Collaborative Educational Virtual Environments Evaluation: The case of Croquet

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Abstract: E-learning systems have gone through a radical change from the initial text-based environments to more stimulating multimedia systems. In this paper we present and compare 3D multi-user virtual environments for supporting collaborative learning. After a pre-selection phase the most promising solution seems to be the Croquet platform. An educational environment has been implemented on top of this platform. Furthermore, this paper presents a case study carried out in a tertiary education department, to assess the educational environment. This environment has been evaluated based on a hybrid evaluation methodology for uncovering usability problems, collecting further requirements for additional functionality to support collaborative learning environments, and determining the appropriateness of different kinds of learning scenarios.

Introduction
In the past few years and due to the evolution of networking and telecommunication technologies a number of interactive Virtual Environments (VEs) have been developed. In order to discern VEs from typical software applications, they can be defined as interactive, multisensory, three-dimensional (3D), computer synthesized environments (Barfield et al., 1995). In other words, all VEs provide a 3D space which presents the environment according to the perspective or view of the user, as well as include interactive components that allow the user to manipulate objects in the virtual world (Schwan & Buder, in press). Three-dimensional VEs come with varying features.

However, most provide three main components: (a) the illusion of 3D space, (b) avatars that serve as the visual representation of users, and (c) an interactive chat environment for users to communicate with one another (Dickey, 2005). Specific types of VEs can be distinguished based on their use or purpose. VEs are most commonly used for commercial gaming (e.g. Everquest, World of Warcraft), socializing or online community building (e.g. Second Life, Google Lively, There) and as educational (e.g. AWEdu, Second Life, EVE, AquaMOOSE 3D) or working environments (e.g. Tixeo, I-maginer).

An Educational Virtual Environment (EVE) (Bouras et al., 2001) is a special case of a VE. EVEs are actually Collaborative Virtual Environments (CVEs) (Oliveira et al., 2000) that can be used for educational applications such as collaborative e-learning. As described in Chee & Hooi (2002), CVEs are powerful and engaging collaborative environments for e-learning, because they are capable of supporting several important learning objectives. These objectives include experiential learning, simulation-based learning, inquiry-based learning, guided exploratory learning, community-based learning and Collaborative Learning (CL). A CVE is a computer-based, distributed, virtual space or set of places. In such places, people can meet and interact with others, with agents, or with virtual objects. CVEs might vary in their representational richness from 3D graphical spaces, 2.5D and 2D environments, to text-based environments. Access to CVEs is by no means limited to desktop devices, but might well include mobile or wearable devices, public kiosks, etc (Churchill et al., 2001).

It is probable that CVEs will play an important role in future education since continuous enhancements in computer technology and the current widespread computer literacy among the public have resulted in a new generation of students that expect increasingly more from their e-learning experiences. To keep up with such expectations, e-learning systems have gone through a radical change from the initial text-based environments to more stimulating multimedia systems.

In this paper we will focus on a specific category of EVEs that aims to support Collaborative Learning. We call these environments Collaborative Educational Virtual Environments (CEVEs).

Collaborative learning is group-based learning, regardless whether this takes place face-to-face, via computer networks, or through a mixture of both modalities. From a constructivist perspective, collaborative learning can be viewed as one of the pedagogical methods that can stimulate students to negotiate information (abstract, ill-defined and not easily accessible knowledge and open-ended problems) and to discuss complex problems from different perspectives. This can support learners to elaborate, explain and evaluate information in order to re- and co-construct (new) knowledge or to solve problems (Veerman & Veldhuis-Diermanse, 2001). According to Petraglia (1997), a technologically sophisticated collaborative learning environment, designed following cognitive principles, could provide advanced support for a distributed process of inquiry, and
facilitate advancement of a learning community’s knowledge as well as the transformation of the participants’ epistemic states through a socially distributed process of inquiry.

Bruckman & Bandlow (2002) summarize the most important benefits of using Computer Supported Collaborative Learning (CSCL) in education. Among others they mention that, using CSCL, teacher-student interactions become more balanced and gender differences are reduced. They also point out that the exploitation of a virtual environment (a) lowers inhibitions; (b) provides strong anchors from which classroom discussions can emerge; (c) can be enjoyed by multiple different personality types; and (d) aids students in discovering aspects of their own identity. Furthermore, Bruckman & Bandlow (2002) refer that CSCL, due to its student-centered learning process could (a) increase the likelihood that students will absorb and remember what they learn; (b) allow students to form personal connections with powerful ideas; (c) help students exhibit higher levels of attention; (d) support the students in becoming more honest and candid toward those in a position of authority; and (e) provide students with motivation.

Due to the above reasons the combination of collaborative e-learning and CEVEs seems to be an effective solution for supporting CSCL processes.

This paper focuses on the comparison of CEVEs, the pre-selection of the most promising solution and its evaluation for supporting collaborative learning scenarios. Therefore, this paper briefly reviewed available commercial and open source collaborative virtual environments, based on the process described by Dimitracopoulou (2005), and through their support for specific high-level functions that should be performed during collaboration. Furthermore, this paper presents a concrete evaluation methodology to evaluate the selected environment for (a) uncovering usability problems; (b) collecting further requirements for additional functionality to support collaborative learning environments, and (c) determining the appropriateness of different kinds of learning scenarios. Finally, this paper presents a case study carried out in a tertiary education department, to assess the selected platform based on the proposed evaluation methodology.

This paper is structured as follows: the next section presents the state of the art in 3D multi-user collaborative virtual environments and their comparison. Following this, the need for an evaluation methodology is identified and in the fourth section a proposed evaluation methodology for CEVEs is presented. Afterwards, the case study is presented. The paper concludes through the presentation of the evaluation results and future work.

Preselection of a CEVE platform
In this section we present the state of the art in 3D multi-user collaborative virtual environments and their comparison.

The presented platforms were initially chosen based on their popularity, proven educational and collaborative value (Bransford, 1990; Bedford et al., 2006), respective user testimonials and support of the generic features and advantages of current systems. The platforms we present are Second Life (SL, http://secondlife.com), Active Worlds (AW, http://www.activeworlds.com/), Croquet (http://www.croquetconsortium.org), I-maginer (http://www.i-maginer.fr/), and Workspace 3D (W3D, http://www.tixeo.com). All the above platforms are (fully or partially) commercial except Croquet, which is free and open source. In the next paragraphs we briefly present specific tools and services offered by the aforementioned environments.

An analysis of the existing collaborative systems shows that a number of tools and functions are designed and implemented in order to facilitate or better support the collaborative process. Furthermore, these tools could support the collaborative learning process. In order to pre-select a tool for further evaluation we need a quick way to review their collaborative features. For that reason, during the pre-selection phase, we have adopted the process described by Dimitracopoulou (2005), and we have reviewed the above environments through the lense of their support for specific high-level functions that should be performed during collaboration. The results of this review are presented in Table 1 and they are discussed in the following paragraphs:

- The appropriate means for dialogue and action: They provide the essential means for the collaborative learning activity itself. In this category we include the following tools: text chat, e-mail, forum, video conference, voice over Internet (VoIP). Other tools that are supported by some of the examined platforms shared text processors, shared web browsers and shared whiteboards. Through a shared text processor, users can co-author a document or a presentation. In most of the environments (e.g. Workspace 3D) users can view the document through a 2D top down perspective since it’s the most simple, accessible and familiar viewpoint. Salaheddin & Qaraeen (2007) for example, reveals that users are satisfied with the current traditional 2D representation of a shared word processor, requesting only the depiction of the document in higher resolution and a translation mechanism. Other useful tools in this category are: simulations and argumentation tools. Argumentation tools are used for the augmentation and presentation of arguments. Other tools include designing tools, brainstorming tools, structured chat mechanisms etc. The goal here is to satisfy needs and activities on a cognitive, social level. These types of activities include conversation,
The functions for workspace awareness: They are related to up-to-the-minute knowledge about partners’ actions in a closed collaborative scheme or in a wide community of collaborators. As presented in Table 1, many collaborative applications, like Active Worlds and Croquet, support project and scenario based learning through role playing. These tools have been realized in 2D collaborative environments with success, but their application in a 3D environment is where the advantages of this type of learning can be fully utilized. As has already been mentioned in the definition of CEVEs in the introductory section, users interact with the virtual world and its inhabitants through an avatar. Some of the basic advantages of using a 3D avatar are summarized by Zhigeng et al (2005): (a) Perception, the user’s ability to perceive the presence of others; (b) Tracking, the user can identify the location of others; (c) Recognition, the user can recognize others from their avatars; (d) Visualization of concentration; (e) Visualization of actions and gestures; (f) Social representation of the self through the avatar’s attire, meaning that users can recognize the task someone is involved with and his place in a hierarchy. Finally, avatars enhance the feeling of trust and security between the members of a group. Another function is action key support (used in Workspace3D for example): the user possessing the action key is the only one with access to the common workspace. The rest of the users can ask to obtain the key from the current owner. In the 3D environment the action key could be represented by a virtual object which can be transferred between the users. In Ang & Wang (2006) users report the transfer of a virtual microphone between them as a pleasant experience.

The functions for supporting students’ self-regulation or guidance: They support or directly guide students’ reasoning on a metacognitive level. Some users request the integration of a private space, where they can keep notes which could then be shared with the rest of the team. In most 3D collaborative environments, the shared text editor (and most shared applications) is embedded into a virtual desk or work space. Also, in a collaborative environment activity replay is the very useful functionality of recording and viewing all the actions that took place during a collaborative session. It serves the post examination of the co-authoring of a document and the co-planning of a project or a simulation. Unfortunately none of the examined applications integrates this capability. Furthermore, many platforms offer programming tools or application programming interfaces in order to create agents for supporting students’ self-regulation or guidance.

The facilities related to teachers’ assistance: They are essential, especially when the systems are addressed to students of primary and secondary education. The number of tools offered in this category is very small. Useful tools are activity replay and log files.

The functions related to community level management: They provide significant tools and functions for the management of the activities and material produced amongst a wide community. Tools that are supported to this direction are file sharing, forum, and voting systems.

In addition, through Croquet’s multi-user 3D virtual environment users can share files and applications, collaboratively browse the web, co-author documents and presentations and communicate through text, VoIP or video. Also, out of the five platforms examined, Croquet is the only one to feature portals which link virtual worlds together. Portals allow users to peer into other environments and share files. Looking through nested portals is also supported.

Finally, Croquet houses a physics engine which is capable of simulating vector fields such as wind and gravity. Although Croquet has many useful features, there are some tools and services which are yet to be integrated into the platform. For example, from Table 1 we gather that Croquet is missing valuable coordination tools, necessary for the management of a collaborative session.

A more concrete evaluation methodology is needed to evaluate Croquet in order to:

- Uncover usability problems
- Collect further requirements for additional functionality for supporting collaborative learning environments
- Determine the appropriateness of different kinds of learning scenarios

The following paragraph reviews the current evaluation processes for evaluating CEVEs in the directions described above.
Table 1: Review of 3D multi-user collaborative environment platforms

<table>
<thead>
<tr>
<th>Category</th>
<th>Tool/Functionality</th>
<th>AW</th>
<th>Croquet</th>
<th>I-maginer</th>
<th>SL</th>
<th>W3D</th>
</tr>
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<tr>
<td><strong>Dialogue and action</strong></td>
<td></td>
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<td></td>
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<tr>
<td>Forum</td>
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<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td></td>
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<tr>
<td>Video conference</td>
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<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
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<td>VoIP</td>
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<tr>
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<td></td>
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<td>Role playing scenarios</td>
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<td>Avatars’ interaction with objects</td>
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<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
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<td>Create objects, build</td>
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<td>Avatars’ teleportation</td>
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<td>Avatars’ manipulation</td>
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<td>Avatars’ perspective control</td>
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<td>Avatars’ gestures</td>
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<td>Avatars’ facial expressions (e-motes)</td>
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<td>Avatars’ interactions with users</td>
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<tr>
<td><strong>Students’ self-regulation/guidance</strong></td>
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<td>Annotation</td>
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<td>Yes</td>
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<td><strong>Teachers’ assistance</strong></td>
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<tr>
<td>Activity replay</td>
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<tr>
<td>Log files</td>
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<td>Yes</td>
<td>Yes</td>
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<tr>
<td><strong>Community level management</strong></td>
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<tr>
<td>File sharing</td>
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<td>Yes</td>
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<tr>
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<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
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<tr>
<td>Voting system</td>
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</table>

The need for an evaluation methodology for CEVEs

In this section we briefly present some methodologies applied by researchers in the studied bibliography for the evaluation of CEVEs either from the usability or from the pedagogical point of view.

Prasolova-Førland (2008) has presented a case study where place metaphors in a number of 3D educational CVEs are analyzed. The methodology followed was based on an exploratory case study in order to answer a number of questions such as (a) How should 3D CEVEs be designed to suit different educational purposes? (b) What place metaphors are typically used? (c) Which design features are beneficial and which are not? (d) How could the virtual place design in such worlds be analyzed in a systematic way? According to this methodology, Prasolova-Førland (2008) concludes that a characterization framework of 3D CEVEs could be based on the terms of learner, place and artefact. This framework is inspired by Activity Theory – activities are performed by learners and are mediated by artefacts, while both learners and artefacts are contained in a place. Furthermore, the characterization for the place dimension could be presented in more detail in terms of outlook, structure and role. Even though the characterization framework presented by Prasolova-Førland (2008) is not an evaluation framework, we believe that it could give some guidelines toward the determination of specific metrics in an evaluation methodology for CEVEs.

Another significant work concerning the way that virtual reality aids complex conceptual learning has been presented by Salzman et al (1999), and applied successfully in the project “Science Space”. Although this work is focused on an immersive virtual environment it is possible to adopt the model’s main ideas for scientific investigations concerning also other types of virtual environments such as desktop-based VEs. Kouk & Müller (2002) and Salzman et al (1999) point out that features of VEs (or settings based on virtual reality) do not act in isolation. Learning content (concept) and learner characteristics influence learning processes and outcomes as well. Moreover, interaction experience (simulator sickness and usability) and learning experience (immersion, motivation and meaningfulness of representations) work together to determine the process and the results. According to this model the first step is to specify the learning concepts and which of the VEs characteristics are able to facilitate the knowledge acquisition. The next step is to gather background
information of the learners. Furthermore, parameters of the learning process and the learning outcome have to be assessed.

Lee & Wong (2008) have also observed that there is a need of a detailed theoretical framework for VR-based learning environment that could guide future development efforts. They point out that critical step towards achieving an informed design of a VR-based learning environment is the investigation of the relationship among the relevant constructs or participant factors, the learning process and the learning outcomes.

According to the above, we can conclude that there is no focused and concrete evaluation framework for evaluating CEVEs. One the one hand, there are many techniques and evaluation frameworks for evaluating either the pedagogical or the technical nature of CSCL systems but none of them is focused on the CVE nature of the e-learning system. On the other hand, there are several evaluation approaches for CVE systems. However, none of them are focused on the pedagogical and educational nature of the e-learning system. Therefore, after identifying the absence of an evaluation framework for CEVEs we are propose a new hybrid model as described in the following paragraphs.

**Toward an evaluation methodology for CEVEs**

Our rationale concerning the evaluation methodology for CEVEs is to organize the evaluation process based on the idea of an iterative and incremental development process of an educational virtual environment (Bouras et al., 2002). An iterative and incremental development process specifies continuous iterations of design solutions together with users. According to Goransson (2001) iteration includes: (a) a proper analysis of the user requirements and the context of use; (b) a prototype design and development phase; and (c) a documented evaluation of the prototype.

Therefore, concerning the evaluation process, which is the main interest in this paper, we need to conduct various evaluation cycles in order to assess each prototype of the system. The evaluation of each prototype system will result in suggestions for modifications in the following version of the prototype system design. In the case of a CEVE we propose to conduct three phases in each evaluation cycle (Table 2), namely: (a) Pre-analysis phase; (b) Usability phase; and (c) Learning phase.

A brief and general description of the necessity of the above phases as well as useful techniques for their successful conduct is presented in the following paragraphs. Afterwards, we describe in detail the specific steps followed for evaluating the Croquet platform.

**Pre-analysis Phase**

The pre-analysis phase is used in order to define the evaluations goals and to detect the characteristics of the evaluators. Evaluation goals can be defined in the form of questions. Two types of questions can be formed (Bruckman & Bandlow, 2002): (a) the evaluation methodology questions and (b) evaluation questions. The evaluation methodology questions concern questions regarding the general process of evaluation.

Usually, the selected evaluation methodology contains specific inherent goals. Therefore, before selecting a specific evaluation methodology, the evaluator’s desired outcomes should be in consonance with the possible results of a framework. A list of questions like those presented by Asensio et al (2006) can aid evaluators in detecting the appropriate metrics and selecting a fitting methodology.

The evaluation questions concern questions regarding usability and learning outcomes. Usability refers to the ability of the system to support the learning process. This covers the effectiveness, efficiency and satisfaction with which specified users achieve specified goals in particular environments (ISO 9241-12, 1998). Furthermore, in the usability questions the characteristics of the system (e.g. tools, modules, avatars, non-verbal signals, and communication) are evaluated. The learning outcome questions concern pedagogical research.

**Usability Phase**

Usability inspections of the initial applications are necessary so as to uncover the main design flaws and allow a clean up of the design, while adapting the method to 3D collaborative aspects. Usability and interaction are very much interrelated. Concerning interaction, social-arbitrary knowledge (language, values, rules, morality, and symbol systems) can only be learned in interactions with others.

Several human-computer interaction rules for display design must be taken into account when implementing any e-learning system. Rules such as consistency of data display (labeling and graphic conventions), efficient information assimilation by the user, use of metaphors, minimal memory load on user, compatibility of data display with data entry, flexibility for user control of data display, presentation of information graphically where appropriate, standardized abbreviations, and presentation of digital values only where knowledge of numerical value is necessary and useful.

**Learning Phase**

The main goal of the learning evaluation phase is to conduct pedagogical research. As proposed by Lee & Wong (2008) the model presented by Salzman et al. (1999) can be a useful guide in designing, developing and
evaluating a VR learning environment. Although this model is focused on immersive virtual environments it could be used also in desktop CEVEs in order to address which CEVEs features are appropriate, what kind of students might gain benefits through learning in CEVEs, and how CEVEs enhance learning by looking into the interaction and learning experience.

Therefore, our proposed evaluation methodology is based on the rationale of this model in order to test scientific hypotheses concerning learning and communicating in VEs through experimental studies. Thus, the main questions to be solved in the Learning phase of the proposed evaluation are:

- What effects does the VE have on process parameters?
- What effects does learning in VE have on outcome parameters?
- How do users rate the system in terms of attitude toward learning in VEs?
- What effects does the VE have on interpersonal parameters?
- In which parameters does the system differ significantly from a comparable platform without VR-technology?

**Case study: Usability and Learning Evaluation of Croquet**

In this section we will describe the way we applied the methodology described previously for the evaluation of the open source platform Croquet. This will be followed by a presentation of the results attained from questionnaires filled in by the participants at the end of each phase.

Using the open source platform Croquet, we created a 3D virtual environment which could be used for collaboration and carrying out online lectures. The design of the environment consisted of two interconnected rooms: a lecture hall (Figure 1) where presentations and classes can be held, and a room where student teams can meet to collaborate. Our proposed evaluation methodology was applied through a group of students interacting within our educational environment design.

<table>
<thead>
<tr>
<th>Croquet</th>
<th>Help</th>
<th>Web</th>
<th>Tools</th>
<th>Admin</th>
</tr>
</thead>
</table>

**Figure 1. The lecture hall of the environment we designed in Croquet**

In October of 2008, a presentation of the Croquet platform took place within the context of the course “Internet Learning Environments”, taught during the winter semester of the fourth year, of the Undergraduate Studies Programme at the Computer Science Department of our university. The presentation was held inside a computer lab with the participation of twenty-four postgraduate students consisting of eleven male and thirteen female students split into two groups of twelve members each. The evaluation methodology we applied in our case study is comprised of three phases spread across three days. These phases and their individual steps and goals are described briefly in Table 2.

In the learning phase, which will be described in more detail in a following section, we chose to utilize the jigsaw teaching technique and evaluate its effectiveness for a 3D CEVE. The jigsaw technique is a cooperative learning method with a three-decade track record (Aronson & Bridgeman, 1979) of successfully reducing racial conflict and increasing positive educational outcomes. Just as in a jigsaw puzzle, each piece, in essence each student's part is essential for the completion and full understanding of the final product.

**Table 2: Case study evaluation methodology**
Several pedagogical advantages have been attributed to the jigsaw process (Aronson & Patnoe, 1997). These educational benefits include listening encouragement, engagement, and empathy by giving each member of the group an essential part to play in the academic activity. Group members must work together as a team to accomplish a common goal and thus each student depends on everyone else. No student can succeed completely unless everyone works together. Also, the jigsaw technique is a typical method for researching certain collaborative interactions in a virtual environment. This "cooperation by design" facilitates interaction among all students in the class, leading them to value each other as contributors to their common task.

**Pre-analysis Phase**

Before participating in the evaluation, participants were asked to complete a questionnaire regarding their familiarity with distance collaboration and 3D virtual environments in general. The nature of this questionnaire would allow the research team to split the evaluators into two groups based on their previous experience with similar environments. The majority of participants responded that they had used distance collaboration software in the past (15 out of 24) and general familiarity with 3D interactive environments (19 out of 24). This allowed the research team to proceed with the definition of advanced and novice groups of CEVE users. In addition to the previous experience questionnaire, the participants were asked to fill in a learning styles modality preference inventory. This test included three sections: visual modality, auditory modality and kinesthetic/tactile modality.

After totaling the score for each section, a score of 21 points or more in a modality indicates strength in that area. The highest of the 3 scores indicates the most efficient method of information intake. The second highest score indicates the modality which boosts the primary strength. Through this questionnaire we could add more weight to the opinions of individuals with strength in the tactile or visual modalities since they are the ones we would expect to benefit more from the use of a CEVE. Results indicated that most of the participants had strength in the visual modality (16 out of 24), with tactile modality allowing a boost of the primary strength.

**Usability Phase**

Following a general presentation of the platform and its functionality, the students had a chance at navigating through the 3D environment we had developed, as part of the familiarization session. As mentioned in Table 2, the goal of this session was to uncover usability problems of the most important parts of the user interface. In this session the users were alone in the environment and allowed to experiment with the user interface and navigation controls. After 45 minutes of experimenting, the participants were asked to complete a questionnaire recording their experience.

Results indicate a positive initial reaction to the general feel of the platform. Users had no difficulty in learning how to operate the user interface or managing basic functionalities such as traversing the portal in order to enter another room. In addition, the rooms of the virtual environment were deemed satisfactory but the 3D graphics were considered disappointing. This is probably due to an uneven comparison to modern proprietary computer games, from the expert users. Functionality such the ability to change the viewpoint and the interaction with 3D windows garnered positive reviews also. Opinions are divided regarding the navigation scheme and the ease of orientation within the platform. Some students mastered the controls rather quickly, while others stumbled even after 45 minutes of practice. The Sketch tool which creates a 3D object from a 2D drawing was considered useful but of little educational value. Finally, students had no difficulty in distinguishing which windows were 2D/3D or which windows were collaborative and therefore common between them.

After the familiarization session, users were asked to test out the collaboration tools in groups of two or three. This was the collaboration session and as mentioned in Table 2, its goal was to uncover usability problems of the communication and collaborative functionalities of the platform. Following 45 minutes of this session, users were asked to complete a questionnaire documenting their experience.

Results indicated a disappointment in the networking performance of the platform. In general, we can surmise that users considered the platform a hindrance to collaboration. The questionnaires reveal a dissatisfaction regarding system stability and system response time. On the other hand, features such as representing an avatar’s viewpoint with an arrow and being able to see the other user and follow his actions were commended. According to the users the major advantages of the platform are the 3D graphics, the support
for collaboration and the communication mechanism. Croquet’s problems as revealed by the questionnaires are mainly regarding technical difficulties, 3D graphics, navigation scheme, user interface and system response time. This double mention of the 3D graphics as both an advantage and disadvantage is due to the variety of experience contained within the evaluator group. In other words, users experienced in the use of 3D graphical environments found Croquet’s graphics disappointing (11 of 24), while novice users were either not sure or satisfied.

Figure 2. The major advantages and disadvantages of the Croquet platform according to the users

Learning Phase
For this phase, the research team attempted to carry out an educational scenario through the platform. We chose to implement a jigsaw-type teaching technique. Split into two sessions, students were organized into four groups of three. Each group member was given a subtopic to research. Next, individual members of the group would break off to work with the members of the other groups which had the same subtopic assigned to them, thus forming three groups of four. Then they would return to their starting body in the role of instructor for their subcategory. In the context of evaluating the CEVE, the process of forming into groups would require the students to join the same virtual world. Also, students were allowed communication solely through the chat mechanism, while a think-aloud protocol was in effect in order to register the users’ attitude, reflection and problems that they have faced. After an hour into the phase, users were asked to complete a questionnaire. Most of the users agreed that a number of technical difficulties hindered the scenario process. Despite this, they still speak in favour of the platform albeit with a few suggested improvements. Results of the questionnaire indicate several features the users would like to see implemented.

Figure 3. Results of the Learning Phase questionnaires, regarding the educational value of the Croquet platform

The students used the chat tool extensively finding it convenient, but encountered difficulty identifying the user that was chatting. In other words, they couldn’t easily relate the user avatars to the chat nicknames. Most students suggested either using speech bubbles, or having the nicknames hover above the avatars. Users also agreed on the implementation of a map of the environment somewhere in the user interface and suggested the augmentation of communication through gestures and facial expressions for the avatars. Specifically regarding
avatar functionality, results show that the users would prefer the ability to modify their avatar’s appearance. Also, they think collaboration would be augmented if one could distinguish roles from avatar appearance alone. On the other hand, users do not consider humanoid avatars a necessity for meaningful learning. Private spaces for the users, argumentation and voting tools, recording tools and file sharing capabilities were also discussed and recommended by the users.

From the students’ answers we can surmise an uncertainty concerning the pedagogical value of the Croquet platform. As mentioned by one student in her questionnaire: “I found the software application entertaining even though I am not used to 3D environments, but I am also not sure about its educational value”.

Moreover, the students kept a neutral attitude regarding the degree of ease that they consider the organisation and following of courses through the virtual space, presents.

**Conclusion and Future work**

The main goal of this paper was to evaluate the exploitation of CEVEs for supporting computer supported collaborative learning scenarios. In this paper we reviewed available commercial and open source collaborative virtual environments (Second Life, Active Worlds, Croquet, I-maginer, and Workspace 3D) in terms of their appropriate means for dialogue and action; their functions for workspace awareness; their functions for supporting students’ self-regulation or guidance; the facilities related to teachers’ assistance and their functions related to community level management. Based on this review we chose to utilize the Croquet platform in order to design and develop a 3D educational environment. Furthermore we have realized that none of the examined platforms supports every reviewed feature. Thus, modification and integration of more features seems to be necessary.

Our next step was to follow a more concrete evaluation methodology in order to evaluate the selected Croquet platform for (a) uncovering usability problems; (b) collecting further requirements for additional functionality to support collaborative learning environments and (c) determining the appropriateness of different kinds of learning scenarios. Therefore, after identifying the absence of an evaluation methodology for CEVE evaluation, a new evaluation methodology for CEVEs has been proposed, which consists of three phases namely: (a) Pre-analysis phase; (b) Usability phase; and (c) Learning phase. The proposed methodology has been applied in order to evaluate the selected Croquet platform.

On the negative side of the questionnaire results we can conclude a disappointment in the Croquet platform concerning its use for collaboration. Disappointment is mainly centered on system stability and system response time which hindered the collaboration process. Other problems concern the implemented navigation scheme and user interface.

On the other hand, although a disappointment, the platform was considered by most students both inspiring and entertaining. By overcoming the technical difficulties and implementing their suggestions, users believe the educational process could be revitalized through the use of such novel technology.

Future work includes two alternative steps. We could opt to augment the Croquet platform based on the suggestions and observations of the evaluators and proceed with a repeat evaluation or examine a different platform and by doing so realize a meaningful comparison to Croquet. Either way, we will continue to assess and enhance the effectiveness of our proposed evaluation framework.

**References**


