting space. In this initial stage the students will have to familiarize themselves with the VW platform, the designed places and the supporting tools that will be used.

Problem analysis. Students work in groups to further understand the problem, identify the needs and design action plans. Asynchronous discussions may be recorded in message boards and group meetings may be logged using chat loggers. The results of the discussions can be inserted in an interactive PBL whiteboard object. During the problem analysis phase, the groups may decide for further actions, such as resources to collect, understand and present them to the rest. They can use the resource object to share and organize their document collections and annotations to write down their comments and notes.

Application of New Knowledge. In this phase, students apply the new knowledge acquired during the analysis process to propose a solution to the problem. The solution may be initially designed and refined in a more abstract and conceptual form using message and drawing boards in the collaboration place. Then, it can be constructed in a more detailed form and presented in a realistic context in the simulation place. Their design choices may be explained and justified by attaching annotations in (parts and aspects of) their constructed solution.

Formative Evaluation. The proposed solution is presented to the learning community. The instructors and the students may observe the results, place comments as annotations and request for further explanations. During the evaluation process, the group attempts to identify drawbacks in their solution and to propose alternatives. In some cases the evaluation results may reveal further knowledge deficiencies or alternative ways of applying new knowledge and make the group move back to the previous stages of the process to revise their work.

Abstraction. Finally, students reflect on the abstract knowledge gained during the PBL process by creating reports in the form of resources or attachments that explain their design choices and address the questions raised during the evaluation.

The PBL process has to be facilitated by the instructors to help students overcome the problems and difficulties raised during the research, to track the progress of the working groups and to assist in any technical difficulties. Instructors can schedule regular meetings in the class meeting place, in which the groups will present their progress using presentation tools and the whole class will discuss about the work presented and reflect on the discussions and comments. Furthermore, it is important to schedule specific hours on a regular basis for technical assistance. Given that users with less experience in 3D environments are expected to have difficulties using the VW platform and the tools provided, assistance by the instructors will be necessary to overcome technical difficulties.

3.3 Evaluation

The summative evaluation of PBL activities in VWs concerns aspects of the VW environment and the learning activities. We have developed tools for both aspects described in [Vosinakis et al 2011; Koutsabasis et al, 2011]

4. Case Study

We have applied the proposed framework in the context of an HCI Design Studio course, for which we used a VW to support the PBL process. The course is offered at the MSc program of Design of Interactive and Industrial Products and Systems, at the

University of the Aegean, Greece. The problem presented to students was defined as follows. “Design a (multi-) touch interactive table or kiosk for a public place like a cafeteria, cinema or theatre. The design should take into account tangible requirements like table form, table dimensions, etc.; however it should focus on the aspects of the software user interface and user interaction techniques.” The course lasted for one semester and two groups of five students participated in the activities.

Figure 2. *Class meeting (left) and prototype presentation (right)*

To support the course activities we have installed a VW in the department’s servers and developed additional content in the form of constructed places and interactive objects. We used the OpenSimulator platform to set up a standalone VW server and constructed the following rooms: a class meeting place, collaboration rooms for each of the groups, simulation places to present their interactive prototype and private rooms for each of the students. We have also developed a number of interactive tools (as implementations of those proposed in Table 1) in order to aid students through their activities. The tools were freely available in the class meeting place, and any student could make copies and use them in the world’s private or public places. Fig. 2 shows two screenshots of the environment.

The VW has been used successfully during the course in two ways: as a prototyping tool and as a collaboration environment. A notable advantage of the use of the VW lies in the integration and awareness. The group progress was visible to all, so both the tutors and the groups could be aware of the activities that took place and could observe and comment on the documents and solutions that were proposed. This integrated environment allowed remote users to collaboratively construct solutions and communicate in real-time using voice or text chat. In the second case they could also record their discussion for later use. Furthermore, the VW and the tools created for the course offered asynchronous collaboration capabilities that allowed the group to work on their solution in parallel and exchange opinions and ideas through messages, drawings and sketches. Finally, the creative freedom offered by the VW in the sense that students could modify their appearance and construct and decorate their own collaborative space was highly engaging for the majority of them.

On the other hand, there were technical issues faced during the use of the VW that were quite restrictive. The 3D modeling capabilities of the environment were not as sophisticated as in commercial applications and the rendering quality was significantly lower, as expected. This difference caused some frustration to the more experienced students with background from the arts or architecture. Additionally, some students felt that there was extra burden to convert and upload to the VW the documents that they created using familiar applications, such as Powerpoint and Photoshop and they would like to have a less complicated interface between the VW and external applications. Finally, some users found the simulation objects quite difficult and time-demanding to use, because every single component of each screen should be represented as a different object having its own behavior, and this process could be quite painstaking in the case of more complicated user interfaces.

5. Conclusions

We have presented a framework for designing and evaluating PBL activities in VWs and demonstrated a first application of the proposed framework in an HCI Design Studio course. Our approach emphasizes on the utilization of VWs as a constructivist learning platform through the use of simulations and collaborative problem solving, and it attempts to propose possible solutions to the aspects of designing and implementing PBL activities that are platform-independent. Its first application in the HCI Design studio course was quite successful in supporting PBL activities in a rich and experiential way. It allowed students to remotely collaborate on the problem solution and instructors to monitor group performance and offer assistance. Students also used specially designed simulation objects to construct interactive product prototypes and to test them in a realistic context. However, the selected platform had certain drawbacks that caused technical problems and frustrated students in some cases. Further research is needed in order to improve the usability and effectiveness of VWs and take advantage of their affordances to support constructivist learning.

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Περίληψη

Η μάθηση βασισμένη στο πρόβλημα (ΜΒΠ) είναι μια εκπαιδευτική προσέγγιση που ακολουθεί τις αρχές του εποικοδομητισμού, σύμφωνα με την οποία οι μαθητές μαθαίνουν μέσω της αντιμετώπισης αυθεντικών προβλημάτων. Οι εικονικοί κόσμοι (ΕΚ) είναι ένα υποσχόμενο εκπαιδευτικό μέσο που θα μπορούσε να χρησιμοποιηθεί για την υποστήριξη διαδικασιών ΜΒΠ σε μια περισσότερο εμπειρική μορφή. Σε αυτό το άρθρο προτείνουμε ένα γενικό πλαίσιο για τη σχεδίαση δραστηριοτήτων ΜΒΠ σε ΕΚ το οποίο είναι βασισμένο στις αρχές του εποικοδομητισμού και στις παραδοσιακές και τεχνολογικά επαυξημένες προσεγγίσεις στη ΜΒΠ. Το προτεινόμενο πλαίσιο εφαρμόστηκε σε ένα μάθημα Σχεδίασης Διαδράσεων και παρουσιάζονται τα αποτελέσματα των δραστηριοτήτων.

Λέξεις κλειδιά: Εικονική Πραγματικότητα, Εικονικοί Κόσμοι, Μάθηση βασισμένη στο Πρόβλημα, Εποικοδομητισμός