



# e-Learning through distributed virtual environments

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e-learning is one of the emerging needs of the information age. Access to education is going to become crucial for the success of our information society, and therefore a lot of potential is seen in distance learning and distributed virtual environments. The communicative character of the distributed virtual environments would allow students and staff to meet in social shared spaces and engage in on-line real-time seminars and tutorials. Such technologies may mitigate some of the problems of isolation that distance learning brings. This paper presents our work in multi-user distributed virtual environments which are designed and implemented for educational uses in the bounds of the VES project. Furthermore, it presents our proposal for the extensions and reconstruction of the current system in order to create a more efficient system, which can be characterized as a learning virtual environment.

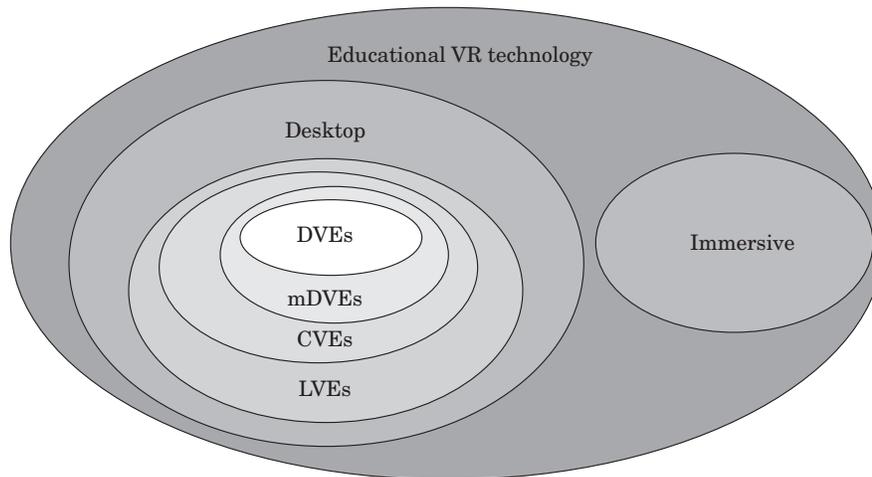
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## 1. Introduction

On the one hand, e-learning technologies aim to accomplish the needs of an educational community, where participants (teacher, students and administrators) can exploit learning and communication capabilities. On the other hand, Virtual Environments (VEs) provide a way to combine the best features of real-world information navigation—memory of places and visual cues—with the best features of online navigation—fast searches and sorting and quick cross-referencing. Networked VEs can contribute to e-learning, offering additional functionality and capabilities to the users. There are many types of networked VEs that can be used in e-learning which are presented in the following paragraphs (Fig. 1).

### 1.1 Types of networked VEs

1.1.1 *Multi-user distributed virtual environments (mDVEs)*. mDVEs allow a group of geographically separated users to interact in real time [1,2]. While a simple virtual environment is a computer-generated simulation with which the user can interact in such a way that he receives real time feedback [3], aiming to provide its users with a sense of realism, an mDVE is something more. In an mDVE, multiple users can interact with each other in real time, and furthermore the VE is distributed, running on several computers which



**Figure 1.** Educational VR technology.

are connected by a network using a series of client server applications [2,4]. mDVEs have many characteristics that can be exploited in the educational process and especially in distance learning. Specifically, mDVEs offer a way of communication and they give a shared sense of space, presence and time [5]. In addition, an mDVE application can meet the requirements for a complete Computer Mediated Communication (CMC) system [6], such as an easy to use interface, cross platform, conversation logs, indication of the presence of the attendees and multi-modal interaction.

**1.1.2 Collaborative VE-systems (CVEs).** An extension of an mDVE would be a CVE, which is an mDVE aimed at a collaborative task. CVEs aim to provide an integrated, explicit and persistent context for co-operation that combines both the participants and their information into a common display space. These objectives create the potential to support a broad range of co-operative applications such as training [7].

**1.1.3 Learning virtual environments (LVEs).** A simple definition of a Learning Virtual Environment (LVE) is a CVE aimed not only at a collaborative task but also at additional educational tasks such as synchronous and asynchronous learning. An LVE is a set of virtual worlds or a virtual world, which offers educational functionality to its users [8]. The avatars (the graphical representation) of these users populate the LVE and they are provided with additional behaviour such as gestures, interaction, movements and sound.

**1.1.4 Immersive virtual environments.** Immersive educational environments are supported by high-end equipment such as datagloves, Head Mounted Displays (HMD), ImmersaDesk and CAVE to visually immerse a user in the virtual world.

These environments allow the users to interact in a shared environment and to have a more realistic experience rather than desktop virtual reality. Furthermore, there are systems that use the immersive technology along with live video displayed in the HMD instead of 3D graphics [7]. These systems constitute a telepresence system, which allows participants to experience a remote physical space through computer and communication technologies.

According to an extended review on the educational uses of Virtual Reality (VR) technology [9], most of the educational VR applications do not support multiple users or do not provide any type of interaction between their users. More specifically, almost 2% of the current applications support multiple users with very limited types of interaction between users. Generally speaking, immersive applications are more effective in the use of VR technology. However, the main feature of educational VR applications is the interactivity and not the immersion. Moreover, a VR application, which is designed for educational use should be suitable for widespread use and mature in the part of the technology. Considering these requirements, immersive VR technology is not mature and it is expensive. On the other hand, desktop VR is more suitable for widespread use regarding the hardware and software requirements. In this paper, a three-dimensional community is described which is implemented in the framework of the Virtual European School (VES) project [10,11].

### 1.2 *The virtual european school (VES) project*

VES is a European project in the educational multimedia sector, aiming to build up a comprehensive resource on teaching and learning material for secondary schools (pupils aged 10–19). The project started in March 1998 and ended in February 2000. Pedagogically, the VES project aims to reduce instructors' hesitation towards using computers as teaching assistants, by offering an innovative delivery system containing a large variety of material, supporting various pedagogical concepts. All material will be adapted specifically for school use by publishers possessing know-how of the educational sector. Additionally, VES aims to enable international social contact between pupils and teachers, providing communication tools, educational games and quizzes embedded in distributed virtual environments. Table 1 shows the participants of the consortium.

The consortium is composed of partners from four countries (Austria, Greece, Italy and the United Kingdom), and school-networks within three countries (Austria, Greece, Italy). In each region, an organization performing and evaluation at content provider sites and schools is participating in the project. In this way, the user feedback loops are ensured. The technical system is set up by the Computer Technology Institute, Systema Informatics, and Joanneum Research. Evaluation of the system has been performed in all three regions, in parallel with teachers training. Scinter, an Italian organization, led this work. Further organizations

**Table 1.** *VES partners*

Participant	Role	Country
Bundesgremium des Handels mit Büchern, Kunstblättern, Musikalien, Zeitungen und Zeitschriften	Evaluation at publisher sites	Austria
Call Austria	Evaluation of the system	Austria
Joanneum Research	Technical system set up	Austria
FH Joanneum	Co-ordinator	Austria
Associazione Italiana Editori	Publisher	Italy
Scienter	Evaluation of the system	Italy
Computer Technology Institute	Technical system set up	Greece
	Evaluation of the system	
Systema Informatics	Technical system set up	Greece
Lambrakis Research Foundation	Evaluation of the system	Greece
Anglia Multimedia	Publisher	UK

with know-how in this field, and designing evaluation guidelines for schools are Call Austria, Lambrakis Research Foundation, and the Computer Technology Institute. The evaluation at publisher sites has been led by the Bundesgremium.

There exist three user groups within the VES: publishers, teachers and pupils. Each of these groups is offered a user interface with special functionalities. Publishers are supported by tools in order to manipulate content in the database. Teachers are provided with an intelligent agent in order to search and compose lessons. Pupils can view the pre-selected material and will normally enter VES through a 3D interactive virtual environment.

The final VES system (February 2000) contains multimedia material, CBT products, and also additional background materials, such as passages from schoolbooks, or Internet resources. A major strength of VES is that a large consortium of educational publishers supports it. Over 20 publishers from four countries participate in VES providing content and designing the system in such a way that VES fits into the working process of publishing houses. Therefore, a smooth work-flow for delivery of material is guaranteed, and VES has the potential to become in short time one of the primary providers of on-line material in the major participating countries, that is, Austria, Italy and Greece. In order to integrate schools in the design process, VES has established a continuous feedback process in each of the three VES countries.

The VES system architecture is based on a network of distributed multimedia databases, which act as the data servers within the VES. One server per participating country (Austria, Italy, Greece) has been installed. These servers can be accessed via a standard Web browser. For each user group, a special Web-based Graphical User Interface was designed. Publishers are provided with a supporting interface for uploading and monitoring the use of teaching material, teachers have search and compose facilities assisted by intelligent wizards, while pupils access the system through a specifically designed interface to work with

selected learning material as well as mDVEs. In general the VES system has two main technical results:

1. The implementation of a distributed multimedia database for storing the multimedia-value added teaching material and additional Computer Based Training (CBT) products.
2. The development of a 3D mDVE providing pupils with a powerful tool for learning and exchanging knowledge.

The VES 3D community consists of mDVEs. These environments have a primary goal of providing educational material and communication facilities to students and teachers through a user-friendly 3D interface. The 3D community described in this paper satisfies the above requirements. First of all it offers multi-user interaction through chat communication and avatar representation. In addition, the described environment is an mDVE and it does not have excessive requirements from the user side. More specifically, the educational material and the virtual worlds are stored in a server and the user can reach the 3D community through a Web browser with the use of appropriate plug-ins. After the evaluation of the VES 3D community by the end users, the need is raised for the improvement of the system in order to satisfy their needs in a more efficient way. Our proposal of an LVE application is presented in this paper.

## 2. Previous work on mDVEs

There are many research projects and systems in the area of mDVEs such as DIVE, SmallTool, SPLINE and VLNET.

### 2.1 *Related systems*

2.1.1 *Distributed interactive virtual environment (DIVE)*. The Distributed Interactive Virtual Environment (DIVE)<sup>†</sup> [12] is an Internet-based multi-user VR system where participants navigate in 3D space and see, meet and interact with other users and applications. DIVE supports the development of virtual environments, user interfaces and applications based on shared 3D synthetic environments. DIVE is especially tuned to multi-user applications, where several networked participants interact over a network.

2.1.2 *SmallTool*. SmallTool [13,14] has been developed by GMD—German National Research Center for Information Technology, Institute for Applied Information Technology (FIT).<sup>‡</sup> It is a toolkit for realizing shared virtual environments on the Internet and is based on a number of libraries to build (VRML-based)

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<sup>†</sup> <http://www.sics.se/dive/>

<sup>‡</sup> <http://orgwis.gmd.de/~broll>

networked VR applications. The SmallView VRML browser and the SmallServ application server are such applications, which allow users to participate in shared VRML worlds.

2.1.3 *Scalable platform for large interactive networked environments (SPLINE)*. SPLINE<sup>†</sup> was designed and implemented by Mitsubishi Electric Research Laboratories (MERL) researchers and provides capabilities such as multiple users, spoken interaction, computer simulations, human computer interaction, 3D graphics and sound, run-time modifiability and open Interfaces.

2.1.4 *Virtual life network (VLNET)*. Virtual Life Network<sup>‡</sup> supports Network Collaborative Virtual Environments and emphasizes in interaction between users [15]. It was developed by MIRALab-University of Geneva. The VLNET system uses realistic avatars (Virtual Humans) for the representation of the users in order to improve the communication and interaction between the users. The VLNET is a simple client/server architecture and can work with a typical HTTP server. The system provides administration of the virtual humans in a modular and open architecture. The design of the system facilitates its use in various ways, changing the system modules. This feature makes the VLNET system flexible.

## 2.2 *Related projects*

In addition, there are many projects that try to introduce VR technology in education such as BREVIE, COVEN, LIVE, and VRLEARNERS.

2.2.1 *Bridging reality and virtuality with a graspable user interface (BREVIE)*. The main objectives of the BREVIE<sup>§</sup> project are: to demonstrate the feasibility and the advantages of a new kind of learning environment for vocational training in production engineering and to establish a baseline for network supported co-operation between media developers, research institutions and media users (teachers and learners).

2.2.2 *Collaborating in a virtual environment (COVEN)*. COVEN<sup>¶</sup> was a four-year ACTS-EU (European Union—Advanced Communications Technologies and Services Programme) project. The main project objective was ‘to comprehensively explore the issues in the design, implementation and usage of multi-participant shared virtual environments, at scientific, methodological and technical levels’.

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<sup>†</sup> <http://www.merl.com/projects/spline/index.html>

<sup>‡</sup> <http://miralabwww.unige.ch/~vlnet/>

<sup>§</sup> <http://www.brevie.uni-bremen.de/>

<sup>¶</sup> <http://coven.lancs.ac.uk/>

2.2.3 *Learning in virtual environments (LIVE)*. The LIVE<sup>†</sup> project is one of the longest established programs at the Mixed Reality Laboratory (MRL) of the University of Nottingham. The current work in the project is involved with a consortium of schools in order to establish potential educational usage of virtual environments at particular Key Stages, and using the laboratory's collaborators in the schools to help define a feasible virtual environment.

2.2.4 *Virtual reality learning environment for network of advanced educational multimedia resource centres, museums and schools (VRLEARNERS)*. The VRLEARNERS<sup>‡</sup> project [16] has the major goal of facilitating multimedia access to Europe's cultural heritage. One of the main results of the VRLEARNERS project is the development of a collaborative virtual learning environment providing access to digital archives of European museums.

### 3. Virtual european school (VES) project work on mDVEs

As has been mentioned, one of the two main technical results of the VES project was the development of a 3D mDVE, providing pupils with a powerful tool for learning and exchanging knowledge. This mDVE is presented in this paper. Currently, the VES system and the corresponding mDVE can only be used by registered users. We have also established an alternative 3D community [17] for testing and evaluating purposes. The evaluation of the VES system is divided in three main cycles:

**First cycle:** The evaluation of the internal prototype: in this step the feedback has been received by the project partners.

**Second cycle:** The evaluation of the validation phase: in this step the main feedback has been received by exploiting the VES system at Austrian, Greek, and Italian schools as well as by publishers and project partners.

**Table 2.** *Projects in the area of mDVEs*

Project	Technology	Scope
BREVIE	Immersive VR, Graspable User Interface	Vocational training
COVEN	DVS, DIS, VRML, MPEG-4	Design, implementation and usage of multi-participant shared virtual environments
LIVE	—	Establishment of potential educational usage of virtual environments
VRLEARNERS	DVS, C, C++, VRML	Access to Europe's cultural heritage

<sup>†</sup> <http://www.mrl.nott.ac.uk/projects/learning.html>

<sup>‡</sup> <http://www.vrlearners.iis.gr/>

**Third cycle:** The evaluation of the pilot phase using the same evaluation sites as the second cycle of evaluation.

The results from both the first and second cycles of evaluation regarding the formation of the 3D environments are presented in the next paragraph. These results have guided us to reconstruct our first 3D community in order to accomplish the user needs. This 3D environment, which is named the ‘VES 3D community’, is a pilot application and it is presented afterwards.

### 3.1 *Main results from the first and second cycles of evaluation regarding the formation of the 3D environments*

The first step of the implementation resulted in the internal prototype, which has been evaluated by the VES project partners (first cycle of evaluation). After some changes in this prototype, the 3D environment has been used in real situations in schools, where both teachers and students have evaluated it (second cycle of evaluation). Also, project partners and publishers have evaluated the system. A set of questionnaires has been distributed to the end users in order to collect comments and suggestions about the formation of the 3D environments. According to the documents [18,19], which report the results coming from the feedback forms filled in by VES partners and end-users (publishers, students and learners), the main results about the formation of the 3D environment were the following:

**Technical difficulties:** The major problem signalled was the slowness of the downloading and launching times of the system. Furthermore, the DVEs requirements surpass existing school equipment by far.

**Interesting features:** The environment has been rated as quite interesting, particularly concerning the search and chat capability, as well as the overview window which has been seen as very useful.

**Not particularly appreciated features:** The graphical interface has been rated as poor, anonymous, old style and not fashionable enough. Besides this, the navigation in the 3D environment has been regarded as complicated because of the control system. The environment is not ‘interesting’ enough for young people, being too ‘static’ and ‘aseptic’. This target group needs an enthralling environment to be attracted to and to catch the attention for a time sufficient to visit at least part of the environment.

**Proposed additional features to provide added value to 3D:** Some suggestions for increasing the added value of the system have been made, such as:

- It would be useful to insert a thematic room, with material organized around the room, or a discussion place.
- It would be important, in order to catch the attention of the visitors, to create a more interactive and more attractive environment, with regard to design. It would be sufficient to add some interactive characters.

- Different elements which are not directly linked with a scholastic environment (for example slide show) should be added to the environment, in order to ensure that the students continue to access VES.
- It has been stressed that it would be nice to have the possibility of choosing different avatars, maybe from a given avatar gallery.
- It has been suggested that the 3D world ought to be divided into two different separated areas in order to avoid a media-mix, since content documents often contain text which must be displayed in a separate window. However, the general opinion is that as much information as possible should be given, embedded into the VE.

**Usage of this environment in school:** Among the different uses identified for the VES 3D environments, the principle ones are:

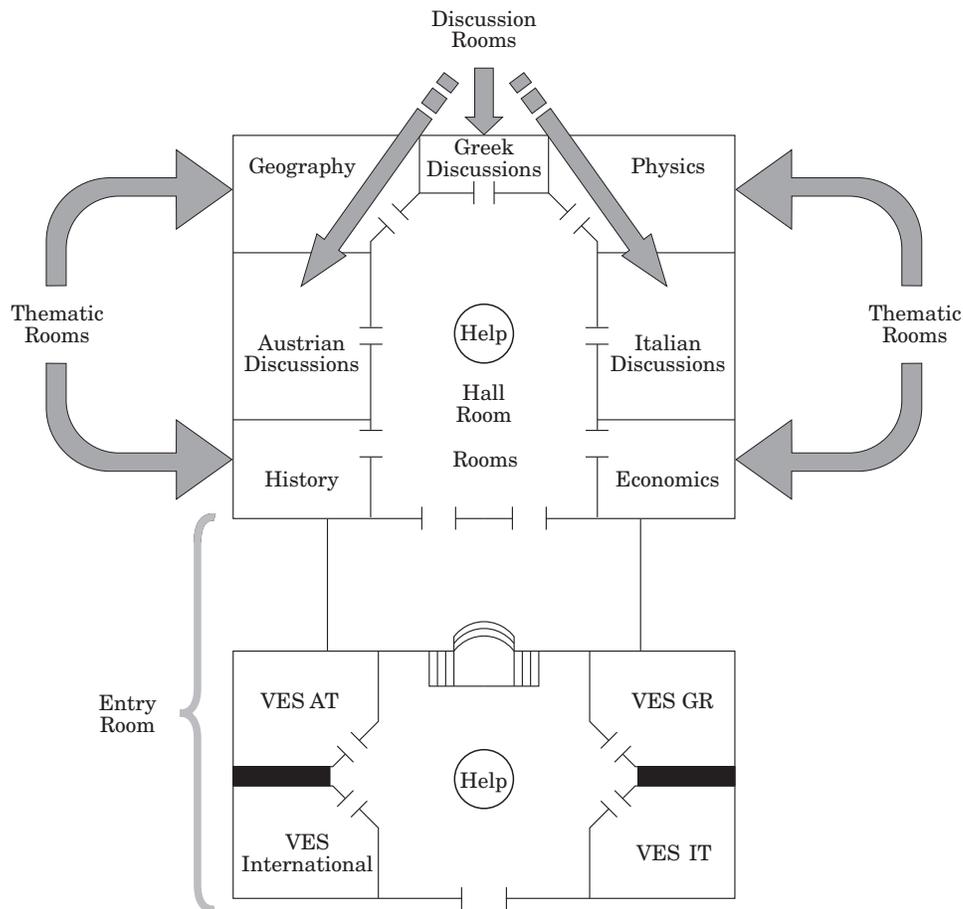
- A communication tool (chat).
- A virtual library of educational material.
- Organization of 3D environment: the need for a classification of the materials has been stressed, a thematic criterion could be followed:
- Use of the 3D room of the environment for private lessons and use of different rooms for different lessons.
- Use of one 3D room of the environment to create a 'news-room' for pupils and teachers.
- Use of one 3D room of the environment for each publisher and each partner.

### 3.2 *VES 3D community*

The VES 3D Community has been implemented according to the above suggestions and comments. It consists of nine virtual worlds (.svr files) [11,20]. The first world acts as the entry room to the whole environment and provides general information about the VES project and the three VES access points (Austria, Italy, and Greece). The second world is the hall room from where the users can reach seven other rooms that act as workplaces to be used by teachers and students for interactive communications through 3D avatars and text chat. There are three rooms dedicated for national discussions (Austrian, Italian, and Greek) and four rooms dedicated for thematic subjects (Geography room, Economics room, Physics room and History room). In Fig. 2 the ground plan of the VES 3D community is depicted.

### 3.3 *Functionality*

In order to achieve a friendly and appealing user interface, the interaction of the user with the virtual world should resemble real situations. In every virtual world certain functions are defined and these functions are activated by certain events. These events are related with objects (active objects) and the way that



**Figure 2.** Ground plan of VES 3D community.

the user interacts with them. The triggering mechanism of these events can have the following alternatives:

- When the user's avatar enters in pre-defined areas within each virtual room.
- When the user's avatar hits certain objects (collision).
- When the user clicks with the mouse over a certain object (touch).

By using one of these ways, we can have an interactive environment where the user is able to navigate and perform certain activities. An example of the thematic room functionality is shown in Fig. 3.

Functions that were designed in the virtual worlds are listed as follows:

- Information providing

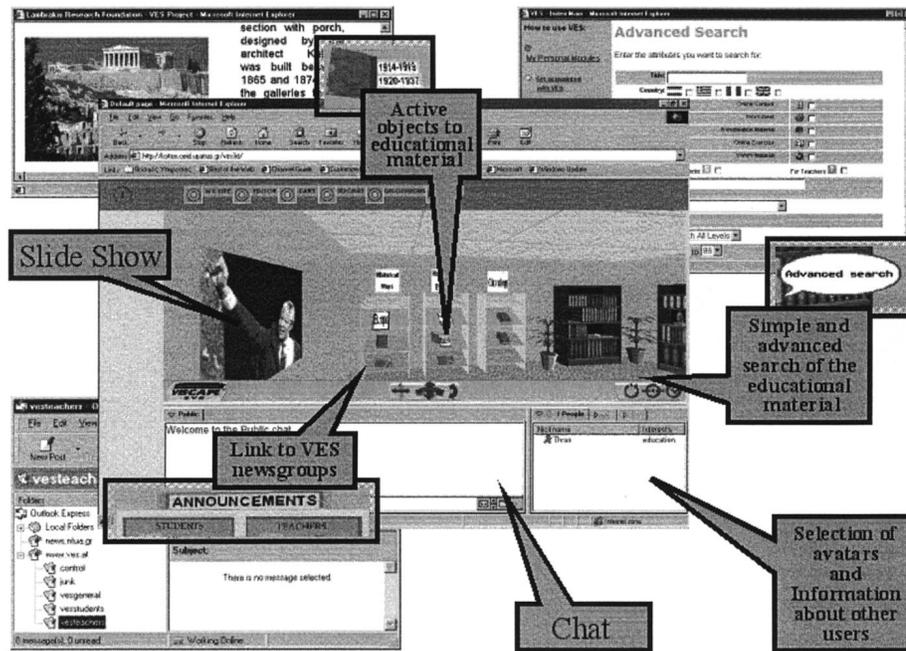


Figure 3. Thematic room functionality.

- Access to VES web-site functions
- Presentation of thematic material
- Help, through navigational aids, hints, and help desk
- Animations (slide presentation, moving humans, predefined paths—tour)
- Chat facility (Public chat—see Fig. 4; private chat and whispering capabilities—see Fig. 5).

### 3.4 *mDVE's development*

Several issues have been considered in the development of the distributed virtual environments, in particular user interfaces and supporting architecture [2,9]. In our case, through the development process we had to deal with several substantial technology related questions, e.g.:

- Finding an appropriate compromise between the desire to design a sophisticated 3D environment and the demands (e.g. reasonable response time, minimum hardware and software needs for the user),
- Creating solutions for the interaction of the virtual worlds and the databases of the VES system and the representation of the obtained information,



Figure 4. Public chat window.

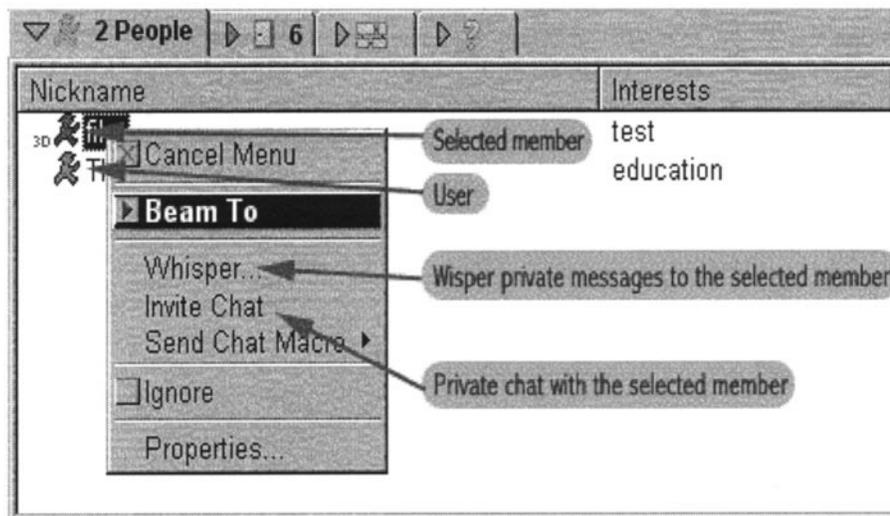


Figure 5. Private chat and whisper menu.

- Integrating varied action modes within the environment (e.g. wandering through 3D space, manipulating objects, browsing html pages or viewing content units).

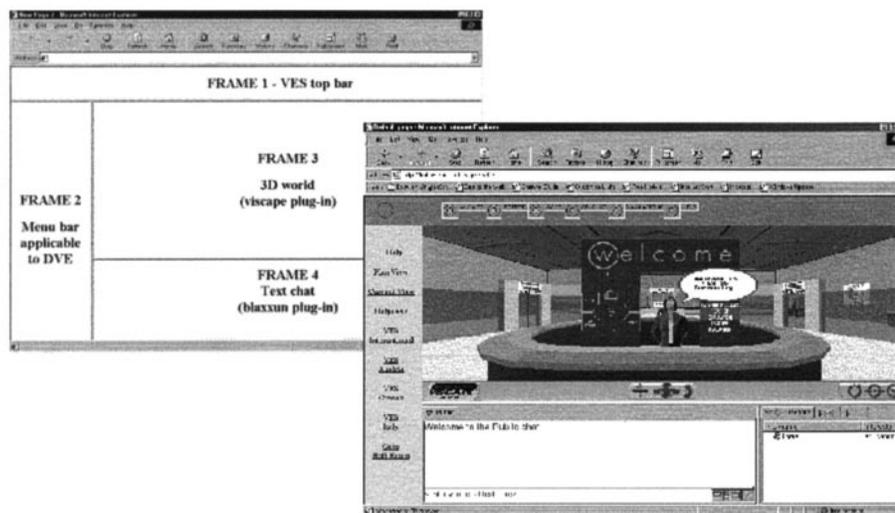
While designing the 3D community the main issues that were taken into consideration [20] were the creation of 3D worlds (which is based on Superscape<sup>†</sup> VRT [21]), the multi-user interaction (which is based on the use of blaxxun Community platform<sup>‡</sup>) and the user interface layout. After some proposed interface layouts and their evaluation from teachers, pupils and preceptors, the implemented user interface layout was decided to follow that depicted in Fig. 6.

## 4. Proposed extension to LVE

### 3.5 Motivation

The VES 3D community issues (formation, functionality, and implementation) that are presented in the previous paragraphs are based on the results of the first and second cycle of evaluation. The implementation of the VES 3D community was followed by a third cycle of evaluation. The main results of this evaluation can be summarized as follows [22]:

- Positive features: The structure of the VES 3D community in thematic rooms; the chat interaction.
- Negative feature: the complex procedure for setting up the communication facilities and 3D environment; the lack of more functionality to support the educational process; both the graphics and the interface need enrichment; the navigation requires improvement.



**Figure 6.** User interface layout.

<sup>†</sup> <http://www.superscape.com/>

<sup>‡</sup> <http://www.blaxxun.com/>

The above results and comments motivate us to review the current VES 3D community and to add more functionality. In order to implement the new features and to meet the need for an open system, we propose the use of different technology. Therefore, we propose the following improvements to the system:

- Additional functionality in order to support on-line lectures and to facilitate users' communication and information provision.
- Re-design of the system architecture in order to offer an open, scalable, customizable system based on accepted standards and technologies.
- Design and implementation of two types of shared spaces (lecture virtual rooms and chat virtual rooms) in order to support various educational scenarios.

These issues, which are relative to the additional functionality and the new architecture and technology, are discussed in the following paragraphs.

### 3.6 *Additional functionality*

In order to improve the system and to meet the user requirements exactly there is a need to implement additional functionality. This guides us to propose an improved system. The proposed system aims at offering innovative opportunities for the educational use of shared spaces for distance teaching and communication. It provides gathering grounds for interaction and offers the participants experiences through which knowledge could be more easily and pleasantly acquired. The initialization of certain events when a user enters specific areas, the integration of sounds, interacting by clicking on certain objects, the animation of objects in the virtual worlds and the interaction of the worlds with other applications enhances the user's sense of realism. The LVE provides the users with a shared sense of space, as all participants can be presented with the illusion of being located in the same place such as in the same room, building, or terrain. It also supports a shared sense of time, meaning that participants are able to see each other's behaviour as it occurs.

Based on the above, it is obvious that the LVE comprises a media over which educational procedures and interpersonal communication could be performed in a manner closer to the end user's need and perception. By simulating well-known everyday life procedures and actions, the LVE aims to present sophisticated services to the inexperienced user. Moreover, the environments could serve as a meeting point among the members of a learning community (e.g. university teachers and students). They provide the means for exchanging ideas, accessing amounts of information and collaborate on learning activities. There are three basic scenarios of use that the LVE would support:

- Communication among students and teachers. This scenario anticipates virtual chat rooms where subject-specific conversations among students would take

place and for appropriately designed virtual places, where students can reach and communicate with their teachers.

- On-line lectures. This scenario mainly concerns the lectures given throughout the virtual environments, anticipating for virtual classrooms where appropriate teaching material could be displayed and presented by a teacher to the students.
- Information allowance. Announcement boards, slide presentations, and links to WWW pages would connect the LVE with the amount of information circulated in the learning community and could give access to educational material and other external services.

The above scenarios would be applied in the extended VES 3D community, abetted by additional functionality, which is involved with the interface as a whole by the insertion of additional objects and the improvement of the graphics. Additional functionality would be provided by:

- A calendar of the lessons: In order to organize the lessons and the sessions of the users, there is a need of a calendar in the Hall room to provide the users with information about the lessons, the teacher, the relative 3D world, and a viewpoint to this 3D world.
- Intelligent help: The users are unfamiliar with 3D environments and the navigation in these environments. This complicates their navigation in the 3D environments. A possible solution here will be the use of intelligent help from the system with the form of help intelligent avatars.
- More communication facilities, through the 3D interface, such as non-verbal communication. This functionality implies the creation of new types of avatars that are able to support gestures and ambient movement.

### 3.7 *Model and architecture description*

In order to realize and to implement the proposed 3D community in an efficient way, it is crucial to re-think the use of the current software platform used (blaxxun-Superscape) [23]. Due to certain limitations of the software, available certain functionality that involves collaboration activities within a world cannot be implemented. Object interactions within a world are currently limited, as only the  $y$  rotation and  $x$ ,  $y$ ,  $z$  positions of each avatar are passed to the server. Therefore, certain functions for activating objects could not be used, as only the avatar activating the object will see the consequences. For example, if an avatar tries to open a door by clicking on it, only the avatar opening the door will see it open. Another person avatar watching the situation will see the avatar move through a closed door. The only mechanism available to activate entities within a world and ensure that all avatars see the results is that of utilizing proximity detection groups—enterable group objects with certain attributes that activate the object when an entity moves into the group. This mechanism would be used

where appropriate. For the previously described reason, the functionality that is ascribed to the thematic project workroom could not be implemented. In order to achieve these goals, our design is based on the following concepts:

- Scalability: The ability to support a maximum number of simultaneous users, which could vary according to the specific settings of each virtual world.
- Persistence: This is realized by distributing and synchronizing user input as well as user independent behaviour in order to achieve the impression of a single shared world.
- Extensibility: It should be possible to customize an existing VE, before presenting it to the users.
- Openness: It should be possible to interface a VE to external applications.
- Support of variable content: Several forms of data should be supported and embedded in the LVE.
- Communication: The users in an LVE should be able to communicate.
- A Web-based application implemented with international accepted standards and technologies (HTTP, HTML, VRML, and JAVA).
- H-anim compatible avatars for the animation and the gestures

In actual fact, the LVE system (Fig. 7) is a set of different virtual worlds that aim to offer to the teachers and the students the ability to navigate and interact in a 3D shared space. Based on the basic scenarios of use there are two main categories, into which all of the virtual worlds created can be classified:

- Lectures' virtual rooms.
- Subject-specific chat virtual rooms.

There are also three main entities participating actively or passively in the LVE system:

- Teachers' entities, having the greatest amount of access and authorities.
- Students' entities, having full access but limited authorities.
- Presentation material entities manipulated by the previous two active entities.

The proposed usage scenario of the LVE application is the following: the teachers would interact with the whole system through the appropriate user interface, which consists of a typical Web browser, a VRML browser and a set of Java applets. This interface could give the teachers the ability to upload learning material to the available WWW server and to initiate and control learning sessions within the appropriate virtual worlds. On the other hand, students will participate in the above mentioned learning sessions through a different user interface with less capability. Both user interfaces are easy to use and require no specific knowledge from the point of the user.

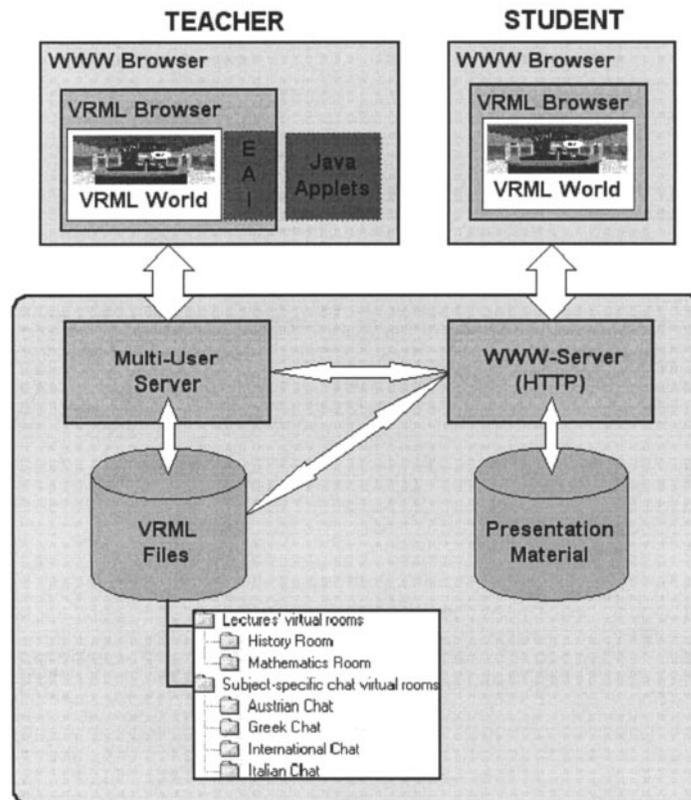


Figure 7. LVE architecture.

### 3.8 Functional specifications of the lectures' virtual rooms

Certain virtual worlds can act as centres for presenting real-time lectures, which are defined explicitly by authenticated teachers. The main purpose of these rooms is to act as a medium for passing knowledge and information from the teacher to the students about the specific subject area that the teacher chooses to present. Therefore, these virtual worlds could provide both teachers and students with the facilities that are vital for such an activity. The following are the main characteristics that this facility has:

- The teachers who are interested in using such a room for giving a lecture should first declare it to the administrators of the LVE in order to define which virtual room is going to be used and give the author the appropriate privileges over that world. After declaring his intention to use such a room, the teacher is provided with a password that he/she could use to gain control over the world and configure it the way he/she likes. There is a mechanism for verifying that only the authenticated teacher is able to configure, use and control the

learning session. After the successful authentication of the teacher, he/she is able to use the appropriate interface that gives him/her the ability to control the presentation of the learning session. Furthermore, the teacher should also declare through appropriate mechanisms (posted messages, e-mail, etc.) to the student community of the system the day and time of his lecture in order that interested students can choose to participate.

- Before the students can enter such a world, the teacher who is going to give the lecture should first configure it with the material that will be presented. The authenticated teacher should define the on-line learning session that constitutes from different types of media (images, text, sound, etc.). There is a mechanism for uploading the content that is going to be used by the appropriate Web server. Through this mechanism, the teacher who is responsible for controlling the learning session defines which media files should be transferred to the Web server in order to be viewable from all other members of the learning session. These media files are constructed by the teacher and should meet a general format that will be given to the teachers by the constructors of the world in order that they can embed them into the world and project them to the suitable objects.
- The learning session is fully controllable by the teacher and the different media types are presented at the suitable objects within the virtual world. As the teacher changes the content that is presented, all the users that participate in the specific on-line session within the world can view the changes. The teacher is able to comment on his presentation so that students can understand what they see each time.
- There is the capability for interaction between the teacher and the participating students through the text chat system. The students could ask questions and the teacher would reply to them. The teacher is provided with an additional chat functionality that gives him/her the ability to control and moderate the conversation between him/her and the students in the lecture room. The teacher can filter the incoming chat and post selected messages to all members of the group. This functionality gives the teacher the ability to guide the conversation and permit only the messages that he/she thinks are suitable for the specific conversation. This functionality simulates the classroom situation where the teacher is granting or permitting speech to the students.

### 3.9 *Functional specifications of the virtual chat rooms*

For the on-line communication of the users over the LVE platform, there are virtual chat rooms, where only a maximum number of users are allowed to participate. Users are able to enter such rooms using a unique name, navigate inside it, see other students' avatars and enter the on-line text-based conversation. The text chat system has the following functionality:

- Members of a virtual chat room can anytime be engaged in real-time multilingual chat conversations with each other, which are supported in various ways. Public chat allows talking or listening to everybody at the same time. Group chat helps to structure the conversations of bigger crowds. Private chats can be initiated any time among any members. In this way, certain combinations among the users could be achieved (e.g. student-student, teacher-students, teacher-teacher) providing a better and more powerful communication model.
- Announcements. Simple text and image based presentation spaces where all sorts of announcements concerning the conversation topics, meetings and activities can be placed.
- Slide projectors. Except for teaching purposes, presentations using slide projectors can also be used for announcements and notifications. Here, users can place short presentations on subjects related to the discussion themes.
- Connection with different sites. Symbolic representations in each virtual chat room leading the users to certain Web sites, with topics relevant to the ongoing conversation (e.g. a 3D bookshelf object can serve as a link to a theme-specific library's Web site).

All of the above functionalities need some input from the virtual chat room's creator, in order to function properly. This input comprises the presentation material attribute of the virtual room and is properly inserted and embedded into the virtual chat room during its creation procedure.

### 3.10 *Implementation issues*

As already stated, the LVE would be accessed by Web browsers through the Internet and is being implemented with the use of international accepted standards and technologies, which are presented in the following sections.

3.10.1 *The implementation of the virtual worlds.* Virtual Reality Modelling Language (VRML) [24–26] is used for the creation of the virtual worlds. As already known, VRML97 (ISO/IEC 14772-1) [27] has already established itself as a standard for the exchange of 3D descriptions on the Internet. VRML was the preferred system from a variety of 3D modelling languages because it has some features that are essential for our application. The most significant are events, eventIns, eventOuts, routes, sensors, and scripts. Besides its power in creating 3D virtual environments, VRML is compact in size where a complex 3D scene is described within a few Kb. This feature enables the distribution of a virtual environment among a large amount of users without considerable time delay or network congestion. Furthermore, for the dynamic modification of a VRML world we propose the use of VRML External Authoring Interface (EAI) [28] which defines an interface between a VRML world and an external environment. It provides a set of methods that an external application can use to interact with, and dynamically update a 3D scene in real-time.

3.10.2 *Adding multi-user interaction.* In order to make the virtual worlds shared (multi-user), an appropriate multi-user technology should be used. In our case, we use the blaxxun server which is a multi-user server that supports the operation, administration and usage tracking of virtual worlds, which can be inhabited by many users simultaneously. It is an open system that supports all relevant standards: HTML, VRML, Java, vCard, ActiveX, OCX, Direct3D and OpenGL, to enable 3D multi-user interaction and it works together with the blaxxun client (Web browser plug-in). The architecture of the blaxxun server offers many basic services (user management, text chat, bots, shared objects, etc.) and a number of optional services (e.g. authorization, and chat moderation). In addition to this, the blaxxun client provides a way of routing VRML events to all visitors of a multi-user place. In this way, all users in the virtual world can view animations and interactions that are triggered by one user. In order to be able to share events, someone should declare in the world the certain mechanism that is provided from blaxxun technology for passing the VRML events that are to be shared, first to the server and then distributed to the other clients. Finally, the blaxxun client supports a VRML 2.0 Script EAI interface [29], which allows JavaScript or VBScript to control the VRML 2.0 plug-in, running on the same HTML page. In particular, this scripting interface allows the reading and writing of any field values of named nodes. Additionally, VBScript (in Internet Explorer) and JavaScript (in Netscape) methods can be called from internal VRMLScript script nodes. Furthermore, the blaxxun client supports the proposed VRML 2.0 Java EAI interface that allows a Java applet to control the VRML 2.0 plug-in. The applet can interact with the VRML world by:

- Accessing the functionality of the browser interface (i.e. to create new geometry).
- Sending events to eventIns of nodes inside the scene (i.e. to change positions or colours of objects).
- Reading the last value sent from eventOuts of nodes inside the scene (i.e. to find the last position of an object).
- Getting notified when events are sent from eventOuts of nodes inside the scene (i.e. when an object is being clicked).

3.10.3 *Technical description.* The blaxxun server in combination with VRML technology gives us a powerful and flexible platform for developing the LVE with the proposed functional specifications, which are mentioned in a previous section. The LVE application uses the functionality of shared events of the blaxxun server and the EAI of the blaxxun plug-in extensively. These two techniques provide the necessary programming mechanisms that allow us to develop the LVE as a shared space with the appropriate functionalities.

The main problem in the creation of such a shared space is how to provide mechanisms that can allow to share events among the different users and to give

control of these events to one authorized person. For example, the teacher should be the only one that could trigger events (e.g. click on an object and change the slides that are displayed during a lecture) and that these events are distributed to all other users so as when the teacher makes a change in the virtual world all the others will see that change.

The solution to the above problem utilizes the shared event mechanism of the blaxxun server. As described in a previous section, this mechanism allows sharing events of different types. This means that the amount of information that is distributed to all clients depends on the type of the event that is to be shared. For example, when sharing an event of type SFBool, a value of 0 or 1 is distributed, while when using an event of type SFString a whole string is distributed. Therefore, careful design of the events that should be shared is very important, as a wrong decision could incur performance problems.

The main idea is to describe in the VRML file and the external programs (Java applets) all the behaviours necessary for the described functionalities. However, instead of using the standard VRML event routing mechanism for passing the events that trigger the behaviours directly to the desired nodes of the world, the event sharing mechanism is used for passing the events first to the blaxxun server and from there to all clients. In this way, when an event occurs in a client's world, this event is distributed and triggers a specific behaviour to all the other clients.

#### **4. Conclusion and future work**

This paper describes our work on educational applications with the use of virtual environments. This work involves the development of the VES 3D community, the evaluation of this community and the new direction and its improvement according to the evaluation. The development of the VES 3D community has given us the opportunity to deal with many interesting technical issues, concerning the creation and usage of multi-user virtual environments. In addition to the technical issues that we have encountered, the educational issues that have come up while using this application have been interesting too, and they help us use the new ways of communication and interaction that distributed virtual reality technologies offer in a more efficient manner. In order to evaluate this environment, we have distributed evaluation sheets to teacher, pupils and schools.

To enable us to amend the current environment according to teachers and students evaluation results and to offer to a more suitable educational environment, we have reviewed the VES 3D community and propose additional functionality and a new efficient architecture to support the functional specifications of an LVE application. Some of the functional specifications require no time at all to implement as they are offered as basic services of the server (e.g. text chat system, moderated discussions, authentication-registration service, monitoring of the space availability of the virtual rooms, etc.). Furthermore, with the appropriate

configuration the server could support some other specifications as well (defining a maximum number of participating users, restricting multi-user scenes, etc.). Many of the functional specifications require additional implementation time after the virtual worlds are created. The development of the lectures' virtual worlds where certain events and material should be shared among the various users requires the editing of the VRML files in order to include the event sharing mechanism of the blaxxun server. Other features such as the control interface of the teachers, the uploading mechanism, the configuration and authorization mechanisms of the shared space require the development of the appropriate Java and JavaScript programs that can work in combination with the VRML files.

Our next step is to design and implement the required virtual worlds. Certain care is given to the design of the event sharing mechanism in order to avoid possible future problems. The development of this application will give us the opportunity to deal with many interesting technical issues, concerning the creation and usage of virtual environments and shared spaces for educational purposes.

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**Appendix – list of abbreviations used**


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ACTS-EU	European Union—Advanced Communications Technologies and Services Programme
BREVIE	Bridging Reality and Virtuality with a Graspable User Interface project
CBT	Computer Based Training
CMC	Computer Mediated Communication
CVE	Collaborative Virtual Environment
COVEN	Collaborating in a Virtual Environment project
DIS	Distributed Interactive Simulation
DIVE	Distributed Interactive Virtual Environment
DVE	Distributed Virtual Environment
dVS	Distributed Virtual Environment System
DWTP	Distributed Worlds Transfer and communication Protocol
EAI	External Authoring Interface
GMD-FIT	German National Research Center for Information Technology—Institute for Applied Information Technology
HMD	Head-Mounted Display
LIVE	Learning in Virtual Environments project
LVE	Learning Virtual Environment
mDVE	Multiuser Distributed Virtual Environment
MERL	Mitsubishi Electric Research Laboratories
NVE	Networked Virtual Environment
PC	Personal Computer
SPLINE	Scalable Platform for Large Interactive Environments
SVE	Shared Virtual Environments
VE	Virtual Environment
VES	Virtual European School
VLE	Virtual Learning Environments
VRLEARNERS	Virtual Reality Learning Environment for Network of Advanced Educational Multimedia Resource Centres, Museums and Schools project
VLNET	Virtual Life Network
VR	Virtual Reality
VRML	Virtual Reality Modelling Language

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