DESIGNING 3D COLLABORATIVE VIRTUAL ENVIRONMENTS TO UTILIZE THE PEDAGOGICAL BENEFITS OF CSCL

Th. Tsiatsos and A. Konstantinidis
Department of Informatics, Aristotle University of Thessaloniki, Multimedia Lab
P.O. BOX. 114, GR-54124, Thessaloniki, Greece

Keywords: Collaborative learning, virtual environments, virtual reality, pedagogy, design challenges.

Abstract: In this paper, we aim to aid designers of 3D collaborative virtual environments in their work by presenting the pedagogical benefits of computer supported collaborative learning (CSCL) and discussing how these can be utilized in the definition of certain design guidelines for CVEs. We also present the challenges faced by CVE designers due to both the inherent characteristics of CVEs and the purpose these applications are designed to fulfil. Finally, based on bibliographical studies we suggest how these challenges can be overcome through thoughtful consideration of certain design principles.

1 INTRODUCTION

Collaborative or group learning refers to instructional methods whereby students are encouraged or required to work together on learning tasks with or without the help of educators. In this paper we will focus on Computer Supported Collaborative Learning (CSCL) and specifically on the use of 3D Collaborative Virtual Environments (CVEs). Generally, a CVE can be defined as 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 (Churchill et al., 2001). CVEs might vary in their representational richness from 3D graphical spaces, 2.5D and 2D environments, to text-based environments. Access to CVEs is by no means limited to desktop devices, but might well include mobile or wearable devices, public kiosks, etc.

The effectiveness of collaborative learning compared to other educational practices (e.g. competitive or personalized learning) has been proven by researchers (e.g. Bruckman, et. al 2002; Ballesteros, 2006) and can be easily deduced through the study of relevant bibliography.
In contrast though, it should be noted that a small percentage of researchers did not encounter this positive pedagogical influence in their research. This contradiction is probably due to the multidimensional nature of the design challenges faced by CVE designers. Challenges concerning the users themselves and the system that supports the CVE or issues regarding interaction, communication and application all have to be addressed. The way to face these challenging issues is the main topic of this paper and will be analyzed in the sections that follow.

In the next section the pedagogical benefits of CVEs will be discussed, as understood through the study of relevant research. Following that, the main challenges facing CVE designers are categorized and presented. Next, these challenges are addressed through the discussion of proposed CVE design guidelines. Finally, the paper conclusions are presented.

2 PEDAGOGICAL BENEFITS OF CVES

Although the reason for the effectiveness of collaborative learning is not perfectly clear we can hypothesize based on the evaluation of the method from multiple distinct scientific approaches.
From a motivationalist perspective, collaborative incentive structures create a situation in which the only way group members can attain their own personal goals is if all the members of the group are successful (Slavin, 1997). In contrast the social cohesion perspective emphasises teambuilding

Tsiatsos T. and Konstantinidis A. (2008).
DESIGNING 3D COLLABORATIVE VIRTUAL ENVIRONMENTS TO UTILIZE THE PEDAGOGICAL BENEFITS OF CSCL.
In *Proceedings of the Fourth International Conference on Web Information Systems and Technologies*, pages 408-413
DOI: 10.5220/0001528204080413

activities and group self-evaluation, instead of external incentives and individual accountability.

Research has led to several educational theories, such as those of constructivism and social learning. Introduced by Vygotsky, the idea of the zone of proximal development has been useful for understanding mechanisms in collaborative learning. This refers to the fact that, more advanced peers are likely to be operating within one another's proximal zones of development, modelling in the collaborative group, behaviours more advanced than those they could perform as individuals (Vygotsky, 1978). It should be noted though, that research has also shown that low achievers progressively become passive when collaborating with high achievers (Dillenbourg et al., 1996) and yet groups, which consist of members with different but partially overlapping expertise, were more effective and innovative than groups with homogeneous expertise (Lehtinen and Hakkarainen, 2001).

This constitutes a challenge for the CVE designer since a method must be devised to achieve homogenous and yet functioning student work groups. Design challenges will be discussed in more detail in the following sections.

The pedagogical benefits of collaborative learning are multiple and varied. Through this technique 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 (Veerman and Diermanse, 2001).

Probably, the major advantage of collaborative learning compared to other educational practices (e.g. personalized learning) is the interaction with others. This collaboration with other students provokes activity, makes learning more realistic and stimulates motivation. Students can ask questions to each other and discuss problems from different perspectives. They can propose various answers and solutions and evaluate them on different criteria (Petraglia, 1997). From this brief presentation of the pedagogical benefits of CVEs we can surmise that the most important factor in designing a CVE is the catering for communication and interaction between the participating students and educators. According to (Bruckman and Hudson, 2001), through CSCL, teacher-student interactions are more balanced and evidence suggests a reduction in gender differences. In addition, learning becomes more student-oriented; with students exhibiting higher levels of attention and motivation, lower inhibitions and more honest and candid attitudes.

This student-centric approach increases the likelihood that students will absorb and remember what they learn while making personal connections with powerful ideas from which classroom discussions can emerge.

3 DESIGN CHALLENGES

The challenges concerning the design of CVEs can be categorized into user, communication, interaction, application and system issues. User issues concern the influence CVEs excerpt on the psychology and sociology of collaboration groups and distinct users. Communication issues relate to the most effective way of supporting communication between the CVE participants. As mentioned in the previous sections catering for communication and interaction is the most important factor in CVE design. Furthermore, interaction issues in CVEs are about enhancing the sense of presence inside the virtual environment, as well as creating effective and intuitive 3D interfaces where these are deemed necessary. Application issues involve the affordances and representations of objects and user capabilities within the environment. Finally, system issues refer to the underlying framework of the environment (e.g. architectures, specifications and technical requirements).

These categories will be analyzed in more detail in the sections that follow.

3.1 User Issues

According to Grudin (1991), groupware (a general group of collaboration software that accentuates multiple user environments, coordinating and orchestrating things so that users can “see” each other and yet not conflict with each other) is plagued by innate characteristics which produce negative effects to collaboration. Effects such as the fact that these types of applications never provide precisely the same benefit to every group member and that the use of groupware is only fruitful if a high percentage of users participate. Also, that the use of groupware might be resisted if it interferes with the subtle and complex social dynamics that are common to groups. Finally, the design of a CVE should be adaptable in order to accommodate for the fact that many organizations are structured in such a way so as to divide responsibilities and minimize overall

communication requirements and social interdependencies.

The more designers know about the kind of users that the CVE will be used by the better they can account for this in their design. Therefore the target demographics are important. Designers should be interested in why users are participating. User's expectations and desires are more important to designers than their age, incomes and geographic locations (Bartle, 2004); For example, as mentioned by Bruckman et al. (2002), the failure of the CVE they created was due to the inability to meet user expectations because of lack of manpower and time. They argue that to create the popular massively multiplayer online role-playing game Asheron's Call, Turbine Entertainment had a staff of over 30 people working for 4 years. A research prototype made by a few graduate and undergraduate students and one faculty member clearly could not compete.

Finally, research is needed in order to assess the social discomfort levels generated in a CVE, caused by participants working concurrently with real people and their avatars. In addition, empirical testing confirms that virtual reality systems induce physical symptoms and effects in CVEs. These are both issues which must be studied in the future.

3.2 Communication Issues

In most virtual learning environments there are sophisticated surveillance tools available for tracking and for keeping records of student activity. It thereby becomes possible to collect detailed patterns of information and to obtain an insight into the individual student's habits (Land and Bayne, 2005). This might gradually push the role of teaching towards one of learning management instead of one of facilitating communication.

Although this may be the case, methods still need to be found in order to improve interpersonal (visual/body language) communications for collaboration groups working in a CVE. Some researchers (Costigan, 1997) assert that the richest communication occurs when people are physically face-to-face, which the most sophisticated technology for connecting people with audio and video cannot surpass. Therefore the CVE should have the ability to adapt to system and network capabilities and still be capable of providing a higher sense of telepresence.

3.3 Interaction Issues

The main issue concerning interaction in CVEs is that some tasks are less "shareable" than others. For instance, solving anagrams can hardly be done collaboratively because it involves perceptual processes which are not easy to verbalise (Durfee et al. 1989). It is the designer's job to find a way of incorporating these less collaborative tasks into the CVE effectively.

Another important issue is the levels of allowable change (who creates content) and persistence (what survives a reboot) employed in the CVE. Generally, an increased number of content creators imply an increased persistence (Bartle, 2004). In proprietary socially-oriented virtual worlds building is considered entertainment. The original designers only create the core of the world and the means by which it can be extended. Thereafter they hand it to the users to do with as they wish.

The use of 3D environments compared to 2D or 2.5D perspectives also introduces unnecessary confusion and complexity to the content material covered. For example many users have trouble controlling their avatar's movement in a 3D setting (Bruckman et al., 2002). This is probably due to the lack of experience from the users in navigating 3D virtual environments. In contrast though, as mentioned in Monahan et al. (2007), continuous enhancements in computer technology and the developing widespread computer literacy among the public will result in a new generation of users that expect increasingly more from their e-learning experiences.

Success is often due to design features that make the interface even better than reality. In other words, not implementing ill-considered 3D features for situations in which simple 2D representations would do a better job.

The overall metaphor generally used in CVEs is of realistic environments reminiscent of places that one might actually visit to perform real-world tasks. However this is confounded by certain functionality being presented with metaphors that although consistent within themselves, are not consistent with the overall world metaphor (Steed and Tromp, 1998). Understanding the differences in human interactions is necessary to ensure the appropriate technologies are employed to design and develop groupware systems that could support e-collaboration effectively. According to Bouras et al. (2007), there are three primary ways in which humans interact: conversational interaction, transactional interaction, and collaborative interaction. Conversational interaction is an exchange of information between one or many participants where the primary purpose of the interaction is discovery or relationship building. Transactional interaction involves the exchange of

transaction entities where a major function of the transaction entity is to alter the relationship between participants. In collaborative interactions, the main function of the participants' relationship is to alter a collaboration entity. Examples include the development of an idea, the creation of a design, and the achievement of a shared goal. Finally, among the challenging problems today is the achievement of a sense of presence in the virtual environment which might duplicate, replace, or improve the human sense of "being there".

3.4 Application Issues

The application issues are generally concerned with the affordances of objects and the lack of help with the CVE itself. They are broad in nature, from problems with objects whose operation is not obvious, to wider topics such as how best to represent group services to group members (Steed and Tromp, 1998). Generally, some of the major challenges are: the distribution of objects and information as well as the delegation of rights and the representation of group structures.

Although the commercial success of CVE's has proven their effectiveness in entertainment, for real world organisational users there is the matter of fitness for purpose and consequently confidence in such novel technology. The CVE must show that it can deliver safety-critical training in simulated real life working environments to senior professionals and lead to its validation by a recognised training and standards body as being of a suitable standard. Finally, the CVE must be accepted by the trainers, trainees and employers who will use it in the end (Turner and Turner, 2002).

3.5 System Issues

System issues include lack of functionality, performance and display quality. A typical issue is that of the CVE slowing or stopping when new scene components are loaded when the user moves around. Given the user's expectation of free movement at all times, this suggests to him/her that an error has occurred, or that the operation has failed. This is also potentially serious for immersed users since the visual and proprioceptive cues will conflict. According to Goebbels et al. (2003), high system responsiveness is perceived as having very positive impact on collaboration. Even downsizing the application in order to decrease the CPU load is recommendable. Findings indicate that good system responsiveness is guaranteed if all inputs and outputs are processed and rendered within less than 50ms.

The architectures that support these types of systems usually fall into one of the following cases (Bouras et al., 2007): (a) client-server architectures, where the clients communicate their changes to one or more servers and these servers, in turn, are responsible for the redistribution of the received information to all connected clients and (b) peer-to-peer architectures, where the clients communicate directly their modifications and updates of the world to all connected clients. The challenge here is that while the client-server model is the most simple it cannot support high scalability and the server presents a possible point of failure. On the other hand, the peer-to-peer model's scalability is restricted by the network. A better design would probably utilise a hybrid architecture which incorporates the best characteristics of both models. Design guidelines such as this will be discussed in the next section.

4 DESIGN GUIDELINES

CSCL is one of the most promising innovations to improve teaching and learning with the help of modern information and communication technology. Eighteen studies presented by Lehtinen and Hakkarainen, (2001) support the theoretically derived hypotheses that collaboration facilitated with information and communication technology would improve student learning. A technologically sophisticated three dimensional CVE, designed around the pedagogical benefits of collaborative learning can augment their effects and provide advanced support for a distributed process of inquiry; facilitate advancement of a learning community's knowledge as well as transformation of the participants' epistemic states through a socially distributed process of inquiry.

The pedagogical benefits and challenging issues mentioned in the previous sections can be translated into CVE features such as desktop conferencing, videoconferencing, co-authoring features and applications, electronic mail and forums, meeting support systems, voice applications, workflow systems, and group calendars (Grudin, 1991). These features and tools can exploit the benefits of communication and collaborating in groups as mention in section 2.

More features based on the communication principles of collaborative learning include flexible methods available for the students, to help them externalise their preliminary ideas and make their thinking processes transparent to other people and interfaces which by inducing a specific distribution

of roles between learning partners help to foster social interaction.

Finally, due to the importance of communication in collaborative learning multiple communication channels should be available. Channels such as asynchronous text-based communication should be utilized to provide time for reflection on messages and allow students lacking in confidence to learn nevertheless by "eavesdropping" on conversations. On the other hand, features such as immediate feedback should be used cautiously (Dillenbourg et al., 1996) because they may prevent fruitful exchanges between human co-learners; relying on the system to test their hypotheses instead of developing arguments to convince one another.

Concerning interaction, the designers should model how the different user types interact, and design their virtual world such that these interactions are both stable and intrinsically interesting for participants and observers (Bartle, 2004).

Several design guidelines discussed in Veerman and Veldhuis (2001), include tasks that should be open-ended so students can share and learn from each other's differences in perspective, prior knowledge, experiences, beliefs and values. Although open-ended, tasks should still be structured and by this way regulate organisational and planning issues.

Regarding communication, Veerman and Veldhuis (2001) suggest the utilization of a transparent and user-friendly system, with clear and distinct discussion threads and with a preference to asynchronous communication when large groups are involved.

Concerning the interaction issues mention in section 3 and specifically effective 3D interfaces, designers should use occlusion, shadows, perspective, and other 3D techniques carefully thereby avoiding unnecessary visual clutter, distractions, contrast-shifts, reflections and keeping text readable. User and object movement should be simple and realistic with the required navigation steps for the completion of a task minimized. To avoid tedious and sluggish movement a teleportation or flying mechanism should also be employed. Other desirable features include: x-ray vision, zooming, global map, history keeping through text and video recordings, rich user to user and user to object interactions, explanatory text such as speech bubbles, tips and labels; marking, measuring and searching tools, overviews through different camera perspectives and increased depth of field. Slater, et al (2000) in studying participants working in virtual and real-world environments, discovered a positive relationship between presence (being in a place), and copresence (the sense of being with other people). In addition, accord in the group increased with: (a) presence, (b) the performance of the group, and (c) the presence of women in the group. In other words, apart from communication, most central to collaboration is the support for: mutual awareness; awareness of the presence of other participants, but also recognition of the identity, role and current activity of the other participants (Steed and Tromp, 1998).

Usability findings indicated that users prefer to get a quick overview of the situation before handling a task; therefore work tools and mechanisms should be designed in order to disburden the users' senses (Goebbels et al., 2003). High cognitive load, uncomfortable, non-intuitive usability and user fatigue also have negative impact on the perception of co-presence and co-knowledge and thus collaboration.

(Bruckman et al. 2002), summarise two general design principles: personal and epistemological connections. Personal connections refer to construction kits and activities that connect to users' interests, passions, and experiences, while epistemological connections are about construction kits and activities that connect to important domains of knowledge and also encourage new ways of thinking.

Finally, several human-computer interaction rules for display design are mentioned by Salaheddin and Omar (2007), such as consistency of data display (labelling and graphic conventions) for efficient information assimilation by the user and minimization of memory load, compatibility of data display with data entry, flexibility for user control of data display, presentation of information graphically where appropriate, standardized abbreviations, and presentation of digital values only where knowledge of numerical value is necessary and useful.

5 CONCLUSIONS

There is a need to establish new conceptual approaches to the design of virtual environments in order to enhance the richness and complexity of our experience in emerging virtual worlds. By delivering "quality of experience", supporting effectively the presence of other users, enhancing communication and designing simple but intuitive interactions developers can hope to attract the positive reception of their target group of users and minimize drawbacks and inadequacies.

In this paper, we aimed at aiding designers of 3D collaborative virtual environments in their work by presenting the pedagogical benefits of computer supported collaborative learning (CSCL) and discussing how these can be utilized in the definition of certain design guidelines for CVEs. We also presented the challenges faced by CVE designers and suggested how these can be overcome through certain design principles.

REFERENCES

Ballesteros, I. L., 2006. *Future and Emerging Technologies and Paradigms for Collaborative Working Environments*, Information Society, European Commission, http://tinyurl.com/3y6aj7

Bartle, A.R., 2004. *Designing virtual worlds*, New Riders Publishing, USA

Bouras C., Giannaka E., Tsiatsos T., 2007. E-Collaboration Concepts, Systems and Applications, E*ncyclopedia of Internet Technologies and Applications*, Information Science Reference, Hershey, New York, USA.

Bruckman, A., Elliott, J. and Adams, L., 2002. No Magic Bullet: 3D Video Games in Education, Proceedings of ICLS 2002, International Conference of the Learning Sciences, Seattle, WA, October 23-26

Bruckman, A., Hudson, J.M., 2001. Disinhibition in a CSCL Environment, *Proceedings of Computer Support for Collaborative Learning (CSCL)*, Maastricht, Netherlands, 22-24 March, 629-630. Boulder, CO [Short Talk].

Churchill, E., Snowdon, D. and Munro, A., 2001. *Collaborative Virtual Environments: Digital Places and Spaces for Interaction*, Springer-Verlag, London Limited, Great Britain

Dillenbourg, P., Baker, M., Blaye, A. and O'Malley, C., 1996. The evolution of research on collaborative learning, in E. Spada & P. Reiman (Eds) *Learning in Humans and Machine: Towards an interdisciplinary* learning science, 189-211, Oxford: Elsevier.

Durfee, E.H., Lesser, V.R. & Corkill, D.D., 1989. *Cooperative Distributed Problem Solving*. In A. Barr, P.R. Cohen & E.A. Feigenbaum (Eds) The Handbook of Artificial Intelligence (Vol. IV, pp. 83-127). Reading, Massachusetts: Addison-Wesley.

Goebbels G., Lalioti V. and Göbel M., 2003. Design and Evaluation of Team Work in Distributed Collaborative Virtual Environments, Virtual Reality Software and Technology *Proceedings of the ACM symposium on virtual reality software and technology,* Osaka, Japan, p. 231-238, ACM Press, New York, USA.

Grudin, J. 1991. *Obstacles to user involvement in software product development, with implications for CSCW*, International Journal of Man-Machine Studies, 34, 3, 435-452.

Land, R. and Bayne, S.,2005. *Screen or monitor? Issues of surveillance and disciplinary power in online learning environments*. In: R. Land & S. Bayne (eds.) Education in Cyberspace. RoutledgeFalmer. New York, 165-179.

Lehtinen, E. and Hakkarainen K., 2001. *Computer Supported Collaborative Learning: A Review*, http://tinyurl.com/226965

Monahan, T., McArdle, G., Bertolotto, M., 2007. *CLEV-R: Design and Evaluation of an Interactive and Collaborative M-Learning Application*, International Journal of Emerging Technologies in Learning, 2(2), Kassel Univ. OJS Press.

Petraglia, J., 1997. *The rhetoric and technology of* authenticity in education, Mahwah, NJ: Lawrence Erlbaum.

Salaheddin Odeh and Omar Qaraeen 2007. *Evaluation Methods and Techniques for ELearning Software for School Students in Primary Stages,* International Journal of Emerging Technologies in Learning. Vol 2, No 3, ISSN: 1863-0383

Slater, M., Sadagic, A., Usoh, M. and Schroeder, R., 2000. *Small-Group Behavior*, Presence, February, vol. 9, no. 1, pp. 37-51

Slavin, R. E., 1997. *Research on cooperative learning and achievement: A quarter century of research,* Paper presented at the Annual Meeting of Pedagogical Psychology, Frankfurt, September.

Steed, A., and Tromp, J. G. 1998. Experiences with the evaluation of CVE applications. *Proceedings of Collaborative Virtual Environments*, 2nd CVE98 Conference, 123-127.

Turner P. and Turner S., 2002. An affordance-based framework for CVE evaluation. To appear in People and Computers XVI, Proceedings of HCI'02.

Veerman, A., and Veldhuis-Diermanse, E., 2001. Collaborative learning through computer-mediated communication in academic education. In P. Dillenbourg, A. Eurelings, & K. Hakkarainen (Eds.), European perspectives on computer-supported collaborative learning: *proceedings of the 1st European conference on computer-supported collaborative learning*, 625-632, Maastricht: Maastricht University.

Vygotsky, L.S., 1978. *Mind in Society: The Development of Higher Psychological Processes*, Cambridge, MA: Harvard University Press.