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Collaboration in 3D Collaborative Virtual Learning Environments: Open Source vs. Proprietary solutions

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Abstract— *This paper focuses on Collaborative Virtual Learning Environments, examining the state of the art in both open source and proprietary software. Issues pertaining to the use of open source CVLEs are discussed and a collaborative learning activity in Second Life is presented. Evaluation results assess the appropriateness of the Second Life platform in executing collaborative learning scenarios, and reveal the students' reactions to a novel didactical approach.*

Keywords- Collaborative learning, Second life, Opensim, Croquet, 3D virtual learning environments

I. INTRODUCTION

Collaborative Learning (CL) is a general term used for the description of educational practices based on the simultaneous cognitive and mental effort of multiple students or/and educators. Students share a common goal, depend on each other and are mutually responsible for their success or failure.

Research (e.g., [13]) has led to several educational theories, such as those of constructivism and social learning. Vygotsky, who is the main supporter of social learning theories, states in the basic principles of his theory that "learning and developing is a social, collaborative activity".

Contemporary research (i.e., [1] and [16]), has proven the effectiveness of collaborative learning in some cases compared to other educational practices (e.g., competitive or personalized learning). It seems collaborative activities centered on a cognitive goal and supported by experts, result in more meaningful and efficient acquisition of knowledge.

The potential pedagogical benefits of collaborative learning, in general, are multiple and varied. Through this pedagogical approach, students can be stimulated to negotiate information such as abstract, ill-defined and not easily accessible knowledge and open-ended problems. Also, collaboration enables the discussion of complex problems from different perspectives and supports learners in the elaboration, explanation and evaluation of information in order to re- and co-construct new knowledge or to solve problems [3].

Probably, the major advantage of collaborative learning compared to other educational practices (e.g., personalized learning) is the interaction with others. According to Piaget, social-arbitrary knowledge (i.e., language, values, rules, morality, and symbol systems) can only be attained through such interactions [8]. This collaboration with other students provokes activity, makes learning more realistic and stimulates motivation. Students can ask each other questions and discuss problems from different perspectives. They can propose various answers and solutions and evaluate them on different criteria.

A Collaborative Virtual Environment (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 [6], but might well include mobile or wearable devices, public kiosks, etc.

From studying the pedagogical benefits of collaborative learning, we can surmise that the most important factor in designing a CVE is the catering for communication and interaction between participating students and educators.

Compared to tools supporting traditional teaching methods, CVEs have many advantages [1]. In addition to supporting real time distance learning, advantages can vary from student motivation and amusement to the simplification of the development of cognitive models from complicated or abstract material. CVEs let users experience environments, which, for reasons of time, distance, scale, and safety, would not otherwise be available, especially to those with disabilities [12].

In this paper we will focus on a specific category of CVEs that aims to support Collaborative Learning. We call these environments Collaborative Virtual Learning Environments (CVLEs). According to [5], a collaborative learning environment is an environment in which:

- The users participating have different roles and privileges.
- The educational interactions in the environment transform the simple virtual space into a communication space.
- The information in the environment is represented in multiple ways that can vary from simple text to three dimensional (3D) graphics.
- Students are not passive users but can interact with each other and with the virtual environment.
- The system that supports the environment integrates multiple technologies.

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- The possibility of implementing multiple learning scenarios is supported.
- Recognizable elements from the real world are visualized.

Regarding CVLEs, there are many issues to be resolved. For example, many practitioners and researchers have concluded that totally free, unguided or unstructured collaboration does not necessarily result in productive activity or learning [11]. Other main issues include:

- The selection of a suitable CVLE among the wide range of CVLE platforms - one of the strongest arguments against the use of virtual reality for education is that the software and equipment require technical expertise and skills beyond that of most teachers [19].
- The design of a CVLE on top of the selected process - designing a CSCL environment is not just a matter of taking a technological tool, an instructional approach supporting collaboration and an approach to studying its effects and putting them all together. The challenges to instructional designers are how to create motivating goals and tasks for students to perform and how to choose educational topics and concepts where the 3D visualization and simulation have clear advantages compared to the more traditional presentation formats such as slides, articles and diagrams [7].
- The organization of an effective evaluation process not only to uncover usability and functional problems but also to assess the potentiality of CVLEs to support collaborative learning scenarios - at present a systematic approach to the design of CSCL environments is missing [9]. Little attention has gone out to the relationship between a theoretical framework and the educational design of a CSCL setting.

The main goal of this paper is to examine whether it is possible to implement collaborative learning activities in a 3D CVLE by evaluating some issues that hinder collaboration. These issues are related to the functionality of 3D CVLEs and the collaboration among students. Initially, this paper presents some open source and proprietary CVLEs and then analyzes the problems encountered in trying to implement a collaborative activity through their utilization. These problems led us to implement the collaborative activity in the Second Life platform. After we discuss the design of our collaborative e-learning environment within the chosen platform, we proceed to present its evaluation. Conclusions and future work are presented in the final section.

II. Presentation of 3D Collaborative Environment Platforms

In this section we present the state of the art in 3D collaborative learning environments. The presented CVLEs were chosen based on their popularity, proven educational and collaborative value (e.g., [4], [10]), respective user testimonials and support of the generic features and advantages of current systems. Specific selection criteria for a 3D CVLE can be found at Tsiatsos et al., (2009) [18].

- **Active Worlds**: In Active Worlds, users can visit 3D virtual environments, communicate with others and create their personal virtual space. The educational capabilities of Active Worlds have been explored by a learning community known as Active Worlds Educational Universe (AWEDU) which provides educators, students, educational institutions and individual programs with the AW technology. Through AW, educators can assess new ideas, learning theories and teaching methods and discover new paradigms in social learning. Institutions already using AW include the Boston Museum of Science, the San Jose Tech Museum of Innovation, the NASA Ames Research Laboratory and many others.
- **Croquet**: Croquet is an open source cross platform 3D environment designed for rich interaction and simulation, with a combination of powerful graphics and multi-user collaborations [14]. Written in Squeak, an object and class based, reflective Smalltalk implementation, it's a combination of open source software and peer to peer network architecture providing an infrastructure for synchronous real time problem solving within shared simulations [17]. For Croquet's interface and architecture, its designers have incorporated many educational principles developed by Piaget, Papert, Montessori and Bruner.
- **Second Life**: Second Life is a very popular persistent 3D world which provides simple modeling tools and a scripting language (called LSL) for the creation of interactive objects and the alteration of the worlds' physics. In Second Life, educators can create real time interactive activities for the support of experiential, project-based and community service-based learning [4]. Chatting with others and navigating the virtual world of the software is without charge, but creating permanent objects and buildings requires the acquisition of land from the developers or from other users. As mentioned in Section 1 a CVE should feature recognizable elements from the real word, thus many companies, institutions and non-profit groups have setup virtual counterparts in the world of Second Life. For example, AOL has launched an interactive mall; Dell and the news service Reuters both have virtual offices.
- **Opensim**: Opensim is an open source server platform for hosting virtual worlds. Its main feature is the compatibility with the Second Life client. Opensim currently uses the Second Life protocol for client to server communication. The modeling tools and the scripting language are the same as the ones in Second Life. Creating objects and importing things (e.g., textures) in Opensim is without charge. Every user has private land on which they can create

anything they want, without restrictions. Of course, this happens only when someone installs the Opensim server on his/her own computer. Afterwards, any user can access the virtual world created by the administrator of the server.

- **Open Wonderland**: Open Wonderland is a Java open source toolkit for creating collaborative 3D virtual worlds. Within those worlds, users can communicate with high-fidelity, immersive audio, share live desktop applications, and collaborate in an education, business, or government context. Wonderland is completely extensible; developers and graphic artists can extend its functionality to create entirely new worlds and add new features to existing worlds. The vision for Open Wonderland is to provide an environment that is robust enough in terms of security, scalability, reliability, and functionality that organizations can rely on it as a place to conduct real business or education. Organizations should be able to use Wonderland to create a virtual presence to better communicate with students, customers, partners, or friends. Individuals should be able to do their real work within a virtual world, eliminating the need for a separate collaboration tool when they wish to work together with others.
- **Workspace 3D**: Workspace 3D offers a 3D collaborative environment for meetings, conferences and e-Learning. According to the developers, using three dimensions enables them to create a more accessible and user friendly workplace, allowing users to intuitively recognize who, where and what someone is doing through simple observation.
- **PIVOTE**: PIVOTE is an open source virtual learning authoring system for virtual worlds. Initially, it was developed for training medical professionals in Higher Education but now it can be used for any sort of structured learning in virtual worlds. The key point about PIVOTE is that all the structure and information content of an exercise is stored on the web, not in the virtual world. This means that it is easy to create, and then edit and maintain courseware, independent of the virtual world. Therefore, since structure and content are separate, similar exercises with varying degrees of scaffolding, help and support can be facilitated.

The main advantage of open source compared to proprietary CVLEs is the cost of implementing a learning activity. There is no charge for creating a virtual learning world in an open source CVLE, whereas in proprietary software you must pay a fee in order to use a virtual space or some necessary features for the process.

Open source CVLEs are almost completely configurable and enable tuning and improvement. In an open source CVLE we can create as many virtual objects as we want, restricted only by computer resources. Also, we can create virtual worlds which are accessible by a theoretically unlimited number of users.

Another advantage of open source CVLEs is the transferability of the virtual worlds. We are not obliged to create a virtual world from the beginning when we want to use a different virtual space for the implementation of a learning activity. What is more, we can use our own server for our virtual worlds instead of paying a company to use its servers.

III. Supporting a Collaborative Learning Activity Using Open Source Collaborative Virtual Learning Environments

Based on previous research (i.e., [2], and [18]) which assessed and compared the characteristics of state of the art open source CVLEs, we selected both Opensim and Croquet in order to examine their ability in supporting collaborative learning activities. Our main objective was to see whether these environments have gained the necessary maturity in order to implement effective collaborative activities in them. Evaluation of both platforms in the aforementioned research revealed a rich set of functionality.

A. Croquet

In order to assess the Croquet platform, a presentation of it took place within the context of the course “Virtual Learning Environments”, taught during the spring semester of the second year, of the Postgraduate Studies Program at the Computer Science Department of our University. The presentation was held inside the computer lab with the participation of twelve (12) postgraduate students consisting of three (3) male and nine (9) female students. Following a general presentation of the platform and its functionality, the students had a chance at navigating through the three dimensional environment we created and engaging in an educational scenario. The environment we created is shown in Figure 1. According to the educational scenario the students would collaborate in pairs of computer stations, attempting to complete four specified activities within the allowed time frame.

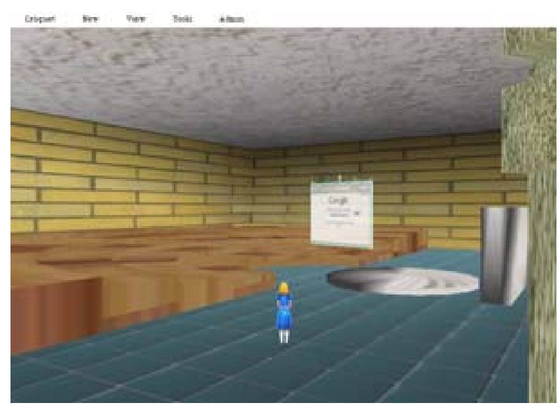

Figure 1. The lecture hall, shared browser and user avatar as seen from inside Croquet

After observing the users, a difficulty with regard to the navigation and orientation inside the virtual environment was identified. The results of the questionnaire, completed by the students, justifies this observation since it seems the students found the navigating more bothersome than any of the technical faults they encountered.

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. Also, the majority of the students would rather use VoIP to communicate with their team.

In another assessment of the Croquet platform, a presentation of it took place within the context of the course "Internet Learning Environments", taught during the winter semester of the fourth year, of the Undergraduate Studies Program at the Computer Science Department of our University. The presentation was held inside a computer lab with the participation of twenty-four (24) 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 was comprised of three phases spread across three days. These phases and their individual steps and goals were the following:

- Pre-analysis phase, which includes the Pre-test session
- Usability phase, which includes two sessions: (a) Familiarization session and (b) Co-presence session
- Learning phase, which includes Learning scenario-based session

After an hour into the scenario, users were asked to complete a questionnaire. Most of the users agreed that a number of technical difficulties hindered the scenario process. Results of the questionnaire indicate several features the users would like to see implemented. 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.

B. *Opensim*

Next, in order to assess the Opensim platform we created an educational scenario which took place in a computer lab with the participation of seven (7) postgraduate students consisting of four male and three female students. The use of Opensim was within the context of the course "Virtual Learning Environments", taught during the spring semester of the second year, of the Postgraduate Studies Program at the Computer Science Department of our university.

The educational scenario included the use of Sloodle in which users would show the deliverables they had been asked to prepare. The use of Sloodle was not proven to be very effective and eventually there was a problem in compatibility with Opensim. Also, sound problems made the activity very difficult as the students had to use text chat to present their work.

According to the questionnaires answered by students, the failure to use voice chat hindered the activity process. Another issue was the responsiveness of Opensim. When the virtual space filled with virtual objects then the response from the server where Opensim was installed was too slow so the students could not work with ease. The problem was not due to the speed of the network connection as the activity took place in a local network and there was plenty of free bandwidth. We also used powerful computers for the Opensim server and clients.

C. *Discussion*

Despite some obvious advantages of open source CVLEs in comparison with proprietary ones, the problems described above led us to implement a collaborative activity in Second Life as it had become obvious that the restrictions which existed in open source CVLEs would not allow the implementation of a collaborative activity in an efficient manner. Second Life is the most popular CVLE and provides an opportunity to use simulation in a safe environment to enhance experiential learning, allowing individuals to practice skills, try new ideas, and learn from their mistakes.

In the next section we will present the utilization of a collaborative learning activity in Second life and the differences regarding efficiency between this activity and the ones in open source CVLEs.

IV. Supporting a Collaborative Learning Activity Using Second Life

This section presents the methodology of the evaluation, carried out at our Informatics Department, with the participation of undergraduate students in a virtual collaborative learning environment inside the Second Life platform.

A. *Methodology*

The main goal of our evaluation was to determine whether Second Life overcomes the problems of the open source CVLEs, thus making it more suitable for the implementation of collaborative learning activities. The evaluation methodology we applied in our case study comprised of two phases. The first phase involved the familiarization of the students with the virtual world, the means of communication and the use and building of virtual objects. The second phase included the implementation of the educational scenario which is described in detail in the corresponding subsection.

Subjects of the experiment were undergraduate students attending the Multimedia Systems course of the Undergraduate Programme of studies in Informatics at our university. It would be unsafe to assume that the characteristics of this specific group of students correspond to the general student population of this level, we can however comment on the homogeneity of our subjects. According to questionnaires evaluating the previous experience of the users, we conclude that the majority of the subjects in the group were experienced in collaborating online through 2D interfaces. On the contrary, the majority of students were inexperienced in the use of 3D virtual environments for either education or entertainment.

B. Phase 1

The goals of the first phase were to: a) allow students to familiarize themselves with the capabilities of the platform, and with the available collaboration and communication tools, b) gather information regarding students' previous experience, c) organize the students into pairs and d) gather first impressions and usability requirements.

To gather the required information regarding students' previous experience, students answered a pre-test questionnaire which inquired about facts such as previous experience with 3D CVLEs.

In order to give students the chance to familiarize themselves with the virtual world, we created a special training corridor (see Figure 2) where students passed through various stages of training.

To achieve this, we placed presentation boards in every room of the corridor where students could watch video tutorials about a specific subject. First, students learn about communication is Second Life using voice and text chat. Next, there is a maze where students have to learn to navigate and fly in the environment, with the guidance of an assistant. Afterwards, the video tutorial shows students how to use the camera of the environment independently of avatar movement. The next room related to avatar appearance in Second Life, since the students would have to wear specific clothes differentiating the collaboration pairs. The last room was about creating objects in Second Life and how students can use them in order to achieve application sharing in the virtual world.

After the familiarization session, students were divided into pairs, because in the next phase they would work collaboratively in order to achieve the specified goals of the educational scenario.

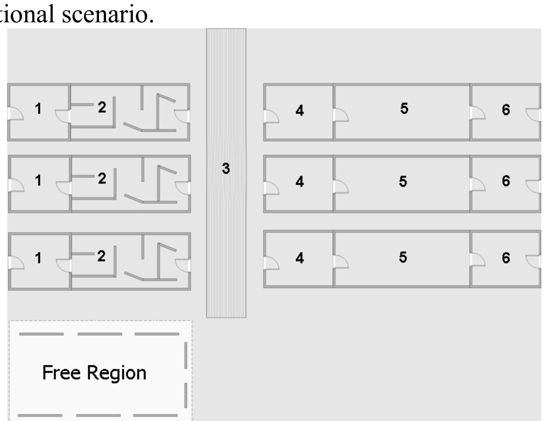

Figure 2. Three replications of the training corridor

C. Phase 2

The goals of the second phase included: (a) the specialization of students in specific tasks, (b) gathering usability, communication and pedagogy requirements, and (c) to support collaboration between pairs of students in order to answer specific worksheets.

In order to implement the second phase we had created a special classroom where there was a central place for discussion and smaller collaboration rooms for each pair of students (see Figure 3).

Students initially wore special clothes for separating each pair so that it was easy to distinguish between them. This had emerged as a need from previous activities in open source CVLEs. Then, a worksheet was assigned to each pair of students which contained questions related to the course under which the activity took place.

The worksheet could be collected by the students from the special library that was created to serve this purpose, but they also had the opportunity to see the worksheet from the web browser that every room had (see Figure 4).

The presentation board in the central room contained the requirements of the work that students had to do. The information search for answers to questions in the worksheets was done using the web browsers which existed in each room. The members of the pairs of students exchanged views with each other through VoIP and by using Second Life notes. They also had the opportunity to utilize application sharing if they considered it necessary in order to facilitate their collaboration. The whole process was supported by four assistants.

After the completion of the information search, each pair had to make a presentation on what they had found. The presentations were made in the central area of the classroom where there was a presentation board in which the assistants had loaded the presentations of all pairs of students on a Moodle environment.

At the end of this phase, each student had to answer an online questionnaire recording his/her experience and suggestions.

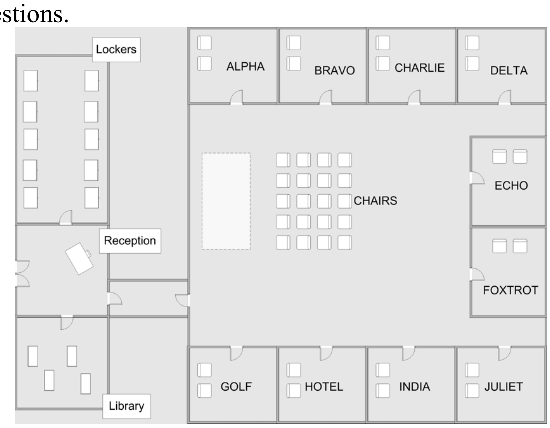

Figure 3. The central classroom area

D. Efficiency of the implementation in Second Life

The implementation of the collaborative learning activity in Second Life gave us the opportunity to overcome some serious issues. These problems hindered the collaboration between the students. In Second Life, there were no sound problems and so all students could communicate with each other using voice chat. That was very important since it was described by students in previous activities as a necessary feature.

The system response time problems we had encountered in the open source CVLEs were completely resolved. This gave students the opportunity to interact with each other and with the virtual objects with ease. Each pair of students had at its disposal special clothes which were very useful as it was easy for everyone to recognize who belongs to which pair.

In general, the students could change their appearance as they wanted; functionality which was not available in Croquet for example. Users could now also use gestures to communicate with each other, utilizing either those that the Second Life platform inherently had or those that we had created.

In general, it seemed that in Second Life there were no usability and functionality problems and more importantly, there were no problems that hindered the collaboration among students, which was the main point we wanted to investigate.

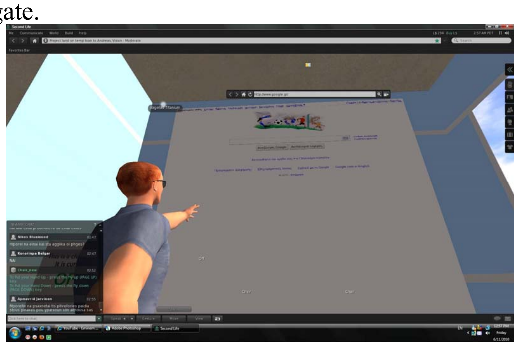

Figure 4. Students using the built-in web browser to search the Internet for information

V. Evaluation Of The Collaborative Learning Activity In Second Life

This section presents the evaluation process and results. After this we discuss and compare these results in order to make conclusions.

Students were asked to comment on the general advantages and disadvantages of using 3D CVLEs for collaboration. The most important advantages of this pedagogical approach were considered to be spatial and temporal flexibility, innovation and originality of method (e.g., 83% of students entered the environment outside of the educational process simply to explore the new environment) and enhanced communication and collaboration tools. On the other hand, disadvantages included lack of face to face interaction, increased technological dependency and learning overhead imposed by the new tools.

With regard to other collaboration methods, the Second Life 3D CVLE is competing against the more traditional approaches of 2D VLEs (or Learning Management Systems) and core face to face interactions. Based on questionnaire results, SL is considered the most interesting (73%), and entertaining (80%) approach, incorporating the best collaboration tools (66%). On the other hand, it is also acknowledged as the least effective, direct and useful approach to collaboration. Thus, it becomes apparent that 3D CVLEs cannot compete with a traditional learning environment but they can assist in case of blended learning or when it is impossible to carry out a face to face collaborative activity.

Moreover, students commented that the SL platform hindered their ability to share information sources with their colleagues, and thus obstructed the collaboration process as a whole. Other issues, mentioned by students, included lack of desktop sharing and average graphics quality. Furthermore, the absence of a user friendly control scheme hindered the efficient use of the inventory system, as well as the appearance editing mechanism. Finally, a bug in the platform allowed the sound from video playback to be heard irrespectively of distance from the source, confusing and disorienting users.

Despite complications, students judged several aspects of the platform positively. According to the evaluation results, students enjoyed the 3D environment, finding it an interesting and immersive experience. One student commented that: "...it makes you want to stay online longer." Furthermore, students considered the SL collaboration process, easier and more relaxing than a teleconference, taking pleasure in the feeling of presence of their peers.

Finally, with regard to specific functionality, students found the ability to move the camera, independently of the avatar, very useful and commented on the value of multiple communication channels: "…I could ask questions without interrupting." The majority of students were enthusiastic regarding the possible future use of the SL platform for collaborative activities, lectures and socializing.

Recommendations for future implementations were many and included:

- Application sharing through the built-in browser – most students believe that application sharing through the SL environment would enhance its collaboration capabilities, simplifying the scenario execution
- Extended periods of familiarization and collaboration sessions – users had limited time in which to familiarize themselves with the interface and complete the collaborative scenario. The majority of students believe that the educational process would benefit if the virtual environment was run in parallel, but not concurrently, to the face to face sessions, in consistency with the context and content of the course. It seems people who work together over a series of sessions develop what has been termed a "collaborative working relation" [15], as they progressively share more extensive mutual knowledge and an enhanced ability to coordinate.
- Increased publicity with the goal of attracting more students and defining a virtual social space – contemporary students are already skilled users of social software and Web 2.0 tools. Modern pedagogy, through 3D CVLEs, should exploit these abilities, by altering the

context, medium and evaluation criteria of educational material.

VI. Conclusion And Future Work

Researchers have proven both the effectiveness of collaborative learning as an educational practice and the use of computers in aiding the acquisition of higher level cognitive and problem solving abilities. Combining the two, CVLEs exhibit many advantages compared to traditional teaching methods, including student motivation and the experience of unique environments.

But certainly not all CVLEs are suitable for carrying out educational activities. There are problems both in terms of function and support of collaboration among learners. The main goal of this paper was to examine whether it is possible to implement collaborative learning activities in a 3D CVLE by evaluating some issues that hinder collaboration. Initially some open source CVLEs were examined, which have certain advantages over proprietary software, in order to consider whether it can be possible to implement a successful collaborative learning activity in them.

The implementation of collaborative activities in open source CVLEs was not very effective and resulted in significant problems that prevented collaboration among students. From the evaluation results we concluded a disappointment in the Croquet platform concerning its use for collaboration. Disappointment is mainly centered on system stability and system response time which obstructed the collaboration process. Moreover, the lack of a voice chat tool made the interaction very difficult and the students had also difficulty in relating the user avatars to the members of the activity. Other problems concern the implemented navigation scheme and user interface.

On the other hand, the evaluation of the activity in Opensim showed that most of the students were left unsatisfied with the platform. The sound problems didn't allow students to collaborate efficiently as it was very difficult to communicate with each other using only text chat. The main problem of the Opensim platform was the delayed system response time which made it difficult even to move within the environment.

Based on the above observations, our next attempt was to implement a collaborative learning activity in Second Life, a good representative of proprietary CVLEs. The use of Second Life gave us the opportunity to overcome previous problems which hindered collaboration between students.

The evaluation showed that the students worked without encountering any serious problems and without restrictions from the environment. Everyone submitted the deliverables which had been requested within the time frame that was set.

It became apparent that open source CVLEs are not mature enough yet to accommodate collaborative activities and allow educators to implement them effectively. There are several problems seeking solution. System responsiveness due to the use of a different protocol for data transmission has disappointed students. Another serious problem was the voice chat communication. Alternatively, sound problems can be addressed and overcome by utilizing a standalone voice chat application that runs in parallel with the virtual world's server and client. There are many other issues that need to be addressed, including the avatar's appearance editor, navigation and orientation.

Future work will include the attempt to resolve all issues identified during the assessment made by students. Solving these problems will allow open source CVLEs to exploit the advantages of proprietary platforms and therefore be very effective in the facilitation of collaborative learning activities.

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