Chapter XV

An Integrated Platform for Educational Virtual Environments

C. Bouras, University of Patras and
Research Academic Computer Technology Institute, Greece

E. Giannaka, University of Patras and
Research Academic Computer Technology Institute, Greece

M. Nani, Research Academic Computer Technology Institute, Greece

A. Panagopoulos, University of Patras and
Research Academic Computer Technology Institute, Greece

Th. Tsiatsos,
Research Academic Computer Technology Institute, Greece

Abstract

In this chapter, we present the design and implementation of an integrated platform for Educational Virtual Environments. This platform aims to support an educational community, synchronous online courses in multi-user three-dimensional (3D) environments, and the creation and access of asynchronous courses through a learning content management system. In order to offer synchronous courses, we have implemented

a system called EVE-II, which supports stable event sharing for multi-user 3D places, easy creation of multi-user 3D places, H.323-based voice- over IP services fully integrated in a 3D space, as well as many concurrent 3D multi-user spaces.

Introduction

The formation of communities among individuals who shared common characteristics goes along with the evolution and socialization of the mankind. This inherent need for communication and collaboration, in combination with the swift growth of the technology, resulted in the development of services that could meet the above-mentioned needs. In particular, the maturation of the Internet services and the melioration of the network bandwidth, along with the users' familiarization with the powerful means of distant communication and collaboration, formed the basis for the widespread establishment of online communities. These communities are described by the term "virtual communities" in order to define their "online" substance.

The definition of a virtual community is comprised of the following fundamental characteristics: (a) people who want to interact socially to satisfy needs, perform roles, and so forth; (b) a shared purpose, which provides a reason for the community; (c) policies, which guide human interaction; and (d) computer systems to support and mediate social interaction. These basic characteristics define the framework as well as the context of the constituted communities and entitle the scope, the concepts, and the intended milestones. In particular, in the case where the shared purpose of these virtual communities is learning, we address them as virtual learning communities.

Currently, the need for a paradigm change in e-learning has been identified, but which has not yet taken place (Laister & Koubek, 2001). In the past, Information and Communication Technologies (ICT) have been developed in a technology-centered way, but we are currently undergoing a change towards more human-centered concepts of using information technology for business, learning, and communicating with each other. However, Resource-Based Learning (RBL), which focuses on the interaction between human and computer, still prevails. Although, the RBL approach has several advantages for supporting individual learning by providing interactive, media-rich resources for learning, several disadvantages have been identified. Some of these disadvantages involve the lack of peer contact and interaction of students working alone, and the need for flexible, available tutorial support. Moreover, interactive distributed learning facilitates the acquisition of a higher level of understanding by the students than passive distributed learning, thus enabling the learning process to be more active and more explorative.

It becomes clear that the key concept of learning, which qualifies a virtual learning community, requires a balanced combination of technology with the human factor. Therefore, a virtual community should be supported by a computer system that should be able to facilitate delivery of e-learning content, collaboration, and distance learning services, both in the industrial and the educational field. We address such an educational technology system as an Educational Virtual Environment.

The main scope of this chapter is the presentation of an integrated platform for the support of Educational Virtual Environments, which has been designed and implemented in order to integrate the current RBL concepts with collaborative e-learning strategies through advanced technological solutions. The above concept has been chosen in order to overcome the limitations of current e-learning applications, as they were described previously.

In order to exploit the advantages of RBL and interactive distributed learning and, in parallel, overcome their disadvantages while still encouraging communication and collaboration among the participants, the platform provides and supports a variety of synchronous and asynchronous services. In regard to the kind and type of functionality that are intended to be offered, these services are dispersed in the system, which consists of the following components:

- **A Web-based e-learning community (EVE Community):** This component constitutes the central part of the platform, which offers to the users (students, tutors, etc.) the necessary tools for asynchronous interactions (as forums, private messages, etc.), accessing lessons and e-learning content, as well as the users roles and rights management.
- **EVE-II Networked Virtual Environments system, which supports 3D multi-user virtual classrooms:** EVE-II is used to provide the multi-user substance of 3D virtual classrooms for collaborative e-learning in order to offer a collaborative work system or, in other words, a collaborative workspace. Using Networked Virtual Environments (NVEs) as communication media, the members of these virtual communities are given the advantage of creating proximity and social presence, thereby making participants aware of the communication and interaction processes with others. In particular, the awareness of other users and the awareness of learning objects and material constitute a critical factor for the Educational Virtual Environments. In addition, based on the fact that users are influenced by the virtual representation, the 3D multi-user component was selected so as to facilitate the e-learning process and offer all the tools necessary to simulate a real classroom. Furthermore, the EVE-II system supports stable event sharing for multi-user 3D places, easy creation of 3D multi-user places, H.323-based voice-over IP services integrated in 3D spaces, and many concurrent 3D multi-user spaces.
- **A Web-based Learning Content Management Element (LCME):** This component offers tools for facilitating tutors to easily develop learning objects consisting of a variety of content formats and build online courses so as to serve their distant students' needs. These tools support the metadata elements defined in Sharable Content Object Reference Model (SCORM). Using the LCME, RBL is facilitated, and searching and retrieval of e-learning content and tracking of students' interactions with the content are supported. Also, the e-learning content can be reused within different learning objects and asynchronous courses.

The EVE Community aims to provide a virtual learning environment that can simulate in an efficient way the interactions, educational material, and learning process of a real educational environment as realistically as possible.

The remainder of this chapter is structured as follows. We initially describe the state of the art in Educational Virtual Environments. We then present the platform from a technical point of view, describing the overall architecture. Afterwards, we describe the EVE community model, structural components, and the hierarchy of the roles and rights that regulate the platform. We then continue with a detailed presentation of the functionality that the community provides. The section that follows is engaged with the description of the Learning Content Management Element that the platform provides for the access, creation, and manipulation of the content. Finally, we present the usage scenarios for the platform, some concluding remarks, and our vision for the next steps.

Related Technologies and Research Work on NVEs

Currently, there are many commercial platforms that support NVEs. The most significant are:

- Active Worlds (http://www.activeworlds.com/),
- Sense8 (http://www.sense8.com),
- ParallelGraphics solution (http://www.parallelgraphics.com/),
- Moove' s Rose (http://www.moove.com),
- SmartVR's SmartVerse (http://www.smartvr.com/), and
- Worlds (http://www.worlds.com/).

In general, commercial products target large groups of users: "the more people, the better" (Greenhalgh, 2000). This leads commercial platforms to be reliable, attractive, and easy to use, as well as to work on available networks, mainly aiming at leisure or 3D chat. However, the generality that characterizes commercial systems makes their use for educational purposes premature, as most of them do not support audio-video and multi-modal user communication. Furthermore, an attempt to modify them by integrating additional components may not be cost effective, because most of them are not based on open standards, and in addition, their development toolkits are very expensive.

The area of NVEs has drawn increased research and development interest. This resulted in systems, tools, protocols, and a variety of platforms for networked virtual environments. The most significant prototypes and research work in the field of NVEs are the following:

- Distributed Interactive Virtual Environments-DIVE (http://www.sics.se/dive/)(Carlsson & Hagsand, 1993),
- Scalable Platform for Large Interactive Environments- SPLINE (http://www.merl.com/projects/spline/),
- Virtual Life Network- VLNET (Pandzic, Capin, Magnenat-Thalmann, & Thalmann, 1996; Pandzic, Magnenat-Thalmann, & Thalmann, 1998), and
- SmallTool (Broll, 1998).

Research platforms emphasize specific research issues such as facial communication, support of heterogeneous networks (Broll, 1997; Pandzic, Joslin, & Magnenat-Thalmann, 2000), or reliability, and tend to be limited in breadth (Greenhalgh, 2000). Furthermore, they focus on particular applications, and their re-usability is limited (Oliveira, Crowcroft, & Slater, 2000). This gives rise to a proliferation of independent, often partial systems, which renders them inappropriate for educational purposes. The solution of integrating or combining effort from different groups tends to be very difficult because of the different philosophies and assumptions, which condition each of these efforts.

To summarize, there are several platforms to support online virtual communities. However, current platforms rarely support both educational communities and the previously discussed goals. The current 3D multi-user communication platforms do not really take advantage of their (theoretical) potential for supporting collaborative e-learning. They are mainly dedicated to avatars movement and text chat collaboration. Features that aim to transport content or support collaborative work are neither integrated nor enhanced. Thus, the increased social presence is not accomplished. These reasons led to the design and implementation of a new platform to support educational virtual environments.

Overall Architecture

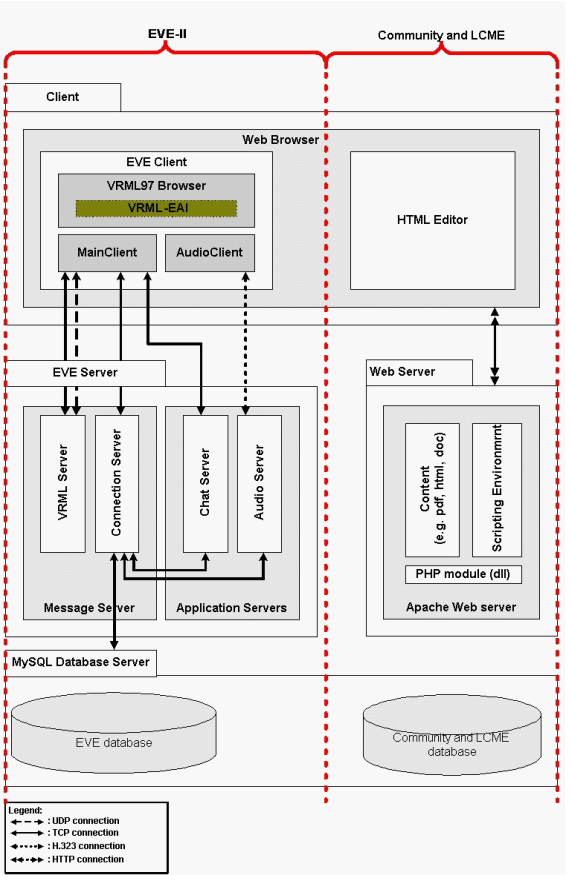
A high-level overview of the main components of platform EVE-II is presented in this section. As previously mentioned, the platform is supported by an EVE-II system, a Web-based community, and an LCME system.

The architecture of the platform is depicted in Figure 1. It is based on an n-tier model where each server is used for supporting specific services. These components are presented in detail in later sections of the chapter.

Client

The client is the end-user's computer with an Internet connection and a Web browser. The user utilizes the Web browser as well as necessary plug-ins (such as a VRML 97

Figure 1. Overall architecture



browser and an HTML editor) and/or Java applets (such as VRMLClient and MainClient, which are described later) so as to enter the system and exploit the offered functionality.

Server(s)

Our platform utilizes a set of servers in order to offer the desired functionality:

- **Web server and scripting environment:** The Web server is responsible for storing the learning content as well as for storing and executing the scripts of the scripting environment. It interacts with the Web browser through the HTTP protocol and

with the database by means of the scripting environment. We use the Apache Web server (http://httpd.apache.org/) as it is free of charge; it runs on almost every platform; it supports a variety of scripting languages; it is reliable; it has good performance; and it is widely adopted.

The scripting environment is one of the basic components of the system architecture. It constitutes the link through which the other system components can communicate with each other and contributes to the smooth and effective delivery of the appropriate content. It supports interaction with the database, system administration, user authentication, manipulation and extraction of the user's role(s) and access rights in the system, whereas it supports the personal desk of the EVE Community and the LCME (which are described in subsequent sections). For the scripting environment, we have mainly used the (server-side) PHP scripting language (http://www.php.net) in combination to the JavaScript. PHP is open source, cross-platform, and extensible. It has excellent connectivity and high performance. JavaScript is also an open scripting language that is supported by all popular Web browsers. The main functionality offered by the scripting environment is: interactions with the database; system administration; user authentication; manipulation and extraction of the user's role(s) and access rights in the system; support of the Web-based community and the LCME.

- **EVE-II server**: As described in the following chapter, the EVE-II server is divided into multiple servers and it is used in order to support multi-user 3D virtual environments that are enhanced with voice and text chat communication. This server is totally implemented in Java, and it is characterized by scalability and openness.
- **Database:** The database management system constitutes the core of the whole system, where the majority of the available information is stored and organized. For the presented platform MySQL server (http://www.mysql.com) has been used, which is supported by PHP and many other scripting languages; it can be integrated with the majority of the Web servers (including Apache) and is supported by the majority of the available platforms. The database is responsible for management information regarding the users, the messages exchanged, the content that corresponds to each module, and the events taking place in each area. Furthermore, it is necessary for storing information about the available learning resources, namely, their metadata elements, their relationships, and information about the students' interactions with the content. In order to provide a common understanding regarding the pieces of content that will be used within the system, we distinguish three types of learning content model components: Assets, Learning Objects (including assessments), and Courses.

Table 1. Interrelations between system and SCORM content model components

System content model component	SCORM content model component
Asset	Asset
Learning Object (including assessments)	SCO
Course	Content Aggregation

These are defined as follows:

- **Assets:** Assets comprise the basic constitutive element of the courseware. They refer to raw media files that can be viewed by a Web browser, such as slides, flash objects, exercises, and 3D simulations.
- **Learning Objects/Assessments:** A learning object refers to the learning content launched by the learning management element and delivered to the end-user during a courseware learning experience. It can be either a collection of one or more assets or an assessment object. Assessments may contain a question of at least four types, namely multiple-choice (true-false and multiple answer are also included), matching, fill-in-the-blanks, and open short-answer questions (including short-paragraph questions).
- **Courses:** One or more learning objects or even courses can be aggregated together to form a cohesive unit of instruction, that is, an asynchronous course. Within a course, the learning objects and courses will be listed sequentially in a tutor-defined order. Using a course as part of another course, tutors have the ability to develop courses nested in any depth and, thus, apply learning taxonomy hierarchy.

To meet the requirements for content accessibility and reusability, the system provides compatibility with SCORM metadata specification (http://www.adlnet.org). In order to apply SCORM conformant metadata to the content model components adopted by the presented system, the interrelations depicted in Table 1 are assumed (Bouras, Nani, & Tsiatsos, 2003).

EVE-II System

The multi-user VR system used is a platform for supporting NVEs called EVE-II. EVE-II is based on open technologies (VRML, Java, MySQL, and PHP). It offers stable sharing of VRML events, text chat, and voice chat communication among the users represented by avatars in 3D virtual worlds. The main characteristics of the EVE-II platform are the

flexibility and extensibility of the architecture, its stability, and the support of an easy way for transforming standalone 3D worlds to multi-user places.

The technologies used for the implementation of EVE-II, the system architecture, the main system components, and their interaction are presented in this section.

EVE-II architecture (Figure 1) is based on a client-multi-server model. The current form of EVE-II constitutes an open and flexible architecture of simple structure, which allows and supports the basic functionality that the platform is intended to offer. Therefore, the servers on which the platform relies are the message server and two application servers, a text chat and a voice chat server. This model offers scalability and flexibility to the EVE-II architecture, because if needed, more application servers could be integrated in order to offer more functionality. Furthermore, the selection of the above-mentioned architecture results in the distribution of the processing load among the above set of servers.

In addition, EVE-II is characterized by openness due to the fact that is based on open technologies and international standards. More specifically, the implementation of EVE-II is mainly based on:

- Virtual Reality Modeling Language (VRML), for the representation of the 3D worlds and the description of the 3D objects;
- VRML External Tutoring Interface (VRML-EAI) (http://www.web3D.org/), for implementing an interface between the 3D worlds and the external tools;
- Java, for the development of the client-server model, and the network communication among the different components of the platform; and
- H.323 (http://www.itu.int), for offering audio conferencing services through the Internet.

EVE-II is the second version of a system for NVEs (called EVE), which mainly improved on the sharing of events and on audio communication among the users. Concerning the sharing of multi-user events, EVE-II goes beyond EVE and other platforms (Bouras & Tsiatsos, 2004). In particular, the VRML data-sharing mechanism in EVE was based on the usage of an SVE file, which maintained every shared event and shared object in order to facilitate the multi-user communication and the initialization process. This updated approach for the sharing of the multi-user events is based on a VRML parser that has been implemented. The VRML parser runs on the server side; it is an extension of the SVE parser and helps the server to recognize the shared events without the usage of an SVE file. Using this approach, EVE-II presents the following improvements over EVE:

- It offers enhanced stability through an improved interface with EAI as well as a better support of avatar and avatars' gestures.
- It supports a facile creation of a multi-user space from a standalone, through the integration of the VRML parser. In particular, the shared events are commented out

(i.e., marked with a "#") in the original VRML file, and thus the standalone world is transferred to a multi-user one.

- It offers server-side syntax checking of 3D spaces in order to support better and faster sharing of multi-user events.
- It supports execution of shared scripts and VRML routes and full support of script sharing (both on JavaScript and Java format).
- It supports server-side execution of scripts, which offers better sharing of events, even in cases that are based on time triggering.
- It supports dynamic insertion of shared objects in multi-user places.
- It supports specific PROTOs (such as "chair" for avatar's sitting).
- It supports better initialization process.

Concerning audio communication, H.323 protocol is supported. H.323 is an ITU recommendation that defines a network architecture and the necessary associated protocols to voice and multi-media calls establishment. H.323 is a protocol suite that can be used for establishing, modifying, and terminating multimedia sessions or calls. These multimedia sessions include both point-to-point and multipoint conferences and Internet telephony applications. The main reason for this choice has been the H.323's modular structure, which offers flexibility and allows the usage of many well-known codecs and mechanisms for the transmission of the data. Furthermore, H.323 supports much more services than voice-over IP, such as videoconferencing, which could be integrated into future versions of the EVE-II platform

In the following paragraphs the main components of EVE-II architecture are described.

Server Side

The servers on which the platform relies are the message server and two application servers (a chat and an audio server).

Message Server

The message server is responsible for the manipulation of the virtual worlds that constitute the training area of the platform. In addition, this server creates and supports the illusion to the participants that they share a common space by updating the view of the world every time that a shared object is modified. Two servers, each of which is used for a specific sequence of operations, constitute the message server. These servers are the Connection server and the VRML server:

- **Connection server:** this server maintains a database, which the system accesses in order to authenticate the user and allow him/her to enter the virtual space of EVE-

II. In addition, the connection server reports every entry or departure that takes place in the platform to all other servers.

- **VRML server:** this server monitors and records every event that takes place in the virtual space and reports these changes to all participating clients of the platform. Thus, by performing these continuous updates, the system assures that the users will have the illusion of sharing a common space. The VMRL server also constantly maintains an updated copy of the world, which is sent to the clients when they enter the system. In this way, the incoming users share the same updated view as the existing users.

Application Servers

The application servers are responsible for providing specific functionality to the participants of the virtual world. In the current form of EVE-II, there are two application servers available, a chat server and an audio server.

- **Chat server:** this server is responsible for the text chat support. It allows group chat, which means text chatting between multiple users, or whispering, which allows the one-to-one communication between two users.
- **Audio server:** this server is responsible for the audio communication between the users of the system. The audio server uses ˜.323 as its main protocol. H.323 is a powerful multimedia communications protocol, which can transfer voice, video, or data over IP networks, and is especially fitted for this application. The main audio service offered by the system is the audio communication among all participants in a virtual world or between pairs of them. So, the audio server is, in fact, an H.323 Multipoint Conference Unit (MCU), which supports audio conferencing among the users. By using H.323, compatibility with a large range of H.323 audio servers and clients is achieved, and the use of audio as a separate service of EVE-II is permitted, while the numerous applications of H.323 can enrich the functionality of the platform—for example, by the future addition of video conferencing capabilities.

Client Side

As depicted in Figure 1, in order for the users' client to communicate with EVE-II servers and have access to the provided functionalities, they need a Web browser, a VRML browser, the main EVE-II client, and an audio client.

- **Web Browser:** The Web browser is used for the communication with the Web server of the system, which provides an initial interface and entry point between the user's client and EVE-II environment.

- **VRML Browser:** The 3D environment of EVE-II is implemented using the VRML language. Therefore, a VRML browser, a plug-in, is essential in order to allow the navigation of the user's avatar in the virtual training space. ParallelGraphics Cortona VRML browser is a tested solution.
- **Main Client:** This client is responsible for the primary connection of the user to the Message Server, the interaction between the user's avatar and the 3D virtual space of EVE-II, as well as the text chat communication between the users of the same virtual space. In particular, the main client, which is a Java applet, makes an initial connection to the connection server, which allows it to present the current connection status and, when the user is authenticated, it passes it on to the VRML server.

During an initialization phase, the list of the current participants in the virtual space is retrieved, as well as some information about the user avatar. Then, the normal message exchange with the VRML server begins. The first message received always contains the world, in its current state, and the users' avatars, so that the initialization phase can be completed and the standard operation be started.

During normal operation, this client is responsible for the interaction between the user's avatar and the 3D virtual space of EVE-II. In particular, every time that a user acts on an object, this client reports the modification and interaction to the VRML server of the platform that performs the update and transmits it to all connected participants.

The main client also includes a chat client. This part of the main client is responsible for the text chat communication between the users of the same virtual space. Every time that a message is sent from the client's side, it is passed to the chat server that, in turn, transmits it to the appropriate destinations.

- **Audio Client:** The audio client is a Java applet that records the audio stream from the user's side and transmits it to all appropriate destinations, allowing the audio communication between participants of the same space. As already described, H.323 is used to support the audio services. The audio client communicates only with the audio server, which is used as an MCU, handling and mixing the audio streams sent by the clients and forwarding them to the correct destinations.

Network Communication

The network communication of EVE-II, like its architecture, is focused on providing the available functionality at the best possible performance. Therefore, for the transmission of the packets and the achievement of the communication of the connected clients with the host servers (message server, audio server, and chat server),as well as for the server-to-server communication, there are three types of communication supported. Each of these types is found to be optimum for certain kinds of messages. Thus, the messages

exchanged in the EVE-II system have been categorized into four basic categories: (a) the messages related to the initial connection of a client to a server, as well as the messages exchanged between the servers of the platform; (b) the position messages that are related with the avatars' position and orientation in the virtual environment; (c) the important messages, which correspond to messages that are vital for the consistency of the networked virtual environment (for simplicity reasons, we consider important messages to be all messages except for the position messages); and finally, (d) messages related to audio streams.

In the following subsections, we describe why a connection type is selected for the corresponding category of messages described above.

TCP Communication

The main characteristic of the TCP communication is the reliability of the transmission of information packets. Therefore, this type of communication is selected for the cases where the reliable delivery of the exchanged messages is essential and vital to the maintenance of the consistency of the networked virtual environment, even if that interferes some delay in the transmission. For the EVE-II system, this type of communication is selected for the following messages: (a) the server-to-server communication; (b) the initial connection of a client to the message server, which includes the authentication; and (c) the messages that are vital for the consistency of the NVE, including the messages that create the 3D world and the avatars when a new client enters the system.

A possible failure or loss of the delivery of this type of messages could cause serious inconsistencies in the presentation of the virtual environment and could introduce security issues to the EVE-II system.

UDP Communication

The main characteristic of this type of communication is the high speed in the transmission of the information packets. However, one of the main drawbacks of the simple UDP communication is that it cannot assure the reliable and correct delivery of the data packets. Therefore, this type of communication is selected for the transmission of messages where their possible loss or failure of delivery would not have a severe impact on the consistency of the virtual world of the connected clients. Such messages are the position message, which carries information about the avatars' position and orientation in the virtual world, since their failure of delivery does not create important scene inconsistencies to the participants.

H.323 Based Voice Communication

As described above, H.323 protocol suite can be used for audio communication, while the transfer protocol used to actually transfer the audio data is the Real Time Protocol

(RTP). A client exchanges RTP packets with the audio server. As already described, the audio server mixes the audio streams and forwards them to the clients, making sure that sounds generated by a client are not sent back to it.

Eve Community

EVE Community (http://ouranos.ceid.upatras.gr/vr/) is a prototype that has been developed to meet the requirements of an Educational Virtual Environment. EVE Community aims to provide the necessary, synchronous and asynchronous e-learning functionalities to its members in order to simulate a real learning environment. In particular, EVE community forms a collaborative educational social space where members have the capability to gain knowledge through dynamic procedures and activities. The system focuses on interaction between the users and encourages communication among them by providing synchronous and asynchronous means of communication and collaboration. A critical factor for the Educational Virtual Environments is the awareness of other users and the awareness of learning objects and material (Bouras & Tsiatsos, 2002). In order to enhance the awareness of the users, especially in the synchronous interaction, EVE community uses multi-user 3D environments, where the users are represented by 3D avatars (Bouras, Psaltoulis, Psaroudis, & Tsiatsos, 2001). Therefore, the community, based on the fact that users are influenced by the virtual representation, is supported by a 3D platform that can facilitate the e-learning process and offers all the tools necessary to simulate a real classroom. Every synchronous course is held in a 3D world, which virtually consists of all the "physical" equipment that could be found in a real classroom. Thus, the platform supports a whiteboard, a presentation table, and chairs where the avatars, which represent the users, sit. In addition, as an educational collaboration space, EVE-II platform supports a variety of communication and collaboration tools that actualize the interaction among the students and the tutor. Text chat, audio chat, and brainstorming are some of the components that forward to this direction. Another important element that EVE community takes into account is the role of the student in the community. The entity of students has advanced capabilities, which allow the users of this role to contribute to the formation of the social and information space. More specifically, students can use all the asynchronous means of communication that are contained in their personal desks, as well as the synchronous means of collaboration within the fields of the virtual classroom, when the tutor allows it. The most important functionality, which takes the student from an active entity to an actor, is the ability to add knowledge material through the uploading of files and his/her ability to create and form courses in the community, as well as becoming a tutor in some courses. EVE community, stepping in the path that educational requirements specify, tries to use available standards and technologies in order to provide an integrated solution.

Community Model

When designing and implementing a Virtual Collaboration Space, there are two main issues that should be taken into account. The first one concerns the fact that the hosted users may not be computer experts nor have a great deal of experience on how to act and navigate in such systems. Thus, the community architecture should offer a friendly to use interface and well-distinguished functionalities, which will guide the user through the learning process without spending much of his/her time on trying to figure out for what each component is used. EVE community is, therefore, structured in sections, where each user, depending on his/her role, can access and use the functionalities offered. The second issue concerns the consistency and efficiency of the hierarchy used in the framework of the community. In order to obtain and maintain a well-structured hierarchy, EVE-II stratified the involved entities and assigned rights of access to each of them. The main concepts that EVE community adopts are the concept of "Organization" and the concept of "Place." The first one is used for organizing the (asynchronous and synchronous) courses offered by the EVE community. The second one is used for the virtual areas that can be visited by the user. Therefore, we could describe EVE community as a set of Organizations that provide e-learning courses and Places that can be used privately by each member or concurrently by groups of users who attend a class. An Organization constitutes the entity that can provide knowledge through courses and can be an educational institute, a University, or even a company. Every Organization has the capability to develop and create categories and subcategories of online asynchronous and synchronous courses, which can be accompanied by e-learning material. These courses are available to all members of the community who can navigate in the system, through a friendly to use interface, and have the capability to view and choose from all the available courses those that meet their interests, as well as view information about the courses for which students or tutors are already registered. The model for organizing the courses offered by the community is hierarchical, and the terms of reference for the levels of the hierarchy (organization-category-subcategory-course) contribute to the flexibility and easy scalability of the community. Also, from the developer point of view, this hierarchy contributes to the consistency of the database schema and the organization of the learning material. EVE community adopts the concept of places in order to simulate and actualize the learning process. The community area is therefore distinguished in three places. The first one, called "Personal Desk," constitutes the user's personal workplace, which is enhanced with asynchronous features; the second one, called "Training area," constitutes the place where synchronous courses are realized; and the third one, called "Courseware area," constitutes the place where the user can access e-learning content in the form of asynchronous online courses. These three types of places are described in detail in the two following paragraphs.

Personal Desk

This term refers to a 2D place that contains all the asynchronous features (apart from the asynchronous courses) a user can access. The personal desk constitutes the unique, for each member, central place where he or she can administer personal holdings. Regardless

of the user's role in the system, every member can navigate through the available (asynchronous and synchronous) courses and join the classes in which he or she is registered as a student, and view details about all other courses that he or she wishes to attend. In addition, the characteristic of the personal desk, as part of a Virtual Collaboration Space, is comprised of tools, which allow the asynchronous communication between the members of the community and contribute to the expanding and sharing of knowledge. Therefore, every member can access his/her personal messages, manage his/her profile and view other users' profiles, view and add information on his/her private and public calendars, upload/download files to/from his/her personal directory in the system, and view, post, and reply to messages in the community's forum. Also, a member can create a course and (if this course is approved) become a tutor for that course. The access levels in this space are altered in proportion to the user's role in the community. Thus, the roles that maintain more privileges from others can view additional features when entering their personal desk. Therefore, the user interface diversifies according to each role. As it is obvious, the personal desk facilitates the support of different access levels of the community. Furthermore, it contributes to make the users active due to the fact that they are free to choose the classes that they wish to attend.

Training Area

This place constitutes the virtual classroom where the synchronous courses take place. In EVE community, this place adopts a 3D representation based on the fact that 3D environments reflect positively on users' performance by creating a sense of presence and realism. Therefore, just as in real classrooms, the virtual classrooms must obtain all the prerequisites necessary for the conduction of the learning courses. Thereby, every course deals with a dedicated tutor, who is responsible for the management and the organization of the learning material, of the students and the course, in general. In addition, the students that attend the class and are represented by avatars have the capability to view the other users in the 3D multi-user virtual classroom, and thus maintain a scene of a real course. Furthermore, the 3D Collaboration world offers tools that contribute to the realization of a virtual course. These features, which according to their functionality and the need for realism, can either be 2D (for example, the text chat and the uploading and downloading of files) or 3D (for example, the whiteboard and brainstorming, as well as some extended functionalities such as audio chat), and access to the content repository are some of the components that develop the environment for the simulation of the real classroom. These features are going to be presented in detail later in this chapter.

Courseware Area

In this area, the student can access the courseware (series of online asynchronous courses), search and retrieve content of his/her preference, access his/her personal and academic records and information about his/her interactions with the content of an asynchronous course, and get support from a tutor responsible for the particular

asynchronous course. There the student can see the table of contents of the asynchronous course in the form of a hyperlink tree. Furthermore, he or she can see a related resources list, which includes all the resources to which the current learning object relates.

User Roles and Rights

An important factor to be taken into account is the definition of the users' roles in the community, as well as the levels of access that each role involves. More specifically, in EVE Community there are six, well-defined user roles, each of which is associated with certain privileges. These user roles are the following:

Visitor

This type refers to users who have not yet been registered to the system. The users in this category can only view information (mainly static) and demos about EVE community and what it can offer, without being able to navigate and test the systems' functionalities. In addition, they have the capability to register with the system by completing a registration form, which will assign them to the member role.

Member

Members of the community are considered to be users who have not yet joined any of the available courses but who are registered with the system, which means that each has a unique username and password, wherefrom they are recognized. These users have the capability to navigate though the available classes and post registrations for the courses that correspond to their interests. In addition, they have the capability to use all the asynchronous features that the community provides, which include the forum, a personal calendar, send and receive messages, maintain their personal profile, and view other members' profile. However, these users, since are not registered for any class, cannot enter the 3D virtual world, the virtual classroom, where the courses take place.

Student

This user role corresponds to members that have registered for at least one class. Therefore, these users have all the capabilities mentioned above (forum, calendar, uploading/downloading of files), as well as some additional collaboration features that arise from their registration for a class. These features involve the insertion of the user into the 3D virtual classroom, his/her representation of avatars, his/her ability to communicate and collaborate with the other students of the course through collaborative tools, such as the use of a whiteboard, the brainstorming, text and voice chat, the dynamic uploading and sharing of files, and access to the courseware.

Tutor

The tutor role is assigned to only one person per course (asynchronous and/or synchronous). This user must be a member of EVE community, without necessarily being registered for a course as a student. As the concept of the hierarchy implies, the users who are assigned to be tutors in a certain course conserve the capabilities of the student category but obtain some additional "privileges" in relation to the lower levels of the hierarchy. Regarding the tutor's role, it should be distinguished in two instances. The first one consists of the asynchronous components that this kind of role can manipulate. More specifically, the users assigned as tutors have the capability to manage the learning material of each asynchronous and/or synchronous course that he or she created, create examinations and tests, view the users who have registered for the course, access information about each student's interaction with the content of a course, and upload files in the synchronous course's directory. The second one is related to the existence of the tutor in the 3D virtual classroom. In this place, the tutor is the most privileged among the users, as the management of the course falls to his/her jurisdiction. In particular, the tutor can create groups of students, assign them tasks, which he or she supervises during the class, and decide what will be presented on the whiteboard. Furthermore, the tutor is the floor manager of the classroom, which means that every time a student wishes to speak or pose a question, he or she must get the tutor's approval. In general, this type of user is responsible for the efficient realization of the course and the management of the students, who he or she has the ability to expel in cases thought necessary.

Course Manager

Each organization appoints a course manager, a person who is responsible for the creation and management of the categories, the subcategories, and the courses, in general. This entity is authorized to set a tutor for every course and decide which members, who displayed interest in the course, will become registered students. In addition, the course manager can view the users' profiles, consider their research areas, and create new categories, subcategories, and courses that correspond to the majority's interests. Like the tutor, the course manager is responsible for the organization and management of all students, in addition to tutors who have subscribed to any synchronous course of the organization that the course manager represents. Thus, this user can add or delete users, accept or deny requests for the creation of courses by tutors, and accept or deny requests for the attendance of a course by students. Moreover, a course manager can view any change in the asynchronous learning material and approve or reject it accordingly. The course manager is also responsible for the administration of the asynchronous means of communication and collaboration, such as the forum and the calendar of events. Regarding these components, the course manager is responsible for the selection of the topics that are going to be posted on the forum and the calendar. Through an administrative console, this user receives the submissions posted by the users (members, students, and tutors) of the community and decides which of the

received information can contribute to the community's facilitation and to the learning process, in order to post it and make it accessible by all members.

EVE Administrator

There is only one person who holds this role, and he or she is the platform owner. Hierarchically, the administrator presents full access to the system, in which he or she can add, remove, and modify functionalities, fix possible weaknesses of the system, and create new organizations. In addition, the EVE administrator is responsible for the management of the course managers and the users of the community, in general.

In Table 2 the access rights of each role are presented. Also, Figure 2 depicts the hierarchy of courses in the EVE community according to organization concept and their relation to the roles and rights that EVE community supports.

What should be significantly emphasized is that the privileges that accompany the role of the tutor stand only for the courses to which this user is assigned. Similarly, the attributes of the course manager stand for the organization that this user represents. For every other entity, these users are treated by the system as members.

Functionality

The main goal of an Educational Virtual Environment is to provide all the tools, applications, and conditions necessary to make up an efficient space where communication and collaboration can be used for the maintenance and exchange of rich knowledge. Thus, EVE community, trying to simulate the learning process from its very beginning until its completion, is enhanced with the tools necessary for the advising, the notification, the encouragement, and interaction of the users, as it would happen in real educational communities.

In the following paragraphs the functionality of our platform is presented, except the functionality of the courseware area, which is presented in the subsequent section.

Personal Desk Services

These services (Figure 3) constitute, in a way, the anteroom, which prepares the users before attending a class (synchronous course), and is mainly comprised of asynchronous features. This space and the information provided are always available for the users, even if no courses are taking place at the time, and contribute to his/her advising, notification, reminding, and troubleshooting in the scope of the community.

Table 2. Table of rights and roles

Place	Rights	EVE administrator	Course manager	Tutor	Student	Member
Organization	Create Organization	v				
	Delete Organization	v				
	Edit Organization's info	v	v			
	Assign course managers	v				
Course category / subcategory	Create Course Categories		v			
	Delete Course Categories		v			
	Edit Course Categories info		v			
	Create Course Subcategories		v			
	Delete Course Subcategories		v			
	Edit Course Subcategories info		v			
Courses (synchronous / asynchronous)	Create Courses		v	v		
	Delete Courses		v			
	Assign Tutors		v			
	Validate Course creation		v			
	Edit Courses' info		v	v		
	Accept / Delete Students		v			
	Register for Course			v	v	v
	Attend Course			v	v	

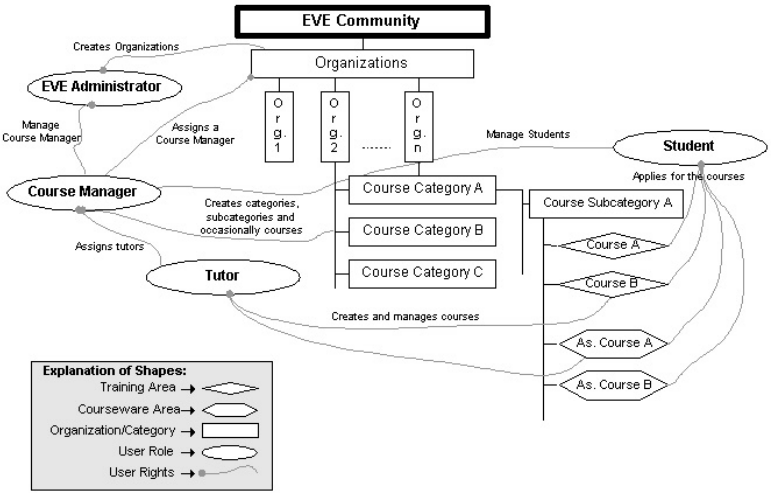
Forum

One of the main services of the EVE's personal desk, as well as of every virtual community (Ganesan, Edmonds, & Spector, 2002), is a forum, which comprises a mean of asynchronous communication. Every registered member can post a topic to the forum with information that he or she thinks is important, and this message is posted to the administrator who ultimately decides whether this message could contribute to the community or not.

Calendar of Events

The calendar of events is a timetable that stores a collection of events and lists them in chronological order. It is an asynchronous mean of communication that can be used for the scheduling of events that take place in the virtual learning community. Each registered user can create a private calendar of events—a calendar in which only the user can see the contents and add posts. The calendar provided by EVE community can support three types of events: public, private, and those related to each course. In the public calendar of events, the members can post their announcements to the administrator, who, in turn, will decide if the announcement is "qualified" to be posted. Furthermore, there can be a course calendar that includes class schedules and venues, schedules

Figure 2. Roles and rights in EVE Community



assignments, examinations, and topics to be covered. The calendar consists of three views. The day view, which is also time scheduled, the month view, and the year view.

Text Chat

This feature allows participants to communicate in a synchronous mode. It is important to notice that text, as well as voice chat, are also supported in the 3D worlds where the students communicate with each other and with the tutor. However, the text chat described in this section can take place among members who do not join the same courses and are not bound to insert into a 3D world. In the framework of collaborative learning environments, text chat has proven to be extremely helpful for members who meet outside of the virtual classroom and discuss issues that concern them, pose questions, and generally interact without being supervised and rated. In addition, a group of people who share common interests can create its own chat rooms. This component also allows users to send private messages in the chat room that cannot be seen by the other members.

User Profiling

As the term indicates, a collaborative learning environment should motivate the communication between its members. In particular, better communication can be achieved between members who share common ideas and interests. Therefore, every member of the community, at the time of his or her subscription to the system, enters personal information that includes his/her interests, hobbies, the research areas that he or she

Figure 3. Personal desk services

prefers, and so forth. Thereby, a profile for each user is created that is constantly enriched with additional information that arises from the selection of courses that the user decides to attend. An intelligent collaborative environment should be able to match users with common interests and encourage the communication between them. This functionality could be achieved with multiple queries in the users' profiles and selections of courses in order to track down areas of mutual interest, which will contribute to the distribution and extension of knowledge. In addition, a system should be able to compare the users' profiles, and especially the fields of research interests, with the available courses and suggest some possible alternatives. These functionalities could contribute to the interplay between the community members and the system, which, in turn, could result in effective distribution of knowledge.

Manipulation of E-Learning Content

A simulation of a real classroom presupposes that the tutor of the class has the capability to add and manage learning content, which should be dynamically changed, and dispose knowledge to the students, providing them the capability to have and process this learning material. In addition, there could be no efficient simulation if the students did not have the capability to maintain their own notebook, which in terms of an e-learning environment means a directory with files and folders for personal use. Such functionality can be supported by two basic operations—the uploading and downloading of files—in the framework of the collaborative virtual environment.

Training Area Services

The training area is exploited in order to host synchronous e-learning sessions. It combines 2D and 3D features in order to provide the users with communication and collaboration capabilities and necessary tools for realizing collaborative e-learning scenarios. There is one training area per course. The main feature of the training area is the 3D representation of a multi-user virtual classroom. This virtual classroom is the central place for realizing the learning process. The participants in the virtual classroom could have two different roles: tutor (only one participant) and students, according to the privileges in the EVE Community.

The users who participate in the virtual classroom are represented by avatars. The users' avatars are able to make various types of gestures: expressing opinions (e.g., agree, disagree), expressing feelings, mimics (e.g., happy, sad), as well as showing actions (e.g., move learning content, select learning content). The virtual classroom is supported by audio collaboration and text chat functionality. Also, it provides the users with the ability to upload their content and show it to other participants in the course. This ability is realized through a 3D presentation table. Moreover, this table offers further functionality, such as shared whiteboard or simulation of a brainstorming board. The user interface of the training area is depicted in Figure 4. More information about the functionality supported by the Training area is available in Bouras and Tsiatsos (in press).

Learning Content Management Element

In this section, the design of the LCME element is presented; an LCME is a tool for the development and asynchronous delivery of high-quality learning objects and courses through the Web. Asynchronous content delivery allows for "any time" and "any place" learning and, thus, implies increased flexibility. Moreover, the functionality that the system offers to its end-users in accordance to their role (Student, Tutor, Course Manager) in the Courseware area is presented. The Web-based tool provides a comprehensible user interface and facilitates individuals with no specific computer science or e-learning skills to easily use the provided functionality (Bouras & Nani, 2004).

Design Characteristics

The tool presented in this chapter for building and accessing learning objects and online courses applies to individuals who are in different geographical locations and interested in a particular, often highly specialized, field. Their shared purpose is to gain knowledge of the field, while taking part in the learning process at any time and any place.

To extract the functional specifications of such a tool, we were based on, but not restricted to, the requirements that an up-to-date platform should meet concerning the content creation and access, and inspired by the current trends of the standardization

efforts made on the learning technology field. The design characteristics can be summarized as follows:

- The system should support the import of a wide variety of content formats.
- The courseware elements, also called content model components, should be easily combined and aggregated to enable the creation of a learning content repository.
- The courseware should be divided into small modules.
- The content should be used and reused within different learning objects and/or courses.
- Online examinations and assessments should be available.
- The student's interactions with the content should be tracked.
- The courseware should be provided on a "distance learning" basis.
- The courseware should be designed to be platform-delivery independent.
- The system should provide the students with tutors with whom they can communicate online.
- The technology to be used should not demand any particular computer science or e-learning skills.

Accordingly to the aforementioned design characteristics, the LCME provides the means for creating and integrating courses and learning objects to the system and facilitates the students' access to the courseware. Students can conduct self-assessments, such as true/false, multiple-choice, multiple-answers, matching, fill-in-the-blank, and open short-paragraph questions, and get support by a tutor. Finally, a Course Manager assures the development and delivery of high quality content.

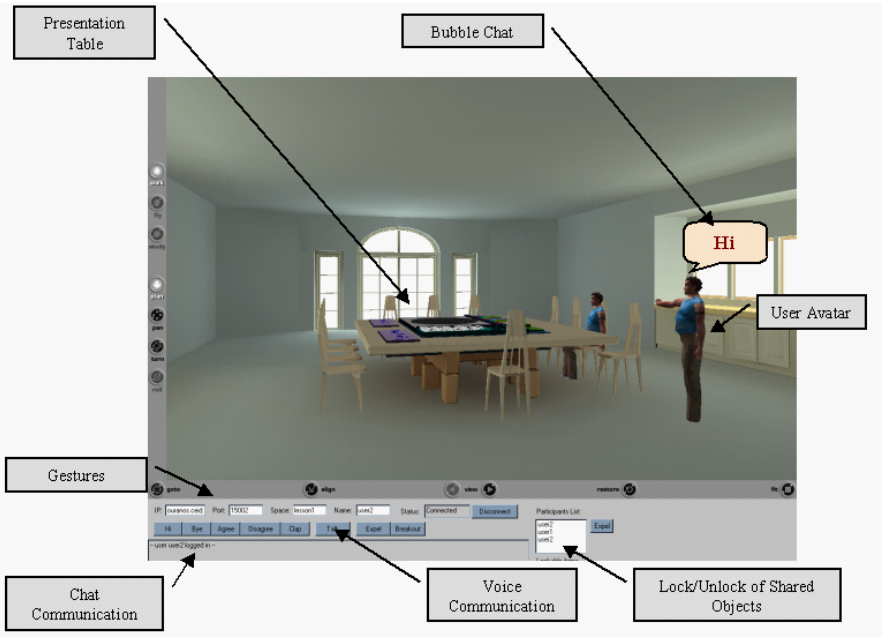
Functionality

The functionality that the platform provides to its end users, accordingly to their role in the Courseware Area, is now presented.

Tutor's Functionality

The main responsibilities of a tutor include the importation of raw material (assets) into the system, the creation of learning objects and assessments, the building of an asynchronous course, the enrichment of the learning resources with the appropriate metadata elements so that they can be accessible and reusable, and the editing of the metadata elements and the structure of an asynchronous course. However, any change

Figure 4. User interface of the training area



to the learning content is not readily available, unless approved by the Course Manager. The main tutor's functionality is: courseware access; upload asset; create learning objects; create asynchronous course; edit course structure; edit metadata; manage courses; and manage students.

Student's Functionality

A student can access the courseware, search and retrieve content of his/her preference, access his/her personal and academic records, and get support from a tutor he or she has selected for the particular course. The student's main functionality is: access the asynchronous courses in browse or study mode; access information about the student-asynchronous course interactions; the learning objects, assessments, and related resources.

Course Manager Functionality

As already mentioned, the Course Manager: decides upon the assignment or not of the role of a student/tutor to a system member; approves or rejects any change to the learning

content, thus, assuring the quality control of the courseware; and decides upon the expelling or not of a member from the courseware. The Course Manager functionality is: to see the number of the pending requests for the assignment or withdrawal of the student or tutor's role; to be informed about any change in the learning resources; and to access information about all the system members that have been assigned the student or tutor's role.

Future Work

In its current form, the platform manages to create and support Educational Virtual Environments, which can offer all the necessary tools for the communication, interaction between the members involved, access, creation and manipulation of the learning content, as well as the prerequisites for the simulation of a real classroom, thus providing all the "material" features that could be found in a real classroom (i.e., whiteboard, library, brainstorming, chat, etc.). However, EVE-II has the potential to be enriched with new features and tools that will exploit the capabilities of Virtual Reality's technologies and standards. Therefore, the graphical representation of the 3D virtual worlds could be enhanced in order to provide a more friendly and efficient knowledge environment. Finally, an important step for the fulfillment of this platform is its evaluation by users, which will bring to the surface any possible deficiencies that EVE-II may have. Furthermore, the integration of intelligent agents in EVE-II system will be a major enhancement of the functionality offered. Intelligent agents can support educational process and they can offer intelligent help to the users for the usage of the system. The incorporation of all these characteristics will lead to an integrated Educational Virtual Environment, from both pedagogical as well as technological aspect.

Concerning the LCME, it would be very useful to allow tutors to modify the various learning objects in addition to a course structure. Thus, tutors would have the ability to keep the content constantly updated without the need to develop it from scratch. This functionality, together with the possibility of replacing an asset in the Web server with a new version, presupposes the implementation of a version-control function. Moreover, the tutoring capabilities of the tool could be extended to allow the creation of new assessment objects. In this case, we should also examine how the users' answers could be tracked. Moreover, our next steps involve the research, design, and implementation of the way in which new user interactions with the content could be monitored. Examples of these interactions are: the time a user spends on an assessment object till he or she provides an answer; and the alternative content type the user selects to view (e.g., text or video). This information could provide useful information about the learning content usage and efficacy, as well as the user preferences.

Moreover, the integration of a Student Modeling System could add a significant value to the provided functionality. A Student Modeling System should facilitate the interactions among the users but, mainly, the user interactions with the system. By monitoring and analyzing the users' actions, the system could provide information about the system use, provide them with pedagogical advice, and encourage them to communicate with

each other. Our future plans also include the design and implementation of a functionality that will allow tutors to export courses created in our system in a SCORM-conformant zip file (package). In this way, content created in our system could be imported into any SCORM-compliant system and, thus, be available to a wider audience.

Finally, after the completion of the aforementioned tasks, assiduous evaluation of the system contribution to the learning process could take place. This presupposes the systematic test of the provided functionality by the end users.

Conclusion

This chapter describes an integrated platform for Educational Virtual Environments. The platform, EVE-II, aims to provide an integrated learning environment, giving emphasis to both the pedagogical as well as the technological texture of the educational place. Therefore, the platform is constituted of three interlinked components, each of which supports certain type of services for providing the participating users with an integrated learning environment. Furthermore, this system is identified by the fact that it is comprised of well-distinguished roles and rights, which simulate the learning process in an efficient manner. The variety of learning tools, both in the asynchronous and synchronous mode, create a sense of community to the students and participants of the environment and form the basis for the realization of the online synchronous courses, which fundamentally provide all the functionalities of a real classroom. Thus, through a friendly to use and navigate environment, the members of EVE Community have the capability to maintain their personal profile in a private space with all their personal holdings and interests, have the potentiality to communicate, access asynchronous courses, interact with other members of the community, and participate in virtual courses, either as students or tutors, in order to obtain rich knowledge.

From a pedagogical scope, EVE has defined mindfully the roles and rights of the involved users, providing the capability to all of the users to become equally transmitters and receivers of knowledge. These roles and the rights that each of them implies form the basis for a learning environment that relies on the communication and interaction of its members, their mutual respect, and their active participation on the way to collaboration and knowledge.

From the technological scope, EVE manages to provide all the functionalities necessary for the asynchronous communication and support of its members and for the simulation of a real training area. Therefore, EVE-II used the technologies and standards available for the implementation and integration of the necessary 2D and 3D tools and created a platform that is characterized by operability and scalability.

The platform presented in this chapter includes many characteristics a distance learning platform should have. In particular, regarding the technological approach:

- The client can access the system through a standard Web browser without compelling the user to install additional software to his/her system.

- The system can run on a wide variety of platforms.
- The system adopts the metadata elements (all the mandatory and the majority of the optional) that are described in SCORM specification. The adopted content model is also inspired by SCORM. Its clear structure in combination with the metadata elements facilitates the easy reuse of the various learning resources for the creation of larger instructional units. Moreover, metadata facilitates the easy search and retrieval of the learning content.

Concerning the pedagogical approach, the platform tries to support collaborative e-learning and RBL services, thus:

- The platform encourages and accepts the users' autonomy and initiative. Students are able to communicate with their tutors in order to get help as well as with the other students. Moreover, all registered users can take part in the learning process through one or more different roles. This distribution of the rights and access levels the role model implies encourages the active participation of all the users involved in the learning process.
- For each action in the courseware area, the system provides the user with continuous feedback. For instance, when a user answers a self-assessment, the system inform him or her immediately about whether each answer was right, and which is the indicative answer to this particular question.

Moreover, the system offers the following services:

- Services for including and updating user profile.
- Services for creating and cataloguing courses.
- Services for creating tests.
- User tracking services.
- Services for creating, organizing, and managing learning content.
- Communication and collaboration tools.

From the above, it is clear that the proposed system presents various characteristics that an up-to-date distance learning environment should provide.

Last but not least, the platform utilizes open source technologies. Open source technologies are available free of charge; they do not depend on particular companies; they are usually reliable; and they have good quality (due to their qualitative control by many people and the primary evolution of the source code).

References

Bouras, C. & Nani M. (2004). A Web-based tool for building and accessing learning objects and online courses. In *Proceedings of the Fourth IEEE International Conference on Advanced Learning Technologies*, Joensuu, Finland, August 30-September 1 (pp. 645-647).

Bouras, C., Nani, M., & Tsiatsos, T. (2003). Building reusable and interactive e-learning content using Web. In *Proceedings of the International Conference on Web-based Learning (ICWL),* Melbourne, Australia (pp. 497-508). Deakin University and The Hong Kong Web Society.

Bouras, C., Psaltoulis, D., Psaroudis, C., & Tsiatsos, T. (2001). Protocols for sharing educational virtual environments. In *Proceedings of 2001 International Conference on Software, Telecommunications and Computer Networks Split,* Dubrovnik (Croatia) Ancona, Bari (Italy), October 9-12 (Vol. 2, pp. 659-666).

Bouras, C. & Tsiatsos, T. (2002). Extending the limits of CVEs to support collaborative e-learning scenarios. In *Proceedings of IEEE International Conference on Advanced Learning Technologies*, Kazan, Russia, September 9-12 (pp. 420-424).

Bouras, C. & Tsiatsos, T. (2004). Distributed virtual reality: Building a multi-user layer for the EVE platform. *Journal of Network and Computer Applications*, April, *27*(2), 91-111.

Bouras, C. & Tsiatsos, T. (in press). Educational virtual environments: Design rationale and architecture. *International Journal of Multimedia Tools and Applications*,

Broll, W. (1997). Bringing people together - An infrastructure for shared virtual worlds on the Internet. In *Proceedings of the Sixth International Workshop on Enabling Technologies: Infrastructure for Collaborative Enterprises*, Cambridge, MA, June 18-20. Las Alamitos, CA: IEEE Computer Society Press.

Broll, W. (1998). SmallTool - A toolkit for realizing shared virtual environments on the Internet. *Distributed Systems Engineering Journal*, Special Issue on Distributed Virtual Environments, *5*, 118-128.

Carlsson, C. & Hagsand, O. (1993). DIVE: a multi-user virtual reality system. In *Proceedings of IEEE 1993 Virtual Reality Annual International Symposium* (pp. 394-400). Piscataway, NJ: IEEE Service Center.

Ganesan, R., Edmonds, G., & Spector, M. (2002). The changing nature of instructional design for networked learning. In C. Steeples & C. Jones (Eds.), *Networked learning: Perspectives and issues* (pp. 93-109). London: Springer-Verlag.

Greenhalgh, C. (2000). Implementing multi-user virtual worlds (panel session): Ideologies and issues. In *Proceedings of the Web3D-VRML Fifth Symposium on Virtual Reality Modeling Language*, Monterey, CA, February 20-24 (pp. 149-154).

Laister, J. & Koubek, A. (2001). Third generation learning platforms requirements and motivation for collaborative learning. EURODL 2001. Retrieved 2001, from *http://www.eurodl.org/materials/2001/icl01/laister.htm*

Oliveira, M., Crowcroft, J., & Slater, M. (2000). Component framework infrastructure for virtual environments. In *Proceedings of the Third International Conference on Collaborative Virtual Environments 2000*, San Francisco (pp. 139-146).

Pandzic, I., Capin, T., Magnenat-Thalmann, N., & Thalmann, D. (1996). Towards natural communication in networked collaborative virtual environments. In *Proceedings of FIVE '96*, Pisa, Italy.

Pandzic, I., Joslin, C., & Magnenat-Thalmann, N. (2000). Trends in a collaborative virtual environment. In *Proceedings of International Conference on Software, Telecommunications and Computer Networks*, Split, Rijeka, Dubrovnik (Croatia), Trieste, Venice (Italy), October 11-14 (pp. 893-901).

Pandzic, I., Magnenat-Thalmann, N., & Thalmann, D. (1998). Realistic avatars and autonomous virtual humans in VLNET networked virtual environments. In R. Earnshaw & J. Vince (Eds.), *Virtual Worlds in the Internet*. Cambridge, MA: IEEE Computer Society Press.