

# Collaborative Learning in a 3D Virtual Environment: Design Factors and Evaluation Results

Nicoletta Di Blas, Caterina Poggi, Politecnico di Milano, Via Ponzio, 34/5- 20133 Milano, Italy  
Thomas C. Reeves, University of Georgia, 603D Aderhold Hall, Athens, GA 30602-7144, USA  
Email: diblas@elet.polimi.it, poggi@elet.polimi.it, treeves@uga.edu

**Abstract:** The paper describes the design and evaluation of three collaborative 3D virtual environments for learning (i.e. 3D worlds shared through the internet in which learners meet together at the same time). Since the first program was launched in 2002, more than 3,600 students and 180 teachers from Europe and Israel have been involved in these projects. The educational impact has been carefully monitored using a variety of evaluation strategies. The results – in terms of achieved knowledge, skills and attitudes, as well as in terms of overall satisfaction – exceeded our expectations. The design elements that make up these complex educational *experiences* will be described in a manner that highlights their *interplay* (rather than as isolated design details) and explains the achievement of both expected and unexpected benefits.

## 1. 3D for education: our experience

Although online 3D virtual reality (VR) environments were initially applied primarily for military training and medical education, online 3D VR has recently been explored in K-12 school environments (Barab et al., 2005; Nelson et al., 2005). However, most of the early applications mainly involved simply *showing* people what things look(ed) like, with a hope of involving them, rather than for teaching substantive knowledge, skills, and/or attitudes. Early VR applications have rarely been used in a structured educational experience. The paper describes the main design elements of three educational projects that have employed virtual reality to provide students (aged between 14 and 19) with a meaningful and robust educational experience. Since 2002, the three projects have involved more than 3,600 students and 180 teachers from both Europe and Israel.

*PROJECT 1 - SEE (Shrine Educational Experience).* The first project was SEE (Shrine Educational Experience) and was developed by Politecnico di Milano in cooperation with the Israel Museum, Jerusalem; SEE's topic were the Dead Sea Scrolls (the famous ancient manuscripts held in the Shrine of the Book at the Israel Museum) and related religious, historical, sociological issues. The SEE initiative stemmed from a previous project, called "Virtual Leonardo" (see the works of Barbieri et al.), a 3D reproduction of an Italian museum (the Museum of Science and Technology in Milan), in which online users could "visit" the museum together, through the internet (Paolini et al., 1999). It turned out that people enjoyed meeting other online visitors and chatting with them, but the environment was not structured to provide a meaningful learning experience. When building SEE (that addressed schools), the designers therefore decided to stress cooperation and also to engage students in using the environment through educationally meaningful activities (Di Blas, Hazan, & Paolini, 2003). Other features, such as the presence of a human guide on-line throughout the experience and the integration of a competition based on "cultural" performances, helped making SEE a successful project (see the works of Di Blas, Paolini, & Poggi). Customer satisfaction and educational results were revealed through focus groups with teachers and questionnaires (Di Blas, Paolini, & Poggi, 2005c).

*PROJECTS 2 and 3 - Stori@Lombardia and Learning@Europe.* In 2004, two new projects were developed: Stori@Lombardia (funded by the Regional Government of Lombardy, Italy) and Learning@Europe (in cooperation with Accenture International Foundation). Both projects deal with history: Italian medieval history for the first, European modern history for the second. Like SEE they both are based on a structured set of activities, the core of which take the form of on-line meetings in a 3D virtual world. Both programs underwent their first experimental phase in spring 2005, involving 600 and 1000 students respectively.

## 2. The experiences' structure

Each "experience" is a complete "path" including 4 on-line sessions, assignments completion and interaction via forums. "Sessions" (i.e. virtual meetings) in a 3D world are blended with asynchronous cooperation via forums (or mailing lists) and traditional school activities (studying, group work, research, etc.). Four classes

from four different countries are involved at a time in each experience. Over a period of 6 to 8 weeks, students progress from a passing acquaintance with the program's topic (session 1) to in-depth knowledge of historical issues, ending up with their own reflection concerning the issues at stake (session 4, completely devoted to homework discussion). Figure 1 shows the educational path of the Learning@Europe project.

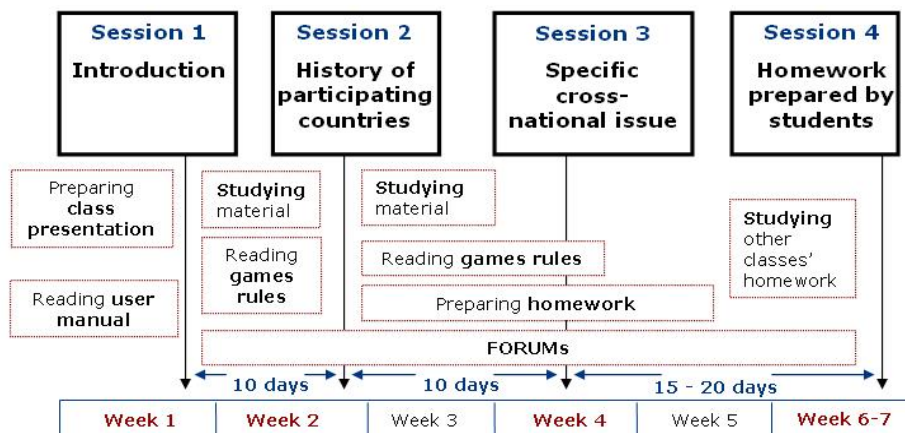


Figure 1. Learning@Europe educational path

### 3. Monitoring tools

Although in SEE we only monitored customer satisfaction and self-reported educational results (through questionnaires to teachers and students and focus groups with teachers), for Learning@Europe and Stori@Lombardia, several monitoring tools were used to reveal educational impact. Data were (and still are for this year's edition) collected using:

- *Surveys* to teachers and students, before, during and after the project. Obtaining data from most of the participants is critical to understand what is actually happening in schools.
- *Reports*, by online tutors (the guides) and supervisors, are written immediately at the end of each session. The tutors record problems and notable events that occurred in the 3D world and the chat.
- *Chat transcripts* of every synchronous online session are recorded and archived. Notable excerpts are extracted for analysis.
- *Forum* discussions are periodically evaluated. The online tutors evaluate all the forums they moderate. Reports are collected and analysed.
- *Student-produced artefacts*. All the students' work is systematically collected and archived.

Other sources of information, that do not cover all participants, are:

- Online sessions recorded with Camtasia from the point of view of the online tutor.
- Students' interactions video-taped in schools during sessions.
- Focus groups with teachers from all the participating countries.

### 4. Results (Spring 2005)

We refer here to the results of Learning@Europe (SEE was evaluated less thoroughly and Stori@Lombardia, though it scored even better than Learning@Europe, may be of less interest to an international audience). Learning@Europe is a collaborative educational project that blends advanced technology with innovative learning methodologies to enhance and motivate learning. It addresses students from all over Europe, aged between 14 and 19, in learning about European history, in particular about the birth of nation-states.

The core of the project involves 4 online meetings in a shared 3D world, in which students from far away countries explore, discuss cultural issues and engage in competitive games together. Online forums allow students to keep in touch and work together, during the project and even beyond its end. Robust cultural content is provided to students: all the discussions, games, activities taking place in the 3D world and in the forums are aimed at achieving educational benefits.

Very high benefits have been achieved, but this can only be summarized in this brief paper. The reader can find both the rough data and a more complete report in the project's website ([www.learningateurope.net](http://www.learningateurope.net): L@E Final Report). Results are presented from 2 different points of view: the students' and the teachers'. The scale ranged from 1 to 5, where 5 was best.

#### 4.1 Benefits for students

We asked teachers (and partially students themselves) to evaluate the students' improvement in terms of knowledge, skills, attitudes. The overall *educational impact* on the students was rated in average by teachers 4.26 (with 42% rating it 5 and only 5% rating it 2).

As regards *knowledge*, for example the improvements in understanding *national history* were rated 3.77 by teachers (with 16% rating it 5, and 49% rating it 4) and 3.56 by students (with 15% rating it 5, and 39% rating it 4).

As regards *skills*, the most important benefits were related to the use of technologies in learning processes (rated 4.32 by teachers, 3.73 by the students), the use of functional English (rated 4.18 by teachers, 3.78 by the students) and the capability of working in groups (rated 4.30 by teachers, 3.78 by the students).

As regards attitudes, important results were achieved: teachers reported an increased motivation in school activities (4.09) and – most surprisingly – an increased proficiency (3.58). Increase of curiosity and tolerance towards other cultures was another important result, given the project's topic: teachers rated it 4.05.

Although they are self-reported in the case of the students, and based on judgment on the part of the teachers, the educational benefits are impressive. What must be stressed is that we asked both teachers and students to evaluate their *improvement* and not the “absolute” value: we wanted to check the project's impact rather than the pre-existing value of proficient students.

#### 4.2 Benefits for teachers

The participating teachers were relatively young: 45% less than 39 years old, and 20% over 50 years (none above 59 years of age). The *overall satisfaction* for the project was 4.27 (with 43% rating it 5 and only 5% rating it 2). The benefits for teachers are related first and foremost to their students' improvements (see above), and then to their own professional development: 100% of these teachers were able to successfully introduce ICT into curricular activities even though, in most cases, they were not technology-experts.

### 5. The educational experience's main elements

All the above projects are the result of the interaction among various elements that make up a quite complex scenario, as shown in Figure 2.

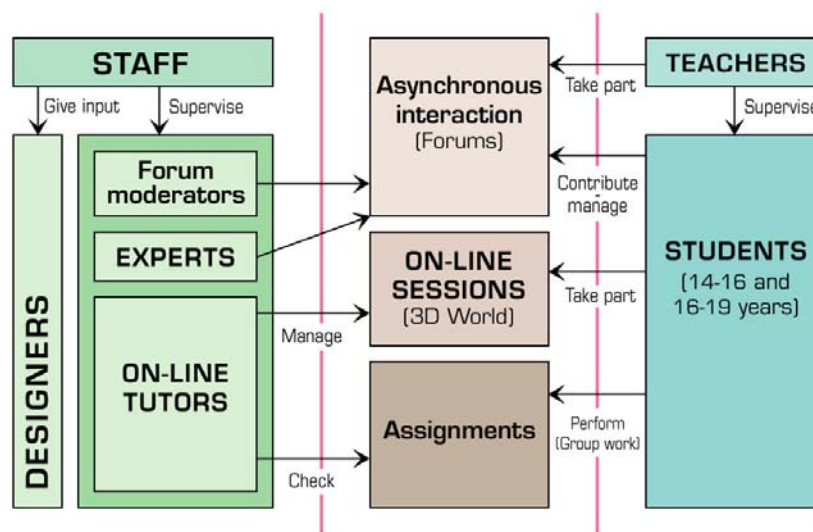


Figure 2. The educational experience's main elements

*Staff.* The staff is in charge of running the experience: organization of the calendar, contacts with schools, monitoring of the sessions (evaluation). It strongly interacts with the designers for changes on-the-go, according to the feedback they receive.

*Designers.* In that its goal is to build a comprehensive educational experience, the projects' staff is markedly multidisciplinary; the main areas are: humanities (communication sciences, learning sciences, philosophy, history, literature), technology (computer science, industrial design), human-computer interaction (usability).

*On-line tutors.* Each on-line session is managed by two on-line tutors: a guide and a helper, with the following duties: keep the pace of the experience, ask questions and provoke cultural exchanges among the students, introduce new topics of discussion, assign scores for any sort of positive behavior (correct answers, interesting remarks, good interaction) as well as penalties for misbehavior (e.g., offensive language), help in case of organizational/technical problems. From a cultural/educational point of view, the tutors' role is to provoke discussion among students but never put forth their own personal point of view.

*Forums' moderators.* Learning@Europe and Stori@Lombardia offer students and teachers the possibility to cooperate through on-line forums (following up to comments of teachers who had taken part in SEE: they wanted to be allowed to keep in touch with their new remote friends). Forums are partly moderated by students themselves, partly by the projects' staff: the role of the moderator is similar to that of the on-line tutors: enhance discussion, sometimes putting forth new topics if students do not do it themselves, oversee the interaction to see that it runs smooth. In forums students are allowed a wider space for their opinions and ideas and very often start interesting threads (e.g., in Stori@Lombardia, students were looking for summer readings in a thread about historical contemporary narratives!).

*Experts.* The programs' content is provided to schools by the staff and consists of a set of documents in the form of interviews (a sequence of questions and answers), derived from real interviews made by the staff with renowned experts in history, sociology, politics, etc. The experts continue their "conversation" with the students (who read their interviews to get ready for the on-line discussion) in a specially dedicated forum ("Meet the experts").

*On-line sessions.* The core of each educational experience are 4 on-line meetings lasting more or less one hour each. Students are divided into 2 teams (each composed of 2 classes, from different countries) and are immediately involved in a competition that lasts till the end of the experience. The sessions' key role is to create enthusiasm and involvement. Being very fast paced, the online sessions cannot host an in-depth cultural discussion (as the chat transcripts' analysis demonstrated): they provide the stimulus for studying the content and perform the various assignments (see below).

*Forums (asynchronous interaction).* In Learning@Europe and Stori@Lombardia, students interact via forums between the sessions: forums can be used to perform the collaborative assignments, and for asking the guide about "practical matters" (e.g. "how many points do we have?"), but their most important function is to allow a deeper cultural discussion, even with the scholars.

*Off-line interaction (assignments).* Students are asked to perform various assignments, ranging from their class presentation, to a research in their surroundings of material evidence related to their country's history, to more traditional investigations on a given topic. In all assignments they are asked to collaborate, within the class (group work) as well as with their remote team members, using ICTs. They also have to prepare a presentation of their works, suitable to be shown in the 3D environment (HTML pages).

*Teachers.* Our experience has taught us that teachers play a crucial role in the success of the experience: they are – each in her/his own environment – co-designers of the program. Data from surveys and focus groups showed the many surprising ways in which the program was introduced, managed and steered in the classes, with successful results by the teachers. The key points are: (1) the teacher becomes a facilitator, not being involved directly in any of the activities but supervising (in various degrees) her/his students work; (2) the teacher can successfully integrate ICT-based teaching activities in class even if s/he's not a technology expert her/himself.

*Students.* Students perform the following activities:

- control the avatars (i.e. graphical representations of the users) in the 3D world; 2 users at a time for each class are engaged in the use of the 3D worlds
- interact via chat; 1 or 2 users at a time for each class are engaged in the use of a specially dedicated chat while the on-line session takes place
- study the background material (consisting of interviews to leading international experts; on the whole, 9 interviews are read, each being maximum 6 pages long – for elder students – and 3 pages long – for younger students)
- complete the assignments (see above)
- use the forums (either as a group or as individuals, if they want)
- counsel and... cheer during the on-line sessions!

Focus groups with teachers revealed that two basic strategies were applied with respect to tasks' distribution: either all the students take turns in all the roles, controlling the avatars in the 3D, using the chat, studying all the interviews... so that everybody tries everything, or students get "specialized" in a specific activity, according to their skills and preferences (e.g., some will be the content experts, others are selected because they can quickly move the avatars, etc.).

## **6. Conclusion: the magic glue (and what matters *not*)**

In the light of the above results and of all the feedback collected during the various trials of the 3 projects, we can summarize the key points of success as follows:

*Collaboration.* One of the projects' keywords is collaboration: students (and even teachers) are pushed to interact and work together in all the phases of the experience, from the assignment completion to the 3D games, where they constantly have to consult each other, take decisions together, interact, etc. This enhances the sense of responsibility: students realize that "the success of the whole team depends on everyone's contribution" (Italian teacher) and they even "start understanding what a deadline is" (Polish teacher, quote from the surveys).

*Intercultural exchange.* One of the most fascinating features of the projects is the meeting between different cultures: during the assignments students are invited to compare their everyday life (e.g. "How do you spend the week-end? What kind of music do you like?") as well as their countries' histories, their festivals, etc. Students discover interesting differences as well as amazing analogies, broadening their horizons ("before the Learning@Europe project my students felt French; now they feel French and European"; French teacher, focus group).

*Virtual presence.* Collaboration and thick exchanges generate what in literature is known as virtual presence (Mikropoulos & Strouboulis, 2004; Carassa et al., 2004; Johnson, 2005); students feel involved all together in a situation, totally forgetful of the technological means that enable their being together. Time runs quickly and when the session is over they do not want to log out (as shown by chat transcripts); they overcome linguistic barriers ("my students were so involved that I think they did not even notice they were chatting in English for an hour"; French teacher, surveys). The competition works as a powerful glue for keeping the team together: "when the guide declared us winners, students roared as if they were at a soccer match" (Italian teacher, focus group).

We also discovered which aspects are not so relevant for the success of the educational experience; for example, high quality *graphics* (that would hinder the technical performance in any case) seems to be of no relevance at all. In spite of the simplistic graphics we used in all the projects, in no reports did anybody complain about it: the focus is all on interaction/collaboration (Di Blas, Gobbo, & Paolini, 2005). The sense of being together is so strong that the chat analysis, triangulated with the guide's reports and the surveys, have shown that even organizational or technical failures do not limit enthusiasm.



Figure 3. Students during an on-line session



Figure 4. S@L: avatars in the Labyrinth space

Our aim now is two-fold: on one hand we want to better understand how students benefit from the programs as individuals (and not as a group), so as to better tailor the activities in order to involve everybody. On the other hand, we want to understand how each of the above elements adds to the overall success of the programs: we know they work well all together, yet we must better understand what is each element's specific contribution.

## References

- Barab, S., Thomas, M., Dodge, T., Carteaux, R., & Tuzun, H. (2005). Making learning fun: Quest Atlantis, a game without guns. *Educational Technology Research and Development*, 53(1), 86-107.
- Barbieri, T. & Paolini, P. (2001). Cooperation Metaphors for Virtual Museums. In D. Bearman & J. Trant (Eds.), *Selected papers from Museums and the Web 2001*. Pittsburgh: Archives & Museum Informatics.
- Barbieri, T. & Paolini, P. (2000). CooperativeVisits to WWW Museum Sites a Year Later: Evaluating the Effect. In D. Bearman & J. Trant (Eds.) *Selected papers from Museums and the Web 2000*. Pittsburgh: Archives & Museum Informatics.
- Barbieri, T., Garzotto, F., Beltrame, G., Gritti, M., & Misani, D. (2001). *From Dust to Stardust: a Collaborative Virtual Computer Science Museum*. ICHIM 2001 International Cultural Heritage Informatics Meeting, 2001, Milano, Italy
- Carassa, A., Morganti, F., & Tirassa, M. (2004). Movement, Action and Situation. In *Proceedings of the Seventh Annual International Workshop Presence 2004*, Universidad Politecnica de Valencia, Spain.
- Nelson, B., Ketelhut, D.J., Clarke, J., Bowman, C., Dede, C. (2005). Design-Based Research Strategies for Developing a Scientific Inquiry Curriculum in a Multi-User Virtual Environment. *Educational Technology*, 45(1), 21-27.
- Di Blas, N., Gobbo, E., & Paolini, P. (2005). 3D worlds and Cultural Heritage: Realism vs. Virtual Presence. In D. Bearman & J. Trant (Eds), *Museums and the Web 2005. Selected Papers from an International Conference*. Toronto: Archives & Museums Informatics.
- Di Blas, N., Hazan, S., & Paolini, P. (2003). The SEE experience. Edutainment in 3D virtual worlds. In D. Bearman & J. Trant (Eds.), *Selected papers from Museums and the Web 2003*. Pittsburgh: Archives & Museum Informatics.
- Di Blas, N., P. Paolini, C. & Poggi, C. (2005). A Virtual Museum where Students can Learn. In L. Tan & R. Subramaniam (Eds.), *E-learning and Virtual Science Centers*. Hershey: Idea Group.
- Di Blas, N., Paolini, P., & Poggi, C. (2005)b. 3D Worlds for Edutainment: Educational, Relational and Organizational Principles. In *PerCom Workshops 2005 - Proceedings IEEE International Workshop on Pervasive eLearning* (pp. 291-295). New York: IEEE Press.
- Di Blas, N., Paolini, P., & Poggi, C. (2005)c. Educational benefits: testing and evaluation of a collaborative 3D world. In *Proceedings of ED-MEDIA 2005 - World Conference on Educational Multimedia, Hypermedia & Telecommunications*. Montreal: AACE.
- Di Blas, N., Paolini, P., & Poggi, C. (2004). *Learning by Playing. An Edutainment 3D Environment for Schools*. In *Proceedings of ED-MEDIA'04 - World conference on educational multimedia and hypermedia*. Lugano: AACE.

- Di Blas, N., Paolini, P., & Poggi, C. (2003). SEE (Shrine Educational Experience): an Online Cooperative 3D Environment Supporting Innovative Educational Activities. In *Proceedings of ED-MEDIA'03 - World conference on educational multimedia and hypermedia*. Honolulu: AACE.
- Hypermedia Open Center (2005). *L@E final report*. Retrieved March 10, 2006 from [www.learningateurope.net/pdf\\_en/final\\_report.pdf](http://www.learningateurope.net/pdf_en/final_report.pdf)
- Johnson, B. (2005). Place-Based Storytelling Tools: A New Look at Monticello. In D. Bearman & J. Trant (Eds), *Museums and the Web 2005. Selected Papers from an International Conference*. Toronto: Archives & Museums Informatics.
- Mikropoulos, T. A., & Strouboulis, V. (2004). Factors that influence presence in educational virtual environments. *Cyberpsychology & Behavior*, 7(5), 582-591.
- Paolini, P., Barbieri, T., Loiudice, P., Alonzo, F., Gaia, G., & Zanti, M. (1999). Visiting a Museum together: How to share a visit to a virtual world. In D. Bearman & J. Trant (Eds.), *Museums and the Web, Selected papers from Museums and the Web99* (pp. 27-35). Pittsburgh: Archives & Museum Informatics.
- AA.VV. (2004). *Presence 2004. Proceedings of the Seventh Annual International Workshop*. Universidad Politecnica de Valencia, Spain.

## Acknowledgments

We wish to thank all the people who work in the projects described above (the development staff of SEE, Learning@Europe, Stori@Lombardia), and our partners (the Israel Museum, the Accenture Foundation and the Regional Government of Lombardy).