TELEPRESENCE FOR DISTANCE EDUCATION: LESSONS LEARNED

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ABSTRACT
We present lessons learned from the construction of a telepresence platform for distance education. The platform main component is a full computer-assisted collaborative work tool for synchronous distance instruction that combines teleconferencing with a networked virtual environment. Our aim with the platform is to bring education to places with limited access to schools and colleges. In this paper we report results and lessons learned during the development and use of the platform in a simulated distance education setting for three actual courses taught at Eafit University.

KEY WORDS
Advanced Technology in Education and Training, Collaboration, University, Multimedia, Audio and Video Streaming, Virtual Reality, Evaluation of Learning Technology Systems

1 Introduction

As high-level education becomes increasingly important in our society, distance learning plays a key role in bringing knowledge to everyone regardless of distance. A real situation, in which distance education is of vital importance, occurs when access to academic institutions is limited in rural areas of developing countries by circumstances such as warfare, lack of adequate locations, prohibitive costs, and other geographic, social and political conditions. Another common case takes place when it is not possible for instructors or students to move to a location in a different institution to offer or take a course.

Different technologies, in which each student works alone at their own pace, could be considered as plausible alternatives to overcome the distance. Such technologies include web pages [1] [2] [3] and video based pre-recorded courses, which have become common due to the availability of multimedia devices in low-cost personal computers [4]. This technologies are asynchronous in nature due to the fact that the students and instructor are unable to interact simultaneously. In many cases, these technologies cannot replace the interactivity of a normal class. And sometimes, specially for advanced courses, synchronous interaction is desired, as it enhances the productivity of the educative activities [5].

We found that a telepresence system can be a suitable alternative for providing synchronous remote distance education. Telepresence consists in providing the sense of presence at a remote environment through a system [6]. We selected three essential components to give a sense of telepresence in an instructional environment, namely: teleconferencing, a shared slides application and a shared virtual environment.

Remote courses can benefit from teleconferencing to compensate for the instructor's absence. Internet teleconferencing is already possible even for geographically distant regions thanks to widely available tools as [7] and [8]. The importance of teleconference lays on the necessity of knowing facial expressions as an indication of the student's and instructor's attention on the matter being studied. We discovered this on a previous research involving virtual environments for education [9]. Slides are convenient in order to be able to do presentations covering the subjects explained in class. In addition, some topics have to be illustrated and observed in detail to augment the understanding. In many cases this involves the use physical objects representing the problem of study, for example, a human body or the model of an engine. In such case distributed virtual reality environments can be used. Virtual Reality has proved successful for applications in which the students and the instructors share experiences that are related to various educational contents [10] [11] [12] [13]. In these applications, users share a networked virtual world and a set of objects they can interact with, providing the illusion of a shared space in which they can collaborate. The potential of virtual environments for education has been identified in [14].

We created a telepresence platform integrating the above mentioned components. Our final aim is to bring education to places with limited access to schools and other adverse conditions. During the development we have encountered several factors that we consider important to share with the research community. Those findings could be employed in further developments.

Our main observation, from a pedagogical perspective, as we will show in section 5, is the ability of the platform to compensate for the physical distance of the instructor. For this we employed the Teaching for Understanding (TFU) Framework [15], developed at the Harvard Graduate School of Education to assess the levels of understanding on the students. Then we used the results to measure the effects of computer-mediated distance learning in order to verify the success of the system. Additionally, findings on resource disposal, instructor and students profile, and contents were observed and later documented. We will present them in the following sections.

The rest of this paper is organized as follows. Section 2 describes similar existing applications and how our approach differs from them. Section 3 describes the telepresence platform in detail. The main experiments and results obtained are described in section 4 and 5 respectively. Section **??** explains the lessons learned during the development of the tool. And finally, section 7 describes the conclusions and future work.

2 Related Work

Several applications involving SVEs and synchronous communication mechanisms have been created for several applications fields. This section describes some of the most representative ones and how our application differs from them.

The NICE project [11] was created as an immersive learning environment for children, implemented using CAVEs [16]. In NICE, several children could collaborate with other remotely-located children to, for example, construct and cultivate simple virtual ecosystems. Children could communicate via voice, but each participant could only see a 3D avatar of the other, lacking any facial expressions. Our tool adds video in order to alleviate this deficiency.

AVALON [9] was previously created by our group to explore the use of Networked Virtual Environments as means to support distance education. Users moved freely inside virtual worlds that were created to support specific contents of an Environmental Awareness course. Users could communicate with voice, sent over the network. The instructor could project slides in a whiteboard, located in a specific part of the virtual world. Each participant was represented with a 3D avatar, but no video was transmitted. In order to compensate for the lack of video, students could choose among a set of expressions in order to communicate their status to the instructor. These expressions were then displayed on top of the corresponding student's avatar. Similar to AVALON, MUVEES [13] and Active Worlds [12] provide different education oriented virtual worlds that vary in contents according to topics being studied. Avatars represent users and there is some basic support for artificial facial expressions. Video-conference is not part of any of these systems.

ISABEL, a Computer Supported Cooperative Work application meets most of the requirements for developing a synchronous remote class, including teleconference and shared applications (e.g., slides presentation) [17]. The shared application model of ISABEL relays upon VNC, what does not extend well for shared virtual environments as all user have the same view of the application window. In our virtual environment a user can change the world view and interact with it independently.

3 Telepresence Platform

The application described in this paper was built using Java to ensure portability an mododular development. Also because there are Java APIs for 3D graphics and multimedia applications. The application integrates several forms of interaction, namely: Slides, Video-conferencing and a Shared Virtual Environment. Figure 1 shows the application's window with virtual environment panel. The window is divided in two panels, the right-hand panel shows the local (top) and remote(bottom) video windows, the left-hand panel is shared between slides and the virtual environment. Only the instructor can switch them by an easy access toolbar at the top of the main application window. Local and remote video windows are shown at all times. Bi-directional voice links are also active among the two points at all times. This allows the instructor and the students to communicate in a very natural and effective manner.

Each slide is converted into an individual graphical file that is sent to the student side when displayed by the instructor. Controls at the bottom of the instructor's window, allow him/her to navigate among the slides. The instructor's mouse pointer position is reflected in the students' window.

Several virtual reality contents have been developed for a Computers Graphics and an Electricity and Electromagnetism course. Contents for the Computer Graphics course include, among others, parametric lines, curves and surfaces, objects as polygon meshes, 3D transforms and illumination. Electricity contents include charge transfer, Coulomb's Law, Gauss's Law, magnetic fields, etc. Each of the contents includes a 2D panel with formulas, object attributes and some adjustable parameters. Both the instructor and students can interact collaborative with the virtual objects. The instructor use a telepointer (3D arrow) to point inside the virtual world. The instructor's telepointer is commanded by a Polhemus 3D tracker, allowing for a very natural interface. For the students' application a normal mouse and keyboard can be used for interaction. The instructor and the students can move their viewpoints around the shared virtual environment using the arrow keys in the keyboard. The students' point of view is represented by a red telepointer, allowing the instructor to see from where they are observing the environment from.

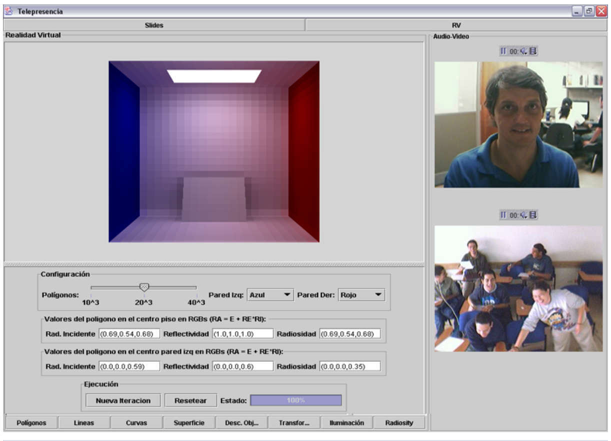


Figure 1: Telepresence Platform

In a normal lesson, the instructor explains the theory first and then performs a demonstration in the shared virtual environment. Students interact with the virtual objects next, guided by the instructor. Then they can adjust the parameters freely.

4 Experimental Setup

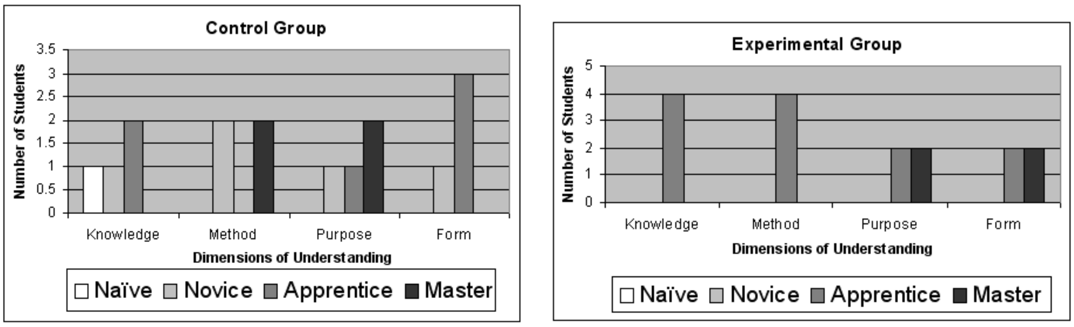
In order to measure the effectiveness of the tool in an actual learning environment two experiments were conducted during the second semester of 2003 and first semester of 2004. For the first experiment the 3D unit of a Computer Graphics course at Eafit University was chosen. For the second experiment a unit of an Electricity and Electromagnetism course, taught at Eafit University for Engineering students, was selected. In both cases students were randomly assigned to an experimental group or a control group. Students in the control group received the traditional class with overhead projector and whiteboard. Students in the experimental group received a “distance” class using the tool. The unit topics were designed from scratch using the Teaching for Understanding approach. The TFU design of the unit, including the generative topic, through lines, goals of understanding and performances of understanding can be seen at [18].

According to Teaching for Understanding, deep understanding takes place when the individual is capable of extrapolating the acquired knowledge to situations different from those presented in the learning process. For this reason, students in the experimental group, as well as those in the control group, were asked to undertake a small project for local industry. Each group had an industry tutor to assist in the development of the project. At the end, students presented their work to the class and a group of experts, including the industry tutor, who graded their performance.

We will now describe the physical setup. The instructor and the student locations were linked through the campus local area network. Output of the application was projected into a large screen on the students’ side. Students were then asked to perform similar actions, allowing them to demonstrate (and at the same time increase) their understanding. In the experimental group, the instructor was in an office in the campus and students were in a remote classroom. The classroom was equipped with a web camera, speakers, a projection surface, a microphone and a desktop computer. The instructor station consisted of a web camera, a headset microphone and a desktop computer. The instructor sat in front of the screen while the students were in normal classroom chairs. The hardware setup is being studied and has been reconfigured trying to achieve the best functionality at lower costs. We are particularly careful with the physical aspects since we consider the lesson development may be affected by the physical absence of the instructor and even more by the use of different technological widgets. The arrangement of the devices plays a vital role. For example we found out that the location of the camera influenced the students’ attention to the class. If the camera pointed only at part of the group, the students not in view became easily distracted. We then relocated the camera to cover most of the classroom. Audio feedback was also an issue. Volume settings on the Operating System alleviated the problem. A headset microphone was the best option for the instructor’s side.

5 Results

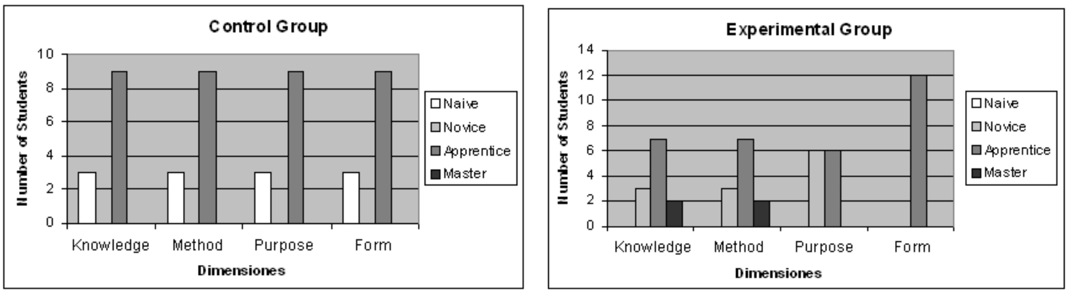
As mentioned in the experimental setup, for both experiments, students presented their work and were graded by a panel of experts according to the four levels of understanding (1 = naive, 2 = novice, 3 = apprentice, 4 = master). The criteria for assigning a level of understanding on each question were described in rubrics matrices, in order to unify the grading process done by the experts. The rubrics matrices can be found at [18].



(a) Computer Graphics - Control Group

(b) Computer Graphics - Experimental Group

Figure 2: Levels of Understanding achieved in the Computer Graphics course



(a) Electricity Course - Control Group

(b) Electricity Course - Experimental Group

Figure 3: Levels of Understanding achieved in the Electricity course

For each experiment there were 11 questions. Each question was related to one dimension of understanding (knowledge, method, purpose, form). Averaging over the grades assigned by the experts and the questions for each dimension, each student was assigned a numerical grade in each dimension. Floating point grades were rounded to the nearest integer in order to assign a level of understanding to each student on each dimension of understanding.

Figures 2(a) and 2(b) show the results of the experimental and control groups of the Graphics course. Students in the experimental group achieved levels of Apprentice and Master in each dimension of understanding. Students in the control group achieved levels of understanding from naive to master.

Figures 3(a) and 3(b) show the results of the experimental and control groups of the Electricity course. Most of students in the experimental group achieved levels of Apprentice in each dimension of understanding. Students in the control group achieved levels of understanding of Naive and Apprentice.

Statistical tests (Mann-whitney and student-t) were conducted on the data obtained for each course. In both cases, the levels of understanding achieved by the experimental groups (group of students using the tool) prooved to by higher than those of the experimental groups. For more details on the statistical tests, see [19]. These results are very encouraging, since they suggest that the telepresence tool, hand in hand with an appropriate pedagogical framework (TFU), can compensate for the lack of physical presence in a distance education environment.

After the sessions, students in the experimental group filled out questionnaires about the tool and about its impact on their understanding. Several students reported that the tool was an important aid in their process of understanding: “[The tool] allows me to experiment and see the topic at hand”. “[The tool] helps me understand the concepts explained by the instructor”. Others reported on the interaction among students in the group: “We search for solutions as a group, and this makes understanding easier”. Visualization of examples aided in the case of complex concepts: “[The tool] allows me to see the concepts at hand, which are already quite abstract, when I can interact with the Virtual Reality part”.

6 Lessons Learned

This section describes the lessons learned by the group in developing the project. Depending on funding availability, the tool described earlier will become available as a product in a web server next year. This lessons serve the purpose of helping groups deploying this, or similar tools, avoid the most common pitfalls.

6.1 Logistics and Hardware

Logistics problems can adversely affect the experience. For this reason, it is necessary to test thoroughly the complete setting in beta-test sessions. Some of the items that have to be tested are:

- *Cameras*: commodity web-cams are sufficient. If enough bandwidth is available, firewire should be preferred over regular USB ports.

  Location of the camaras are important to allow for a correct view of the student group at one end, and of the instructor, at the other. After several configurations were tested, the student camera was placed over the projection surface. The instructor camera was located on top of the monitor.

- *The rooms*: The rooms where the instructor and the student are located should be relatively free of noise. Commodity microphones pick up ambient room, which affects the quality of the communication.

- *Lighting*: Light should be enough for the cameras to pick a clear image of the instructor and the students. Nevertheless, on the student side, too much light may affect the quality of the projection (depending on the power of the projector and the quality of the projection surface). Therefore, the ability to control individual lights in the student room is desirable.

6.2 The Instructor

The instructor must learn about Teaching for Understanding (TFU) well in advance. TFU is a profound change in the teaching practices and the instructor must be able to adapt his/her teaching practices before the actual sessions start.

Proper tranning on the use of the tool is necessary. Only by practicing can the instructor find the appropriate entonation and speed that allows his/her voice to be clearly understood by the students.

An open attitude, which at the end is related to the instructor's personality, is also necessary. The instructor must be inclined to attend promply any issue, wheater technology– or padagogy–related. Frequently asking students for feedback is therefore, not only convenient, but necessary.

6.3 Contents

Contents should be designed in order to utilize the full potential of the tool. The ability to manipulate virtual objects in the shared virtual environment, in particular, should be exploited.

Some courses are more suited than others by the nature of the topics. A biology course, for instance, can benefit from the manipulation of a virtual creature. A philosophy course, on the other hand, can hardly benefit from the collaborative manipulation of virtual objects.

6.4 The Students

In TFU, the students become particularly important, since everything aims towards their profound understanding. Consecuently, several trial sessions should be conducted in advance allowing the students and the instructor to adapt their communication to the tool. It is also important to monitor the students' motivation and satisfaction at the end of each session. This is the best guide to adjust any issue as soon as it arises.

7 Conclusions and Future Work

The results obtained in the experiment suggest that appropriate use of the telepresence tool, with the support of the TFU pedagogical framework in a distance education envioronment, can compensate for the lack of physical presence.

The experience gained during the experiment also suggest that the commitment of the instructor with the TFU framework and the proper use of the tool, which require a significant amount of insight and work, are at least as important as the use of the technology itself.

The main future work we aim at, is to convert the tool into a finished product, freely available for institutions to download. This requires technical and pedagogical documentation, as well as an API (Application Programmer's Interface) allowing for the development of new contents.

Additionally, the tool needs to be adapted to be deployed over low-bandwidth links, allowing it to be used on Wide-Area-Networks. This will probably require the use of Quality-Of-Service techniques allowing different priorization for different modalities (voice, video, virtual reality messages), as explored in [20].

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