Exploiting Virtual Environments and Web2.0 Immersive Worlds to Support Collaborative e-Learning Communities

Ch. Bouras[1, 2], E. Giannaka[1], Th. Tsiatsos[2, 3]
[1] Computer Engineering and Informatics Dept., Univ. of Patras, GR-26500 Rion, Patras, Greece
[2] Research Academic Computer Technology Institute, N.Kazantzaki Str. Patras University GR-26500 Rion, Patras, Greece, Patras,Greece
[3] Department of Informatics, Aristotle University of Thessaloniki, PO BOX 114, GR-54124, Thessaloniki, Greece

Contact Address:
Department of Informatics, Aristotle University of Thessaloniki, PO BOX 114, GR-54124, Thessaloniki, Greece
Tel: +30 231 0 998990
Fax: +30 231 0 998419
e-mail: tsiatsos@csd.auth.gr
(c/o Dr. Th. Tsiatsos)

Abstract

The main goal of this chapter is to facilitate educational designers and developers by providing a point of reference for making decisions on how to incorporate 3D environments into the applications they develop as well as for extending their capabilities by integrating more functionality. Therefore, this chapter presents the design principles for virtual spaces, which aim at supporting multi-user communication in web-based learning communities. In addition the implementation of these principles is presented using as point of reference EVE Training Area. This environment constitutes a three-dimensional space where participants, represented by 3D humanoid avatars, have the ability to use a variety of 3D e-collaboration tools for learning together. Furthermore, this chapter presents how these principles could be used as criteria for validating and extending ready Web2.0 Immersive worlds for supporting collaborative e-learning. Finally, collaborative e-learning usage scenarios that could be realized by exploiting collaborative virtual environments are described.

Key words: Collaborative Virtual Environment (CVE), Virtual Reality (VR) Virtual communities, Collaborative e-learning, EVE, Second Life, Web 2.0 Immersive Virtual Environments, Virtual Worlds

1. Introduction

Nowadays, the use of Internet has been widely broadened and is being adopted not only for accessing information for news and entertainment but also for facilitating the creation of on-line communities in order to assist the interaction among individuals that share common interests and goals. These communities are described by the term "virtual communities" for highlighting their "on-line" substance. A key factor for the success and the subsistence of the virtual communities is a strong interest among the people concerned. Such a case could form a group of people that want to share knowledge and learn together and consequently constitute a learning community.

A variety of tools and technologies have been developed and used for supporting e-learning communities. The current components, tools and systems available can be divided into three different basic categories as described in the literature (Spellmann et al, 1997; Bouras & Tsiatsos, 2006): a) document-focused web-based training tools, b) meeting-focused tools, and c) three dimensional (3D)-centered multi-user tools, which are based on multi-user Virtual Reality (VR) technology. In particular, the document-focused web-based training tools (e.g., WebCT, www.webct.com) focus on the management of documents and on individual learning. As far as it concerns the meeting-focused tools, they focalize on the support of synchronous communication of a user group, which is independent of place. These tools that can be separated into video-conferencing tools (e.g., Microsoft's NetMeeting, www.microsoft.com) and synchronous training tools (e.g., Centra Symposium, www.centra.com), offer web-based communication support, where participants are represented by their name and live video picture. Some of the video conferencing tools were designed especially for the purpose of training situations. The approach of these tools is to virtually represent the concept of frontal learning – that is the situation of a lecturer sending information to a group of learners, with rather little feedback and almost no intended horizontal communication among the learners (Koubek & Müller, 2002). A general problem of these tools is the reduced social presence of the participants that are represented in windows, by means of live pictures. Often, these pictures are simple icons that have a low resolution and are quite small. Therefore, participants in such e-learning sessions experience a feeling of distance more than a feeling of group awareness (Kuljis & Lees, 2002). As far as it concerns multi-user Virtual Reality tools, in their majority, focus on letting each participant experience the existence of other participants as well as the interaction between them. The participants of a 3D virtual session are represented by avatars, which can navigate through 3D environments, and are able to view the actions of all other participants. Multi-user Virtual Reality technology tools, when used as communication media, offer the advantage of creating proximity and social presence, thereby making participants aware of the communication and interaction processes with others. In case that multi-user VR technology is used for supporting collaboration among the users we refer to collaborative virtual environments (CVEs).

Multi-user VR technology tools as well as meeting-focused tools could be used for supporting learning communities. However, current e-learning applications have many limitations that should be overcome. Some of the main limitations involve the lack of peer contact and interaction of learners/users working alone and the need for flexible, available tutorial support. In addition, the theoretical advantages of multi-user VR technology are not exploited in an extended manner as they mainly offer text chat communication and users' representation through avatars. For example, advanced communication features, as voice or user gestures are not commonly utilized.

The main goal of this chapter is to facilitate educational designers and developers by providing a point of reference for making decisions on how to incorporate 3D environments into the applications they develop as well as for extending their capabilities by integrating more functionality. Furthermore, this chapter presents collaborative e-learning usage scenarios that could be realized by exploiting CVEs.

The remainder of this chapter is structured as follows. In Section 2 some basic issues of adopting virtual reality for supporting learning versus traditional methods are presented. Section 3 summarises the related work on VR in education, training and collaboration, while Section 4 proposes design principles for tools and spaces aiming at supporting learning communities and e-collaboration. Section 5 presents the implementation of 3D collaborative virtual environments used for e-collaboration and e-learning, for demonstrating the way that the principles could be applied. The section that follows proposes collaborative e-learning usage scenarios that exploit multi-user Virtual Reality environments. Finally, some concluding remarks and planned next steps are briefly described.

2. Virtual Reality vs. Traditional Methods

According to Kalawsky (1998), there are many areas where VR could be used for supporting education: (a) simulation of complex systems, where the benefit compared to traditional methods is the ability to observe system operations from a number of perspectives, aided by high quality visualisation and interaction; (b) macroscopic and microscopic visualization, where the benefit compared to traditional methods is the observation of system features that would be either too small or too large to be seen on a normal scale system; and (c) fast and slow time simulation, where the benefit compared to traditional methods is the ability to control timescale in a dynamic event. This feature could operate like a fast forward or rewind preview of a video recorder.

Other significant characteristics of VR that could be exploited for supporting education are the following:

- High levels of interactivity that VR allows: The benefit compared to traditional methods is that most people learn faster by ‘doing’ (Tornincasa, 2001) and the VR system provides significantly higher levels of interactivity than other computer-based systems. Given the fact that the interfaces are intuitive and easy to use, the degree of interactivity could be very beneficial.

- Sense of immersion: Sense of immersion is a powerful characteristic, especially in applications, where the sense of scale is extremely important. For example, architecture is an area where the sense of scale is required for visualising the impact of a building design on the external environment and the inhabitants.
- Inherent flexibility/adaptability: The inherent flexibility of a VR system arises from the underlying software nature of the virtual environment. A VR system can be put to many uses by loading different application environments. This means that it is feasible to use a VR system for a wide range of learning applications (Kalawsky, 1998).

In Liebregt (2005), a good overview of these systems is presented, showing that there is a wide variety of possible roles for Collaborative Virtual Environments in education: (a) supporting social awareness of students; (b) increasing communication and discussions possibilities on a wide scale; (c) supporting constructivist learning of ecological and cultural concepts; (d) increasing information available to users and possibilities for collaborative culmination of knowledge; (e) making available virtual experiences for learning difficult concepts; and (f) incorporating aspects of direct learning into indirect learning and the other way around.

Winn and Jackson (1999) describe various propositions related to the usage of virtual environments in education. Koubek & Müller (2002) believe that four of these propositions are of special interest. The first proposition is that virtual environments create a feeling of presence by techniques, which shift attention from the real world to the virtual world. The second significant proposition is that virtual environments situate learning in a meaningful context. The environment's "landmarks" play a special role. The third proposition states that collaboration is possible and efficient in virtual environments. Additionally, users represented by avatars in the virtual world support the feeling of presence and the joy while learning. Finally, as it becomes possible to learn by interacting with other students and virtual objects in virtual environments in a way similar to the interaction with real people and objects, it becomes important to investigate the design principles that should be adopted by educational designers for designing effectively virtual spaces for e-learning and e-collaboration. The current research on the design of collaborative e-learning virtual environments results in various issues and aspects of such environments. This chapter, later presents a list of design principles for virtual spaces that are focused on supporting collaborative e-learning.

3. Related Work

This section presents an overview of the related work on the usage of VR technology in distance education, learning and collaboration. VR has been exploited in various projects for supporting education, training and/or collaboration. A very good overview of relative projects is presented in Hay et al. (2002). These projects aimed at creating learning environments based on the exploration of various scientific concepts. Concerning education, much research has been done on the exploration of the unique features of VR and their interaction with cognition and learning in high-end, laboratory-based projects. Examples are the following: (a) exploration of scientific concepts where 3D models were important to conceptual development; (b) exploitation of VR's ability to shrink or expand 3D distances to make the models easy to manipulate; and (c) usage of the simulation mode of integrating models into learning environments and capitalization VR's ability to more accurately present the phenomena to the learner, thus building superior understandings.

Furthermore, VR technology has been used in other areas such as military training and medical education and training. Examples are: NPSNET-IV (Macedonia et al, 1995), Gorman's Gambit (Weil et al, 2005), VirRAD (Virtual Radiopharmacy, http://www.virrad.eu.org/) European project; Medical Readiness Trainer project (http://www-vrl.umich.edu/mrt/index.html) and CeNTIE project (Hutchins et al, 2005). In addition, multi-user Virtual Reality technology, which allows collaboration among users (and then referred as Collaborative Virtual Environments), integrates networking technology with immersive virtual environments and supports synchronous interaction of multiple users at various locations (Singhal & Zyda, 1999). Multi-user Virtual Reality technology is being used for co-operative work (Dumas et al, 1999), for education and training, for engineering and design, for commerce and entertainment, and is being studied extensively in 3D and time dependent representations of scientific and technical models (Singhal & Zyda, 1999; Hay et al, 2002).

VR applications, which are specifically designed to support learning, come in many different forms, from desktop virtual worlds to fully immersive virtual environments (Jackson & Winn, 1999). 3D collaborative e-learning environment adopt ideas of distributed constructionism to allow multiple users to work together in the same virtual space and to provide them with the power to construct shared representations of the topic they investigate. Examples of current applications of Collaborative Virtual Environments in education are: CVE-VM (Kirner et al, 2001), DeskTOP (Portugal et al, 2000), DigitalEE and DigitalEE II (Okada et al 2001; Okada et al, 2003), Viras (Prasolova-Førland & Divitini, 2003), and NICE (Roussos et al, 1997; Johnson et al, 1998).

A very good review about Web 2.0 Immersive Virtual environments has been elaborated by Redecker (2008). According to this review Web 2.0 Immersive Virtual Environments like Second life (SL, http://secondlife.com/) or similar online 3D virtual worlds, such as Active Worlds (http://www.activeworlds.com) provide users with a online game-like 3D digital environment to which users subscribe (OECD, 2007). SecondLife appears to have a rapidly growing base of 1.3 million "active residents", representing an increase of 46% in the number of active residents from January 2007, 61% of which are European (Pascu, 2008). According to Calongne (2007) In March, 2007, more than 250 universities, 2500 educators and the New Media Consortium (NMC), with over 225 member universities, museums and research centres, had a presence in Second Life.

Furthermore, NMC has conducted a survey (NMC, 2007) among 209 educators using Second Life, and found that the manifold uses of 3D environments for educational purposes are the following: 60% of educators took (43%) or are planning to take (17%) a class in Second Life;

58 % taught (29%) or are planning to teach (28%) a class in Second Life.

Other activities include:

- supervising class projects and/or activities
- conducting research in SL
- class meetings
- virtual office hours
- mentoring student research projects
- student services and support activities.

According to the same survey (NMC, 2007), 8% of respondents taught a real life class entirely in Second Life; 19% are planning to do so. Asked about the potential of Second Life for education, a majority of respondents see a significant or high potential for role-playing (94%), simulation and scenario activities (87%), artistic expression (86%), group work, collaboration and meetings (78%), distance learning programs (74%), team building (73%), conducting training (71%), professional development (68%), and teaching full courses (60%).

4. Towards a set of design principles for virtual spaces focused on collaborative e-learning

This section presents the design principles that should be taken into account by designers and developers when designing a virtual space for collaborative e-learning communities. Before defining these principles, the main aspects of Collaborative Virtual Environments as well as the fundamental design elements of collaborative e-learning environments are presented. Issues in the design of Collaborative Virtual Environments in education are also listed and taken into account in the proposed set of design principles.

4.1 Main aspects of a collaborative virtual environment

For implementing a functional and effective e-learning collaborative virtual environment, the first step is to investigate its main functional features. These functional features should differentiate an e-learning environment from other virtual environments (3D or not), which are designed and implemented for general use. The virtual spaces should be designed in accordance to the concepts introduced by Dourish & Harrison (1996) about space and place: "A space is always what it is, but a place is how it's used" (p. 69). In addition, according to Dourish & Harrison (1996), design has to deal with some aspects of the "real world", which can be exploited by virtual spaces for collaboration and learning. The real-world value of the features listed below is that they provide critical cues, which allow individuals to organize their behaviour accordingly (such as moving towards people to talk to them, or referring to objects so that others can find them). Every tool designed for supporting e-collaboration should exploit aspects of space and spatial mechanisms, such as providing identity, orientation, a locus for activity and a mode of control, which can be considered as powerful tools for the design. According to the above, the designer of a CVE should include specific tools and take into account specific aspects in order to support the creation of places by the collaborators/students. By that way the designer facilitate the emergence of places by the collaborators/students people who is able to create meaning of things by engaging in social interactions.
In particular, these aspects are:

- **Relational orientation and reciprocity**: The spatial organization of the tools should be the same for all participants. Since people know that the world is physically structured for others in exactly the same way as it is for them, they can use this understanding to orient their own behaviour for other people's use.
- **Proximity and activity**: People act, more or less, where they are. They pick up objects that are near, not at a distance; they carry things with them and they get closer to things to view them clearly. An understanding of proximity helps relating people to activities and to each other. The learners/collaborators in the environment should not be passive but active and able to interact.
- **Partitioning**: Following on from the notion of proximity and activity is the notion of partitioning. Since actions and interactions fall off with distance, this distance can be used for partitioning activities and the extent of interaction.
- **Presence, awareness and support of users' representation**: The sense of other people's presence and the ongoing awareness of activity allow them to structure their own activity, integrating communication and collaboration seamlessly, progressively and easily. The use of avatars for user representation in virtual environment is a key feature for supporting e-collaboration and collaborative e-learning. According to Clark & Maher (2006) "the role of the

4.2 Design elements of a collaborative e-learning environments

Additional design elements of a virtual space, which is focused on e-collaboration and e-learning, could be extracted by a generalization of the design elements presented in Bouras & Tsiatsos (2006) (mainly focused on collaborative e-learning using only 3D virtual environments) and based on Dillenbourg's interpretation of collaborative learning (Dillenbourg, 1999), and Moshman's interpretation of dialectical constructivism (Moshman, 1982). These design elements are the following:

- Situated remote communication by supporting multiple communication channels such as avatar gestures, voice chat and text chat.
- Remote task collaboration: Distributed environments allow users to collaborate on tasks. This design element could be realized by:
  - Tools such as manipulation of shared objects, brainstorming board tool, locking /unlocking shared objects, user handling, as well as slide presentation and creation.
  - Supporting users who have different roles and rights when visiting the environment.
- Remote task support: Remote support by other learners, teachers, moderators and participants. This design element could be realized by uploading material in the virtual space and data sharing.
- Scaffolding tools: Tools that can support collaborative scenarios as well as support the learners to undertake tasks in the virtual space. This design element could be represented by whiteboard, brainstorming and slide creation tools. For example, the whiteboard tool could support the learner in making a presentation of a task that s/he has undertaken. Similarly, both the brainstorming tool and slide creation could support the learners to exchange and collect ideas for a task that has been assigned to them by the tutor.
- Representation of the environment by various representation forms, which can range from simple text to 3D worlds.

4.3 Issues for the design of collaborative virtual environments in education

According to test elaborated and presented in Liebregt (2005) there are important issues that should be taken into account when using CVEs and developing CVEs in the future. These issues are listed below:

- The tutors should be able to guide the learners
- There is a requirement for natural communication possibilities including realistic avatars and the possibility to use body language
- It is important to prevent the users from over engagement with subtasks not directly related to the main goal of the CVE
- It is important to avoid frustration or distraction caused by unnecessarily complex interfaces

Further problems of computer-mediated group learning could be summarised as follows:

- Reduced social presence - problem of social and cognitive orientation (Hsi & Hoadley, 1997)

  - group members tend to feel more as an individual than as a group member
  - the problem of "virtual group identity" leads to a depersonalisation of the group members
  - low collaboration is taking place
  - reduced feeling of social presence, togetherness and group identity
- Unnecessarily high amount of extraneous load (Sweller, 1988)
  - split-attention effect: separation of related information sources increases extraneous load
  - poor exploitation of working-memory capacity due to poor utilisation of prior knowledge (rules and causal connections known from reality cannot be used).

Finally, Kreijns et al. (2002) said that "there are two major pitfalls impeding achievement of the desired social interaction in collaborative e-learning environments: (a) taking social interaction in groups for granted and (b) the lack of attention paid to the social psychological dimension of social interaction outside of the task context.

4.4 Design principles

Based on the aspects and design elements presented above, this subsection proposes a set of principles for assisting design and implementation of desktop collaborative e-learning environments. Their use is mainly viewed as augmenting rather than replacing in overall existing design principles. They express a new emphasis in the use of these environments rather than a radically distinct set of intentions. These principles are the following:

- Principle 1: Design to support multiple collaborative learning scenarios
- Principle 2: Design to maximise the flexibility within a virtual space
- Principle 3: Augmenting user's representation and awareness
- Principle 4: Design to reduce the amount of extraneous load of the users
- Principle 5: Design a media - learning centric virtual space
- Principle 6: Ergonomic design of a virtual place accessible by a large audience
- Principle 7: Design an inclusive, open and user-centred virtual place
- Principle 8: Design a place for many people with different roles

The above principles are analysed in the following paragraphs.

4.4.1 Principle 1: Design to support multiple collaborative learning scenarios

A useful tool for collaboration would support the execution of many e-learning scenarios. Examples of such scenarios are brainstorming/roundtable (Millis & Cottell, 1998; Osborne, 1963), think pair share (Lymna, 1981), jigsaw (Aronson et al, 1978), quickwrites / microthemes (Young, 1997), and structured academic controversies (Johnson et al, 1998). An e-learning environment can support many groups of users (i.e. classes) in various subjects, so some scenarios could fit better in a subject than others. Therefore, the tutor should be provided with the ability to choose among various collaborative learning scenarios. Furthermore, a variety of student-centred and collaborative approaches to learning would increase the variation in student activity in formal classes.

4.4.2 Principle 2: Design to maximize the flexibility within a virtual space

Due to the need of multi-functionality within a collaborative on-line synchronous session, it should be possible to quickly re-organise the virtual place for a particular activity or scenario. An approach for increasing flexibility is the division of the virtual environment in smaller areas, so as to allow for specific functions (e.g. various virtual spaces for formal classes, group work, closed meeting, etc). This approach, however, may result in disorientation and increment of the cognitive load of the users concerning the operation of the virtual space. This chapter proposes a design of a virtual space, where the seating in a formal class area will not impede group work, discussions and interaction.

4.4.3 Principle 3: Augmenting user's representation and awareness

Both current e-learning systems and collaborative virtual environments lack of awareness. There are two types of awareness: the awareness of other people and the awareness of objects. The suitable combination of these two types of awareness is very critical in e-learning environments in order the users to be aware, not only of the others and the content but also of the e-learning procedure.

The goal for satisfying the need of awareness is to concentrate on both the visualization of other users and the representation of their actions on the objects they are communicating about.

The collaborative virtual environments support the awareness of other people and their activity effectively. The avatars, along with gestures and mimics, represent not only the users but they also make their activity shared to the rest of participants.

In the case of objects' awareness, collaborative virtual environments can support shared virtual objects and, generally, media that can be integrated in a virtual world such as pictures, audio and video. Furthermore, documents and/or learning content that cannot be displayed in the virtual world should be supported in an e-learning platform. In addition, the participants should be aware of the number and the identity of the users who view the document each time. Also, the actions on the objects and the documents should be visible from the other users. This could be achieved, for example, by application sharing.

Combining gestures, mimics, user representation, audio and text chat communication as well as application sharing provides to the users the ability to share their views, to show the object that they are talking about while other users are also aware of who and for what they talk about.

4.4.4 Principle 4: Design to reduce the amount of extraneous load of the users

The main objective of an e-learning environment is to support the learning process. Therefore, the users should be able to understand the operation of the learning environment and easily participate in the learning process. The major commands of interfaces should be available in a graphical user interface fashion. Since virtual environments, in their majority, include multiple ways of interaction (i.e. voice chat, text chat, video representation, shared areas), all these functions and tools should be placed in the same window, separating the shared areas from the non shared. It should be possible for the user to see at once the users who participate as well as their contribution.

4.4.5 Principle 5: Design a media - learning centric virtual space

The virtual space should be enhanced by multiple communication and media layers. Each media type (e.g. text, graphics, sound, etc.) has advantages (Schneider, 1996). The virtual space should integrate many communication channels (such as gestures, voice chat, text chat, etc.) in order to enhance the awareness and the communication among the users. VEs need multiple communication channels but they should be available on a basis of needs and availability, i.e. communication should not become intrusive but people should be able to use the right channel for the right task and a social practice for using different channels must be created (Schneider, 1996).

There are three approaches regarding the design of CVEs. The first one (VR-centric view) characterizes CVEs as systems based only on virtual reality technology and nothing else. The second approach, which is a step-up of the VR-centric view, is the adoption of mixed reality systems. In these systems the main user interface is VR and the users can interact with the system navigating only in the 3D world and accessing the rest of media only within the 3D area. The third approach (media centric view described by Robinson et al, 2001) tends to integrate more media in a CVE system. Audio, text, documents, video, etc. are such media. However, in this approach VR is not the access point for the rest of media, and is regarded as one medium among the others.

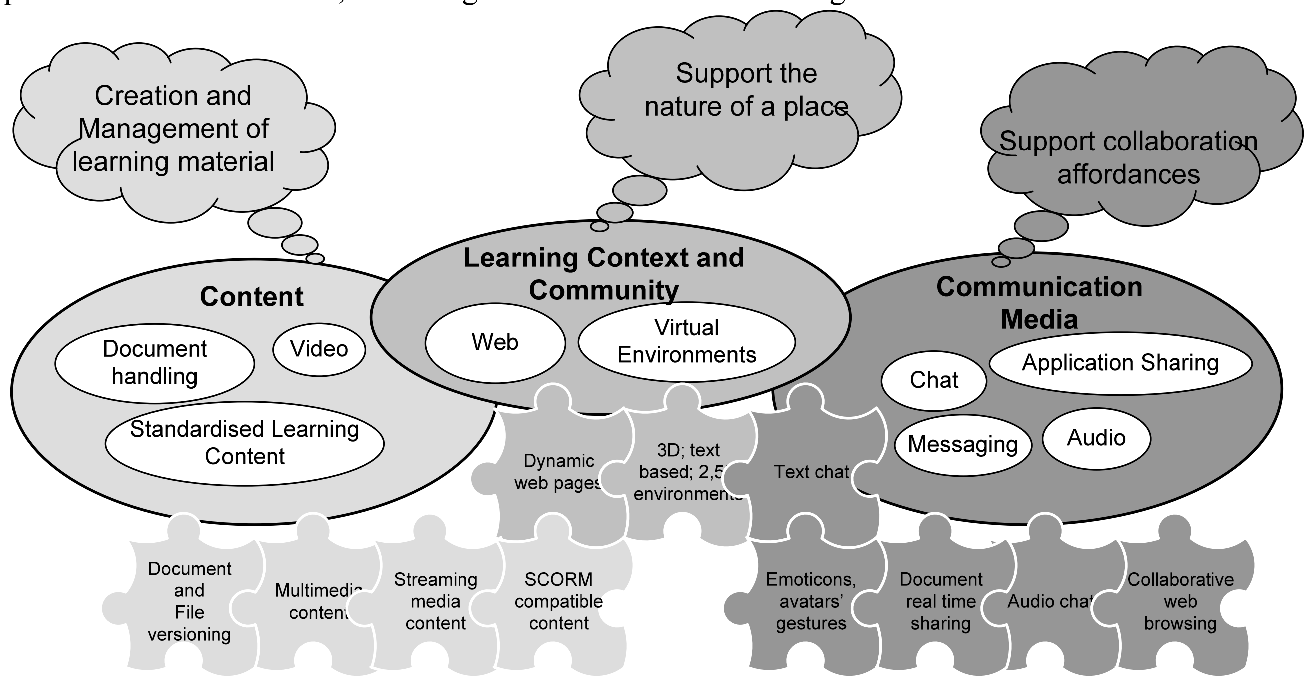


Figure 1: Learning centric view

Regarding e-learning, the most suitable approach seems to be the media centric view. However, this approach needs to be extended in order to realise the e-learning scenarios and to satisfy the users' needs. For supporting a learning centric view we need to take into account the necessary media derived from the above-referred scenarios. Main features and media are the content (learning content), web, virtual reality, video, audio, application sharing and text chat. These media should be integrated in a way that assists the user to learn and to use the system effectively. An example is depicted in Figure 1.

E-learning systems supported by collaborative virtual environments should be based on three main categories: Content, Learning Context and Communication Media. Both Web and virtual environments are the media to support the community and the e-learning context giving the users the feeling that they are in the same place, in an easy way. Communication media (text and audio chat, application sharing, message board, etc.) can support the communication and interaction between the users. The main aim of the communication media is to support and offer communication affordances to the users in order to facilitate the transformation of the learning space to a social learning place. Content is the core medium for learning and supporting learners to learn and tutors to teach. The integration of a module that could be used for the creation and management of the learning material is of critical importance.

However, for supporting collaborative e-learning effectively, more tools for sharing information should be investigated and implemented, such as a presentation table, where all users can present their own content and have the ability to open it, view it and collaborate on it.

4.4.6 Principle 6: Ergonomic design of a virtual place accessible by a large audience

The designers of a virtual place should take into account that a virtual place for e-learning could be used by various individuals with different backgrounds and level of expertise in Information and Communication Technologies. Therefore, the virtual place should be easily accessible and of high usability, even for users, who are not experts on Internet/Web based learning and/or community platforms. In addition, the access to the virtual place should be extremely fast and simple in terms of user registration, software download and installation.

In some cases the virtual spaces address multilingual and multicultural audiences. In such a case it is proposed to design a multilingual virtual space that would support a multicultural, diverse community, which is not dominated by one single culture.

4.4.7 Principle 7: Design an inclusive, open and user-centred virtual place

A collaborative virtual space should be characterized by the following characteristics in order to support as much users as possible:

- *Inclusive*: The virtual place should be accessible as much as possible. Any registration process should be easy, quick and unbureaucratic.
- *Open*: Access to the virtual place should not be restricted by the will of a single person or board, but general rules for access should be formulated and guide the moderators, tutors or generally the people who is responsible for it.
- *User-centred*: The development of a virtual place should be centred on the users. For each piece of technology implementation, processes should be developed within the user community, which guarantee the continuation and broad implementation of such technology.

4.4.8 Principle 8: Design a place for many people with different roles

An e-learning system should support a variety of roles with different access rights. For example, in a collaborative learning scenario the participants could be moderators, tutors, or learners. The virtual space should be designed accordingly for differentiating these roles. For example, the virtual space could provide to the moderator administration and moderation tools, which are not available to a learner. By using these tools the moderator could be able to moderate the communication interaction, to expel members from the virtual space, to admit new members to the virtual space, etc. Also the learners could easily recognise who is the moderator of the session. For example in a three dimensional (3D) virtual space a special chair could imply that this is the moderator’s chair. Another proposal is to support the exchange of roles in the virtual space. This problem could be implemented by using customisable interfaces and virtual places according to the e-learning scenario, supported by a database, which handles the users’ profiles.

5. Implementing the principles

This section describes the way that the design principles presented in the previous section could be implemented in 3D collaborative virtual environments in order to support collaborative e-learning communities.

For demonstrating how the principles could be applied, the EVE Training Area tool is used (Bouras & Tsiatsos, 2002; Bouras et al., 2005). This tool is a three-dimensional space where participants, represented by 3D humanoid avatars, can use a variety of e-collaboration tools. In some cases other tools are used in order to demonstrate different implementations and design approaches.

As previously referred in this chapter, current research on the design of collaborative e-learning virtual environments results in various issues and aspects of such environments. Based on the work done in this chapter the designers could be facilitated by exploiting a list of design principles for virtual spaces that are focused on supporting collaborative e-learning. Although, this list of design principle is useful, another major problem is emerging:

What is a best practice to transform the set of design principles into modelling concepts and or specific and concrete functional features?

In the case of EVE, the first step was to investigate the main functional features. During this investigation and the design analysis the list of design principles have been taken into account. The next step was the creation of a prototype, which has been evaluated by users as described in Bouras & Tsiatsos (2006).

Therefore, the transformation process of the principles was based on prototyping-evaluation process. It should be noted that is difficult (and maybe restrictive for the educational designers) to follow a set of rules for transforming the design principles to functional features. The main problem here is the huge set of parameters that should be taken into account e.g.: collaborative e-learning techniques that will be used, user requirements, users' profile etc. A possible solution to that problem is the usage of these principles as guide during a "Design Rationale" process of software engineering. According to Jarczyk et al. (1992), design rationale in its simplest, is the explicit listing of decisions made during a design process and the reasons why those decisions were made. This definition hides many of the issues that cause the design of systems to support the capture and use of design rationale to be difficult. So the design principles proposed in this chapter could help on that direction as rules-of-thumb.

Furthermore, these principles could be used as criteria to review and select a 3D CVE platform for supporting collaborative e-learning scenarios. In that chapter we have selected the most used Web 2.0 Virtual environment for educational purposes, namely Second life (http://secondlife.com/).

In the following paragraphs, EVE training area is presented and the way that every principle is met in this environment is described. Furthermore, we are validating SL.

5.1 EVE Training Area

EVE Training Area (http://ouranos.ceid.upatras.gr/vr) is designed and implemented for hosting synchronous e-learning and e-collaboration sessions. It combines 2D and 3D features for providing the users with the necessary communication and collaboration capabilities. The main feature of EVE training area is the 3D representation of a multi-user virtual classroom. The user interface of the training area is depicted in Figure 2. The participants in the virtual classroom can have two different roles: tutor (only one participant) and students. In that way EVE training area meets principle 8.

The users that participate in the virtual classroom are represented by humanoid articulated avatars, which can support animations (such as walking and sitting down) and gestures for non-verbal interaction among the users. EVE's avatars support functions not only for representing a user but also for visualizing his/her actions to other participants in the virtual space, which also satisfies principle 3.

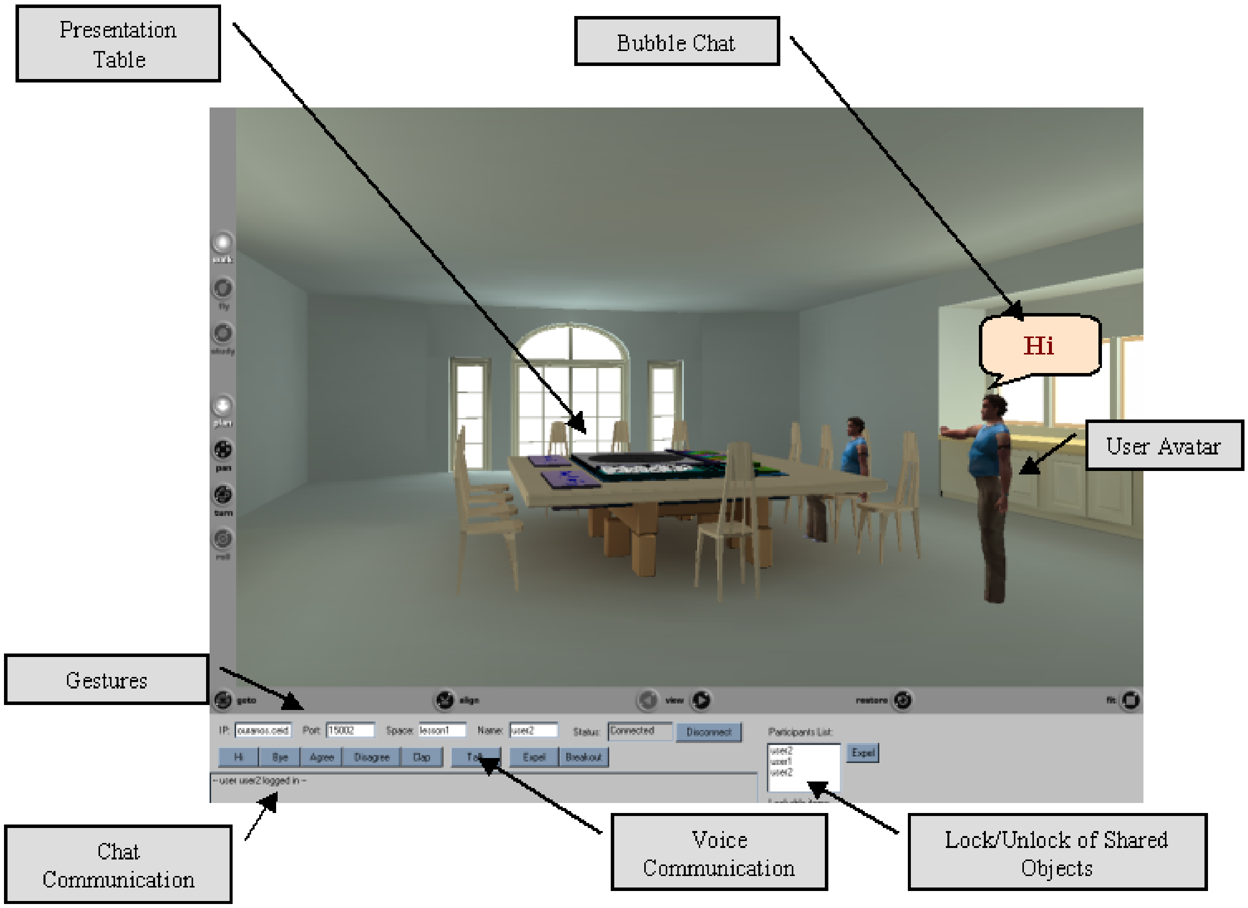


Figure 2: User interface of the training area

Available functions in EVE Training area are: Perception (the ability of a participant to see if anyone is around); Localization (the ability of a participant to see where the other person is located); Gestures (representation and visualization of others' actions and feelings. Examples are: "Hi", "Bye", "Agree", "Disagree", and "Applause"); Bubble chat (when a user sends a text message, a bubble containing the message appears over his/her avatar).

The virtual classroom is supported by various communication channels (principle 5) such as (a) audio chat, which is the main interaction channel, (b) 3D text/bubble chat, (c) non verbal communication using avatar gestures in order to provide a more realistic interaction among users, expressing, when needed, the emotion of each one to the others (Capin et al, 1999). Furthermore, EVE Training Area supports manipulation of users and shared objects by integrating two specific tools: (a) expel learner/participant and (b) lock / unlock objects. EVE Training Area integrates a "presentation table", which is the central point in the virtual space, in order to provide specific collaboration tools. Using the functionality of this table the users can present their slides and ideas, can comment on slides, upload and view learning material as well as view streaming video. The avatars of all participants in the virtual space can have a sit next to this table, viewing not only what is presented on the table but also the other participants. Furthermore, the user can change his/her viewpoint in order to zoom in and out on the presented material. The presentation table has the following functionality:

- 3D Whiteboard: The 3D whiteboard supports slide projection, line, circle and ellipsis drawing in a wide range of colours and text input in many sizes and colours. It also offers "undo last action" capability as well the erasure of all previous actions on the whiteboard.
- Brainstorming Board: The brainstorming board can be used in a range of collaborative learning techniques for learners to present their ideas in a structured way. The users can create cards in three shapes (rectangle, circle and hexagon) and five colours attaching text on them. It should be mentioned that the shape and colour of the cards is attached to a defined argument. They can also move and delete a card.
- Video presenter: Video presenter is used in order the user to attend streaming video presentation/movies inside the 3D environment. The users have the capability to start and stop the movie. Supported formats are rm mpeg, and avi.
- Library with drag and drop support: The users have the capability to drag and drop learning material on the table. This material is represented as a small icon on the backside of the table. When the user clicks on the icon the corresponding file is opened either on the whiteboard (if the corresponding file is picture or VRML object), on the video presenter (if the corresponding file is of rm, mpeg or avi type) or on a new pop-up window (if the corresponding file is not supported by the VRML format).

As described in Bouras & Tsiatsos (2006), after the user-evaluation, the usability of the user interface usability of the prototype has been rated positive. Concerning the support of multiple collaborative learning scenarios (i.e. principle 1) the teacher could design the EVE training area as s/he wants (Bouras et. al, 2007) by:

- Using predefined classroom models and having the ability to reorganize the classroom. More specifically the tutor can create quickly a classroom setup and have the ability to move existing objects or to add new.
- Creating and setting up of a virtual classroom using object library (Figure 3).

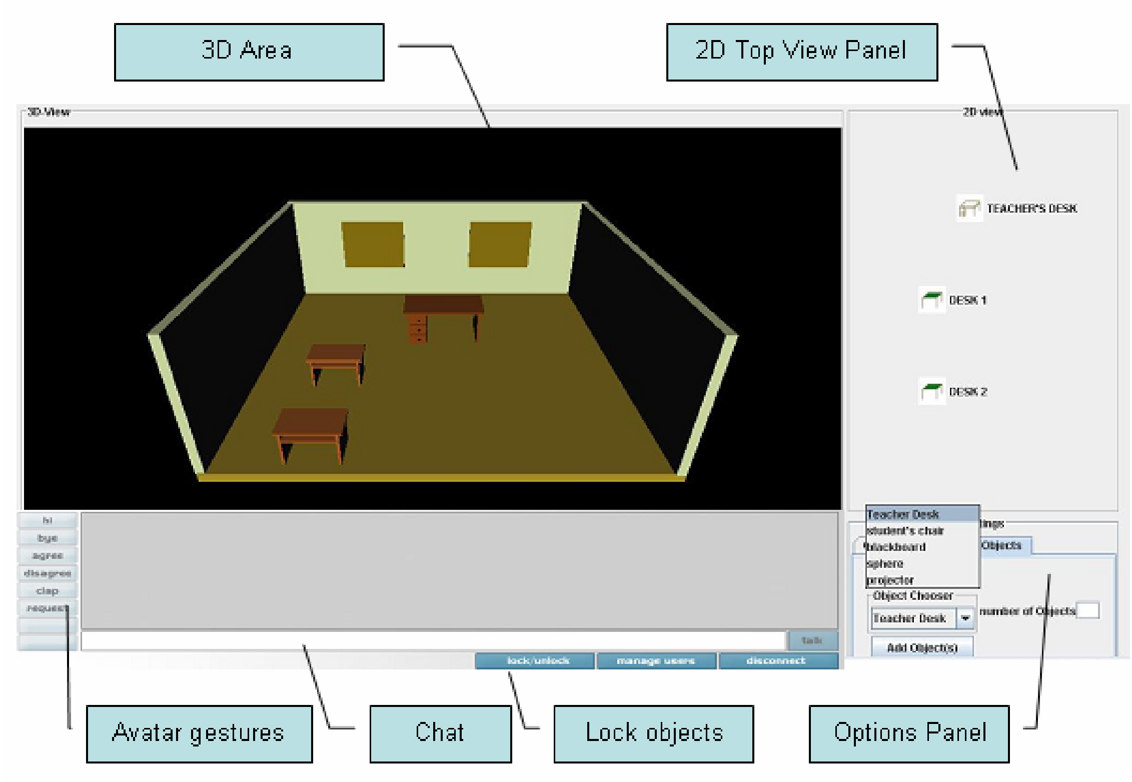


Figure 3: Creating and Changing EVE training area

This function supports the teacher to implement multiple learning scenarios by changing the organization of the classroom and by using different shared objects that can facilitate these scenarios. For example, in order to apply the brainstorming/roundtable scenario (which is described later on in this chapter) the tutor can re-organise the classroom area by creating a table with a brainstorming board and seats for the learners around the table, as depicted in Figure 4.

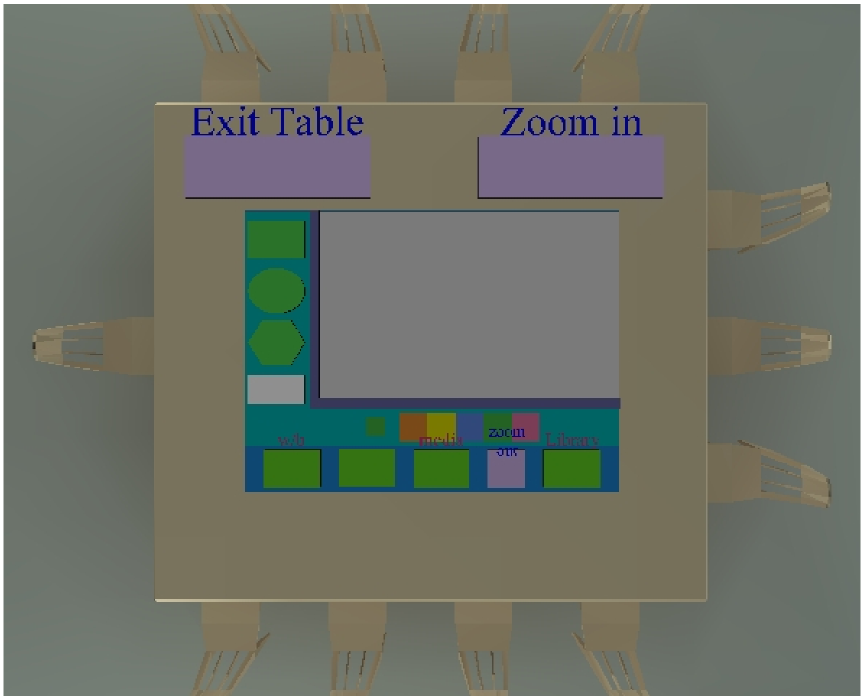


Figure 4: Organizing the EVE training area for brainstorming

Furthermore, EVE Training Area has been design in such a way to maximise the flexibility within a virtual space (in order to satisfy principle 2). As described before, the tutor can reorganise the EVE training area in order to support better the learning needs as well as to avoid misunderstandings in the usage by the students. In that way, the tutor can either create or re-use virtual rooms for formal classes, group work, etc. For example in the organisation depicted in Figure 4 the only action for the user, in order to participate in the brainstorming session, is to move his/her mouse aver chair and to click on it (Figure 5a). By following these actions the viewpoint of the user is changed and s/he can see the presentation table and the other participants (Figure 5b and Figure 5c). After that the user can cooperate with the rest of participants in the brainstorming session by zooming in the brainstorming table (Figure 5d).

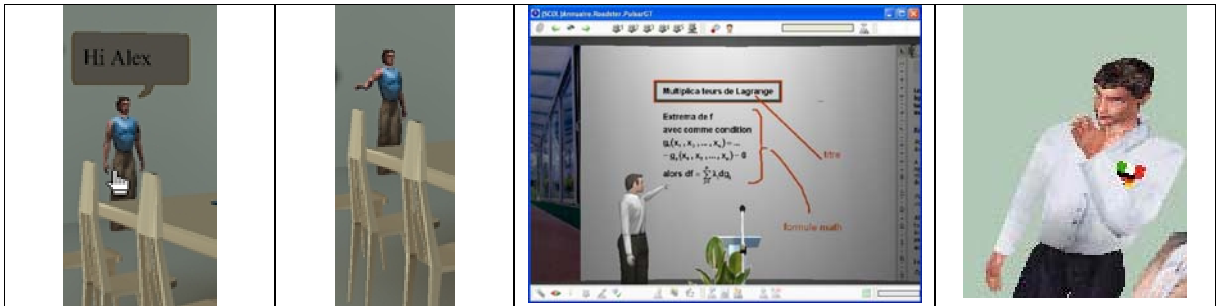
(a) (b) (c) (d)

Figure 5: Brainstorming session

In order to augment the user's representation and awareness (and to satisfy principle 3), the usage of avatars along with gestures and additional icons attached to the avatar could be very helpful (Bouras & Tsiatsos, 2006). Examples of this functionality are the following:

- Bubble chat over the avatars head, which can be used in order to inform the participants of a session about the text chat input of this user. Figure 6a depicts the implementation of a bubble chat.

- User representation and avatar gestures for expressing actions and feelings. In Figure 6b, we can see an avatar of a user to visualize a "Hi" action by a gesture in the EVE training area (Figure 6b). Good examples of other environments are the following: (i) An avatar presenting a theme and pointing on a specific point using its hand (Figure 6c) in I-maginer 3D virtual class (www.i-maginer.fr); (ii) An avatar whispering o another using text chat (Figure 6c) in INVITE project prototype (Laister & Kober, 2002).



(a) (b) (c) (d)

Figure 6: Examples of augmenting user's representation and awareness

Concerning awareness of objects and the action on them, there are many solutions. An example is depicted in Figure 6c, where an avatar presenting a topic is shown. Another example is depicted in Figure 5, where users can share and see the cards attached in the brainstorming board by their participants.

According to principle 4, in collaborative virtual environments the basic functionalities of the interface should be accessible in a graphical user interface fashion. Furthermore, in order to reduce the amount of extraneous load of the users EVE training area follows the following approach:

- Adopts avatars with gestures in order be possible for the user to see at once who is participating and who makes which contribution. An example is depicted in Figure 7a.
- Separates the shared and not shared areas in order to avoid user's misconception as depicted in Figure 7b. A different design that could maximise the amount of extraneous load of the users is depicted in Figure 7c. In that case there are many areas that contain information fully, partly or not shared. Thus, the user could be overloaded in order to discover what the other participants are doing, who is participating, etc.

(a) (b) (c)

Figure 7: Design examples to reduce the extraneous load of the users

As previously described e-learning systems supported by collaborative virtual environments should be based on three main categories: Content, Learning Context and Communication Media (principle 5). The approach adopted in EVE training area with the concepts of (a) presentation table for sharing information; (b) avatars, audio conferencing and text chat for supporting communication; (c) 3D classroom design along with shared library for integrating learning content has been rated very positively as described in Bouras & Tsiatsos (2006). Thus such a design approach is proposed for supporting principle 5.

5.2 Second Life validation against Design Principles

Using SL, 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 (Figure 8): a lecture hall where presentations by the teacher/students can be held, and a collaborative 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.

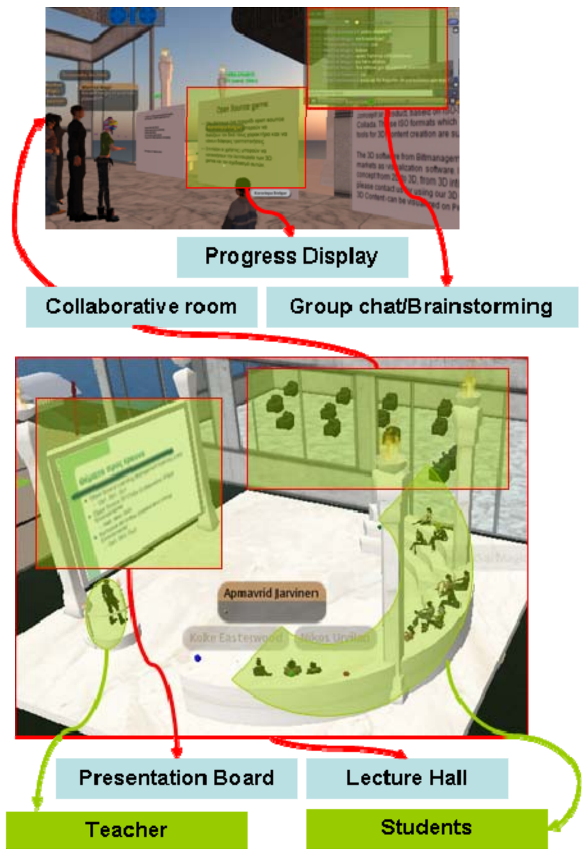


Figure 8: The lecture hall and collaborative room of the environment we designed in Second Life

Some demonstrative tools for a virtual classroom or a collaboration space were designed and implemented on top of SL. These tools are equivalent to the real world ones, but in the virtual world context they may gain additional value, primarily because of the virtual world's inherent lack of spatial and temporal limitations. These tools are the following (Figure 8):

- Presentation Board: This is a simple tool to support collaborative learning activities. A teacher inserts and arranges the steps of a structured team activity into the board. Afterwards, the students start the activity and update the board to indicate the step they are working on, whether they have finished the other steps or need help. This way the teacher can be aware of the teams' progress with less effort.

- Progress display: The learners can use this tool to indicate whether they are working, have finished or are facing a problem. Also, the teacher is notified by the tool whenever the learners call for help. The progress display can also be attached to the door of a collaboration room.
- Group chat/Brainstorming: Though SL logs every chat activity in the respective window learners may want to log their brainstorming session separately. Using this tool, the students can chat in a separate chat channel, and display the conversation floating over the tool. Later, the text can be dumped into the public chat window.

Regarding the design adequacy of SL for online learning purposes, we validated the platform's features, philosophy and policies against the design principles presented before.

- Principle 1 - Design to support multiple collaborative learning scenarios: Many collaborative learning scenarios can be supported in SL due to the fact that it supports text chat (private and public), voice chat, streaming video and audio, interaction with objects and group formation. Also, a variety of tools has been or can be developed. However, lack of application sharing is a definite drawback which needs to be addressed.
- Principle 2 - Design to maximize the flexibility within a virtual space: Space parameters like size, architecture, facilities and the physical environment affect the way learners socialize. In order foster educational value, virtual environments must fulfil the teacher's expectations for spatial and temporal flexibility. Therefore, due to the need for multiple functions within a collaborative online synchronous session, it should be possible to quickly reorganize the virtual place for a particular activity or scenario. In SL there are limitless capabilities regarding the organization of space. The instructor, using custom scripts and 3D objects, can allocate space instantly, satisfying the learners' needs.
- Principle 3 - Augmenting user’s representation and awareness: Combining gestures, mimics, user representation, voice and text chat communication, users can share their views and show others what they are talking about. SL’s avatars are very flexible in customizing so that they not only look quite realistic, but also permit each user to display a unique style, enhancing user representation. Realistic walking and sitting animations, customizable gestures, typing animations and sounds, as well as head and eye movement, increase spatial and user awareness.
- Principle 4 - Design to reduce the amount of extraneous load of the users: SL is designed in a way that prevents user's extraneous load. The built-in browser, the flexible preferences menu that allows the user to select the graphics quality and performance and the obvious distinction between shared and non-shared objects not only prevent extraneous load, but also make it possible for users with older computers to participate in the environment efficiently.
- Principle 5 - Design a media-learning centric virtual space: SL is by design a media-centric platform. Users can communicate through means such as text and voice. Even avatar live-video-mapping is possible. In addition, users can upload textures, or stream audio and video into the world. Support for viewing and manipulating documents may be added in the future if the platform can implement application sharing.
- Principle 6 - Ergonomic design of a virtual place accessible by a large audience: SL is indeed accessible since the in-world tutorials guide the user during his/her first actions.
- Principle 7 - Design an inclusive, open and user-centred virtual place: SL membership is free, anyone above 18 years old can join (there is also a separate world for teenagers) and the virtual content of the world is created by its users. A significant drawback is the fact that organizations must pay monthly fees to the owners of the platform to be able to own and administrate land parcels in the virtual world. While this may be reasonable, as the company takes care of the

maintenance and the expansion of the virtual world, some organizations would rather invest these resources in customizing the world for their own needs.

- Principle 8 - Design a place for many people with different roles: One very important in-world function included in SL is the creation of groups. This function permits the group creator (owner) to assign different roles to group members and to set access rights to each role.

Apart from the theoretical validation of SL's capabilities to support collaborative learning scenarios, we have implemented and evaluated a jigsaw collaborative e-learning technique in SL. The aims of the case study, presented in the next section, are to:

5.3 Discussion

EVE Training Area supports almost all the previous defined design principles. Thus, even if the use of virtual reality technology is not a required feature a priori, it seems that the use of collaborative 3D virtual environments and humanoid avatars along with supportive communication channels fit well as a solution for virtual collaboration spaces.

Concerning SL, it could be said that it stands out among similar web 2.0 immersive virtual environments mainly because it is easily customizable, able to support the creation of learning environments and experiences. The given functions cover the most important needs for communication, collaboration, awareness and administration, and at the same time enable the designers to benefit from them using the built-in scripting language. The demonstrative tools we developed seem to be useful, based on our summative evaluation of the platform, for educational use. Humanoid avatars are a unique solution that 3D-centered tools offer to group communication and learning. It is a fact that persons participating in the virtual learning experience with human like full-body avatars feel more comfortable than in chat or audio-communication (Bouras & Tsiatsos, 2006). The main benefit of the avatars is the psychological feeling of a sense of "presence". The sense of "presence" results in a suspension of disbelief and an increase in motivation and productivity (Bouras & Tsiatsos, 2006). There is a number of important attributes to this experience. The ability to make basic gestures along with a voice or text message strengthens the understanding of the communication context (Redfern & Galway, 2002). Therefore, due to the fact that the user's awareness of the spatial proximity and orientation of others has a strong impact on the dynamics of group communication (Redfern & Galway, 2002), we could say that 3D multi-user virtual spaces have a good potential for supporting learning communities and e-collaboration. In such an environment users feel as though they are working together as a group and tend to forget they are working independently.

6. Collaborative e-learning usage scenarios exploiting Multi-user Virtual Reality Environments

The aforementioned e-learning and collaboration tools could be used for supporting collaborative e-learning scenarios. As the comparison has shown in the previous section, EVE Training Area could be a suitable solution for supporting these services.

Some collaborative learning techniques used today are: brainstorming/roundtable (Millis & Cottell, 1998; Osborne, 1963), think pair share, jigsaw (Aronson et al, 1978), quickwrites / microthemes (Young, 1997), and structured academic controversies (Johnson et al, 1998). These techniques are not presented in this chapter due to space limitations. However, the processes for realizing these

techniques using Collaborative Virtual Environments are presented. Before describing these processes, specific functionality, which is derived from the collaborative learning techniques, is described.
First of all, we propose the tutors and learners to use a 3D virtual classroom (with functionality similar to EVE's Training Area) and supportive break-out session rooms for dividing the users in sub-groups (in case required by the scenario). Both the specific functionality and the access rights on it depend on the e-learning scenario. The transformation and the basic processes are described in the following paragraphs.

6.1 Brainstorming/Roundtable

The tutor and learners enter the classroom represented by avatars. The tutor asks a question using audio collaboration functionality (or alternatively text chat). Furthermore, the tutor can write the question and upload it to the presentation table as a document. The learners can answer to the questions using the audio collaboration functionality (or alternatively text chat). Furthermore the learners can use the brainstorming tool for writing and attach their ideas on it. When the brainstorming phase is completed, the learners can review and clarify their ideas on the text chat area or in the brainstorming tool.

6.2 Think Pair Share

The tutor poses a question (or a problem) as a file on the presentation table or using audio/text chat and introduces the collaboration technique. After a short pause for reflecting, the learners turn into the whisper-mode with their neighbour and discuss privately the problem. Preferable way for whispering would be a private audio-channel within the classroom (audio-whisper function). Alternatively a private text chat can be used. When the assigned discussion time is finished, the tutor gathers the attention of the learners by "ringing the bell" (sending a text message to all of the participants). Then, the learners exit the whispering mode and return to a group for discussion.
For discussing in a larger group, the groups split up into separate corners of the learning environment (breakout session rooms). Each group should have a brainstorming tool available, though the equipment should be in the breakout room available only on demand and not by default. The default situation is a group with high visibility of all avatars, gestures and facial expressions. Again the tutor can send a text chat message to all learners in the different breakout areas ("ringing the bell"). Then the avatars, physically gather back in the virtual classroom place.

6.3 Jigsaw

The whole Jigsaw procedure can be handled within the virtual classroom, which also supports 4 breakout session rooms (in case we have 4 groups of students). The tutor first introduces shortly the procedure and then asks for the number of learners (good numbers are any multiple of four). For 16 learners the tutor suggests study groups of 4 and 4 sections. Then the tutor needs to formulate the sections: s/he divides the users in the sections and attaches the necessary learning content to each section. The tutor then assigns the learners to their role (group number and section number). The learners will then receive an automated message about the room they need to go to: there they find the section description on the presentation table and any study material the tutor might have assigned to the focus group. After that, the learners of each section participate all together in a section-shared place. The places can be virtual small classes (breakout session rooms) with audio collaboration, application, sharing, and text-chat functionality. Also the tutor can also assign documents to this section. These documents will be available to the learners in the breakout room. The learners can take material from the presentation table to their other session, by saving the materials into their local PC and upload it again.

6.4 Quickwrites / Microthemes

The whole procedure for this technique can be handled within a 3D classroom, which has also 4 breakout session rooms. In the virtual classroom and the breakout out session rooms the users can use audio collaboration, application sharing and text chat functionality. The tutor presents to the learners the microthemes in the presentation table space. Also s/he uploads and presents supporting documents on the shared space. The learners can open for themselves a notepad or other text editor; focus on the proposed documents and after completion of the assignment, easily save their result on their local PC and upload it into the shared space. The tutor assigns groups to the themes that should be discussed (2-4 persons). The learners move to the breakout-rooms, pull their documents onto the presentation area in those rooms and discuss the outcomes. One person writes a protocol of the group discussion and saves the result back to his/her local PC and then upload it into the classrooms' shared space. The tutor can visit the breakout out session rooms groups and discuss the status of the work. Furthermore the tutor has the capability to call the learners group to return back to the main classroom area, using text chat or by visiting the breakout session rooms. In the main classroom area the groups present their results using application sharing and audio chat.

6.5 Structured academic controversies

The whole procedure for this technique can be handled within a 3D classroom, which has also 4 breakout session rooms in case of 16 learners. In the virtual classroom and the breakout out session rooms the users can use audio collaboration, application sharing and text chat functionality. The tutor selects and uploads a topic with two different viewpoints on the presentation table. The learners form groups of 4 and divide into two pairs. Each pair goes to a breakout session room and the tutor uploads supportive documentation. Furthermore, the learners can upload their own content that think it could be supportive for formulating their assigned advocacy position. The pairs of learners have the possibility to visit breakout session rooms of the other pairs with the same positions. Each learner pair can prepare a short presentation using application sharing and collaboration on documents and to upload this presentation in the original groups of four learners. Each pair presents its position to the other pair in their group using application sharing and audio chat. In this case, no debate allowed and the tutor restricts the audio, application sharing, text chat, and gestures functionality from the opposite pair. Afterwards, the other pair presents its position, and then the learners debate and provide more evidence. Finally, learners drop their advocacy role and generate a consensus report addressing the original question posed using application sharing, collaboration on documents, and audio chat.

7. Conclusions – Future work

Virtual reality technology could be used to support education in many areas, such as simulation of complex systems, macroscopic and microscopic visualisation as well as fast and slow time simulation. Significant characteristics of VR that could be exploited to support education are the high levels of interactivity, the sense of immersion and the inherent flexibility/adaptability. For that reasons VR has been exploited in various projects in order to support education, training and/or collaboration. This chapter attempted to contribute on the current research on the design of collaborative e-learning virtual environments by investigating and defining design principles that educational designers could follow for designing effective virtual spaces for e-learning and e-collaboration. Thus, this chapter presented a list of design principles for virtual spaces that are focused on supporting collaborative e-learning. These design principles could be useful for software designers in order to enhance current CVEs by integrating supportive communication and collaboration tools and services, as well as tools for effective manipulation of both learning content and the users' roles and rights.

In addition this chapter presents a solution for supporting e-collaboration and multi-user communication in web-based learning communities. After the presentation and discussion of this solution we could say that 3D multi-user virtual spaces could be suitable for supporting learning communities and e-collaboration and for the effective realization of collaborative e-learning scenarios.

Besides the basic principles presented in this chapter, it should be noted that when designing and implementing a system for supporting collaborative e-learning communities, there are some additional parameters that should be taken into account for achieving a higher degree of acceptance by the target users. These parameters are related to the profile of the users that the e-learning system aims to support as well as to the domain area that e-learning processes will be applied. One of the key elements for the success and effectiveness of an e-learning system is the wide acceptance, in terms of use, of the users it targets at. Even though the profile of the users that will use an e-learning system may vary, as e-learning communities could refer to a wide range of users, however, each application could be specialized based on some common characteristics of the majority of the users it aims to support. These characteristics involve, among others, the age of the target group, their IT skills, their educational level, their social and cultural background as well as their orientation to learning.

Another basic consideration when designing and developing collaborative e-learning systems is the learning domain that these systems try to support and the processes that need to be simulated. As learning can refer to every aspect of the human activity it becomes clear that there is an extremely wide range of domains that could be explored by e-learning systems. Each of these domains, however, is characterized by special characteristics, which should be taken into account when designing the technological "texture" of an e-learning environment. In particular, the processes and content of a learning system could be social-focused, technical-focused, experience-focused, etc. This particular focus should be a basic guideline when designing the functionality of the learning system as well as for the selection of the technology and style to be used.

According to this discussion our next steps are to design and implement an adaptive CVE system that can be changed in various learning domains and user profiles. Further steps include research on investigating the relation between the use of the design principles presented in this chapter and learning outcomes.

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