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EIKON: Teaching a high-school technology course with the aid of virtual reality

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This paper presents EIKON, an integrated open educational environment used to support high-school technology courses. EIKON combines state-of-the-art information technologies, such as virtual reality, hypermedia and networking. Our pedagogical approach is constructivism and collaborative learning. Students using EIKON study the evolution of agricultural technology since the prehistoric times. The environment could be used as a starting point for the exploration of virtual reality microworlds and the discovery of multidisciplinary information, which relates to most of the courses taught in modern high-schools (history, geography, physics, chemistry, biology, environmental care, ecological awareness etc). A case study with a sample of nineteen information technology high-school teachers reports on content, pedagogical, and software quality issues. The results indicate competence of multimedia information, very good instructional design, and very good software quality. Especially for virtual environments, all the teachers declared ease of orientation, but only the 26.3% declared ease in navigation using the navigation controls provided by the software.

Keywords: virtual reality; virtual environments; hypermedia; agricultural technology; case study.

Virtual Reality (VR) is a multi-sensory highly interactive computer based environment, where the user becomes an active participant in a virtually real world. First person's point of view, freedom in navigation and interaction, are essential for a computer environment to be characterized as a VR environment (virtual environment, VE). A virtual environment may consist of only a single or many virtual worlds. A virtual environment designed to educate the user is called a virtual learning environment. It should have an educational objective and provide users with experiences they would otherwise not be able to experience in the physical world (Mikropoulos et al., 1997).

Virtual learning environments have been proposed as good places to construct knowledge, the theoretical basis being constructivism (Winn, 1997). Such environments have been designed and evaluated for a variety of disciplines. Bell and Fogler (1995) have addressed the application of VR as a new educational tool in a chemical reaction-engineering course. Dede et al. (1996) have proposed the sciencespace, a collection of virtual worlds designed to aid students in mastering challenging concepts in physics. Mikropoulos et al. (1998) have developed and evaluated a virtual environment for environmental education.

This paper presents EIKON (pronounced eekon), an integrated educational environment used to support high-school technology courses, combining state-of-the-art information technologies, such as virtual reality, hypermedia and networking. The first section of the article presents the system architecture and the second the pedagogical issues involved in the educational environment. The last section concerns an empirical study for the evaluation of EIKON by the educators.

System architecture

EIKON implements a client–server architecture and may be installed either on a LAN, or locally on a PC. In either case, the server side consists of:

- The user authentication module, which manages the user login procedure
- The database subsystem, which contains the database of the multimedia content units, the scenarios and the 3D objects database, and the user database
- The database access modules, which manage client access to the database.

The client application must be installed on the PC of every EIKON user, in order to install a connection with the EIKON server. Each EIKON client consists of three components. The VR component, that normally appears inside a window to the left of the screen. It renders and fetches the current scenario and the associated 3D objects from the database; then, it allows the users to navigate inside the VR microworld, having a first-person experience as they interact with the virtual objects. The current version of EIKON contains four VR microworlds, which have been designed and developed so as to represent the evolution of the same landscape through the ages and to provide visual clues regarding the era where the current scenario is taking place. These VR microworlds are:

- Prehistoric: the landscape is bare and plantation is wild. Only a few, simple agricultural tools appear scattered inside the microworld
- Ancient: the ability of man to construct metal tools is represented by a smeltery, which the students can activate after they have collected the appropriate minerals, and watch the construction of scythes

- Middle Ages: a water-mill is represented and operated by the users to display the ability of man to process the agricultural products
- Contemporary: the landscape in this microworld looks familiar. The students can recognise the contemporary machinery it contains, as well as other human constructs and, of course, the cultivated land and the animals.

The second component is the HTML browser, which appears inside a window to the right of the screen. It displays the multimedia content units of the library, which are stored in HTML format in the database. Each content unit has been designed so as to be reusable and to completely present a subject without becoming tiresome.

The third component involves the teacher and student tools (to be described in the next section), that are displayed as buttons in the toolbar that appears to the top of the screen.

Usage modes

Access to EIKON is provided on the basis of a username and a password. The user authentication module accesses the database, where all the authenticated users are registered, together with the usage mode assigned to each. EIKON supports two usage modes: student mode and teacher mode. Users with student mode rights (students) can use a subset of the system tools but they cannot modify the educational content; these restrictions do not apply on users with teacher mode rights (teachers).

As users log into EIKON, the current tutoring scenario is automatically opened by the system. Students have no right to modify the current scenario; only a teacher can define or change the current scenario. The software environment (Figure 1) consists of three parts: the window of the VR component (left), the window of the multimedia library (right), and the toolbar (top).

On the top of the window, the current VR microworld and the current scenario are shown. This helps users not to become disorientated with respect to the scenery and the operations they can perform. The toolbar is divided into three groups: student tools, teacher tools and the help button (the rightmost one). The latter is accessible to all users and, when pressed, displays the help pages in the library window.

EIKON supports teachers in the preparation and realisation of a tutoring session, as well as in the organisation and management of their class. Teachers have access to all the student tools, as well as to the two teacher tools, namely:

- The ‘scenario management’ tool: when pressed opens the scenario manager (Figure 2). Using this tool, the teacher can define the current scenario, by selecting one of the available scenarios. Only one of these can be defined as ‘current’; a check mark is displayed next to the current scenario.
- The ‘class management’ tool: when pressed, it opens the class manager, which allows the teacher to associate a username and password with each student, to group the

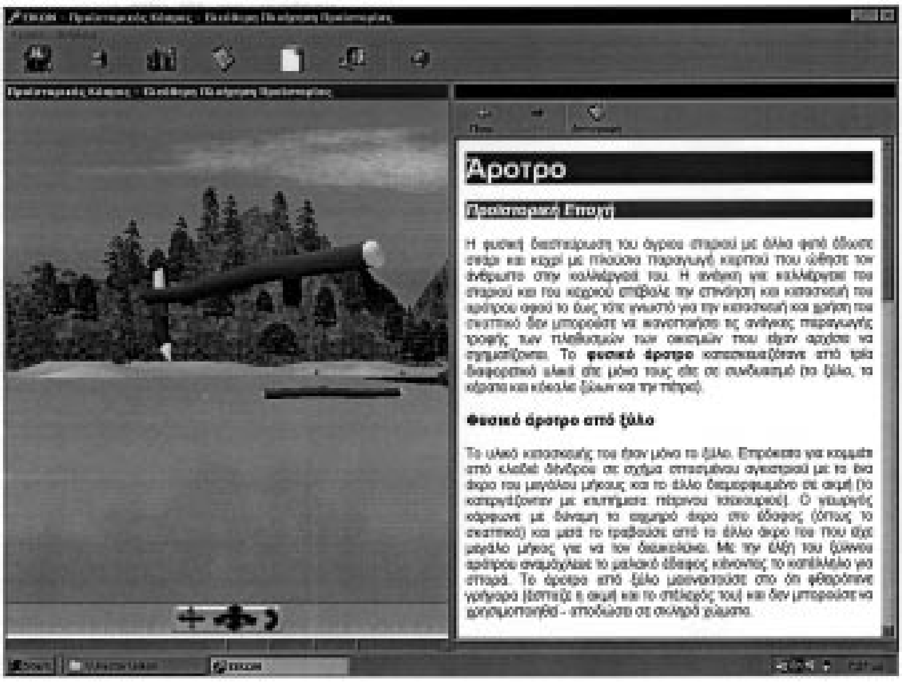

Figure 1. A screenshot of EIKON (prehistoric era). The VR component (left), the window of the multimedia library (right), and the toolbar (top).

students of the class, to assign projects to each group, and to monitor the progress of each student.

A tutoring scenario is designated by its name and may extend over one or more microworlds. Each single-world scenario is 'bound' to the microworld it involves. A tutoring scenario is described with a set of fields. These include a brief description of its contents, a set of educational objectives, the lesson(s) of the curriculum they can be associated with, and steps that can be taken to apply the scenario in a tutoring context. An activity sheet that may be printed and distributed to the students, and the name of the scenario author are also involved.

A scenario includes a set of 3D objects, which are displayed inside the involved VR microworld, when the scenario is rendered. These objects may be active or passive.

Active objects have an associated behaviour that defines the ways that students can manipulate them during the scenario; passive objects are only used as parts of the scenery. Each active object is designated by its name; a brief textual description may also be used to provide more information about it. The behaviour of the active objects is described with an

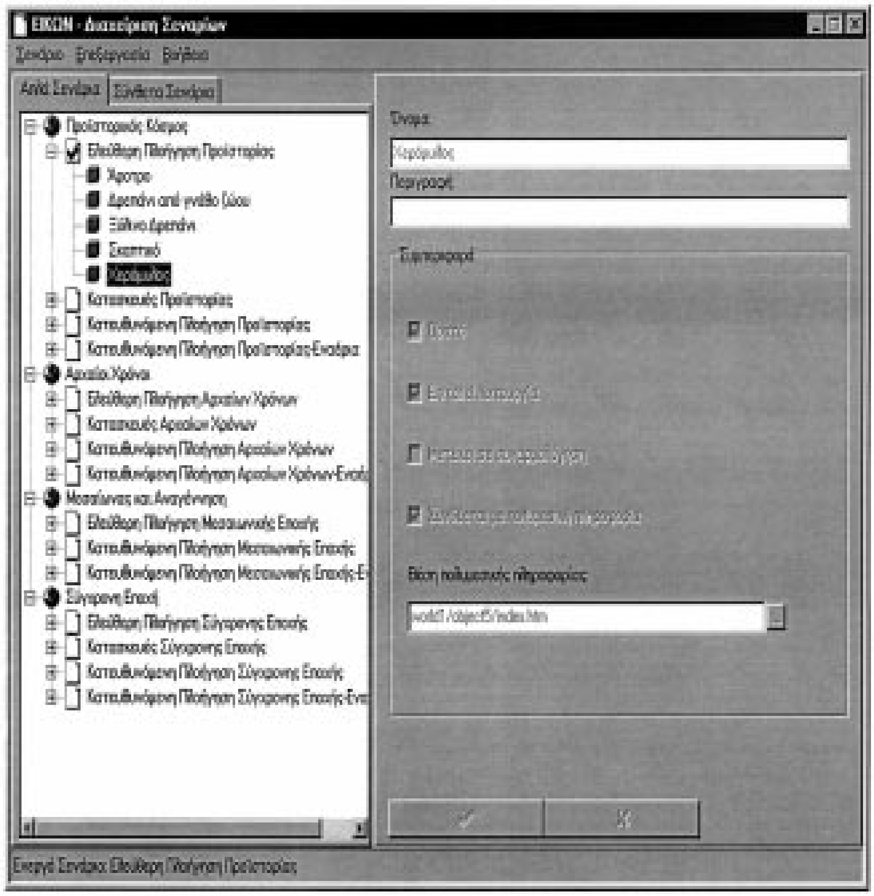

Figure 2. The Scenario Manager.

associated set of attributes. First of all, depending on the scenario, an object may be visible or not visible. Moreover, an active object may:

- Perform a default operation when activated by the students (for example, a watering machine may start spraying water)
- Take part in an assembly sequence, the steps of which must be performed in the correct order by the students (for example, in order for the watering machine to be ready-to-operate, students must connect it to a set of tubes, which they must connect to the water pump)
- Be associated with a multimedia content unit, which is displayed in the library area when students select the object.

The current version of EIKON supports two types of scenarios:

- Guided navigation. Students are navigated through the VR microworld, under the guidance and control of the system. Limited interaction is supported, such as pointing and clicking on 3D objects. Students may select between eye-level and aerial views.
- Free navigation. Students navigate freely within the limits of the VR microworld, by moving a viewpoint attached to their virtual self (who they cannot see). During their navigation, students may interact with objects, activate or assemble them.

EIKON is currently shipped with a set of pre-constructed scenarios. Teachers may use any of these, or they may construct new ones of their own. In order to guarantee correct operation (and to relieve much burden from the teachers), each new scenario has to be based on one of the pre-constructed ones. So, in order to define a new single-world scenario, all that a teacher has to do is to select the basis scenario, give it a new name and (optionally) fill the other fields, and finally, assign values to the attributes of the objects involved in the scenario. The teacher need neither be a computer expert (only typing and point-and-click operations are involved), nor invest a large amount of time (very quickly, the teacher can prepare the scenario of today's class, or even modify it during the lesson). At the same time, a high degree of reusability and robustness is achieved.

In general, students are expected to work with the current educational scenario, which is defined by the teacher. Guided navigation scenarios may be used in order to give students an overview of the VR microworld, or of the era it represents and the tools that were available during that time. During a free navigation scenario, students can navigate freely inside the VR microworld, using the mouse and the navigation controls at the bottom of the VR window. The students can move forwards or backwards, change direction (turn to the left or to the right), or turn their head, without changing their location. The software can also support, in a plug-and-play manner, other interaction devices, such as joystick or spaceball. It also supports 3D vision using 3D glasses.

As students navigate inside the VR microworld, they may:

- Locate a 3D object, which seems interesting. Students can manoeuvre in order to approach the object and take a better look at it. Then, they may select and rotate it, in order to gain a better understanding of its structure (in Figure 1, the digging tool is being rotated).
- Learn more about an object by clicking on it and studying the associated multimedia content unit, which is displayed inside the library area. In this case, the library window displays only the content unit that is associated with the selected object. If students feel they need more information, they can switch to 'library mode'. In this mode, they have unlimited access to all multimedia content units using the contents bar that appears to the left of the library window. Content units are grouped by era (that is, by VR microworld).
- Activate an object and study a real-time representation of a process in which it participates (for example, activate a furnace and watch how minerals melt and scythes are produced).

- Assemble a 3D object, by dragging its parts to their correct position and then study the operation of the assembled object. The required parts may be found in the nearby space, or they might have to be carried from another location in the VR microworld.

Students have access to some of the tools of the toolbar, which include (Figure 1, from left to right):

- The ‘load current scenario’ tool: when pressed, loads the current scenario. This tool allows the teacher to change the current scenario during a tutoring session; then he/she asks the students to load the new current scenario. Moreover, if the current scenario involves more than one VR microworlds, students can use this button (which, in this case, displays a small arrow and opens a pull-down list) to change the current microworld. As a consequence, the VR microworld may change.
- The ‘restart current scenario’ tool: when pressed, this tool resets the current scenario, enabling the students to apply a different problem solving strategy or to return to a ‘home’ position.
- The ‘open/close library mode’ tool: when pressed for the first time, this button opens library mode, allowing the students to access any multimedia content units in the library. The button remains pressed until the students press it once more to close the library mode and return to normal usage. While in library mode, students can still work with the VR microworld.
- The ‘open/close student portfolio’ tool: this tool opens the student portfolio. Students can select any part of a multimedia content unit and copy it to their personal portfolio. The selection is assigned a name and is being displayed inside the portfolio window. Then, they may use the portfolio tool to export the object, through the clipboard, to any Windows application and process it further.

Technical aspects

The system was designed using the UML Object-Oriented Methodology and Notation and implemented using component technology. The system shell, which implements the core client and server functionality, was developed using Borland Delphi. The databases use the Microsoft Access engine, while the NetBeui protocol supports network connections. Two ActiveX components were used: Microsoft Internet Explorer as the HTML visualisation component and Superscape Viscape, as the VR microworld rendering component. The behaviour of 3D objects was programmed in SCL, the proprietary language that VRT supports. The other student and teacher tools were developed using Borland Delphi. The multimedia content units were especially designed for the needs of the users of EIKON.

The open and modular system architecture permits, with different degree of difficulty, the evolution and adaptation of either its functionality or content. As far as the latter is concerned, since Internet Explorer can display any HTML file, teachers may develop

HTML pages of their own, which they may associate with 3D objects through the scenario manager. In this way, the content units of EIKON can be tailored to better suit each teacher's personal style or to accommodate new knowledge. The LAN administrator is also capable of adding content units directly in the system database.

On the contrary, Viscape can render only VR microworlds developed with Superscape VRT. In order to add a new microworld, or to modify an existing one, one should be able to use VRT, in order to design the landscape, develop the 3D objects and program their behaviours. This task is not at all trivial and is limited to the system administrators. New modules with extended functionality are expected to replace the current ones in the final system version.

Pedagogical Issues

EIKON is an open educational environment adopting an interdisciplinary approach to technology courses, and specializing in agricultural technology. The environment is based on constructive and collaborative learning through the enhancement of students' experiences and the allowance of new ones.

The basic theoretical statement of constructivism leads to the estimation that the prerequisite didactic techniques are inefficient. The strict planning of the didactic content, the premeditated choice of the medium, and the form of interactivity in the typical educational process, are not efficient conditions for the efficacious activation of learning mechanisms. Students have to work in real or artificial environments where they can construct knowledge by themselves. Real environments are not always available, so there is a need for artificial environments that simulate the real ones. Virtual (artificial) environments are proposed in situations where students have no direct experiences; they are open environments where students and educators may construct anything they wish. Virtual environments allow students to apply previous knowledge, to manipulate virtual objects and assemble new ones, to get new information and experiences, and to exploit them all to construct new knowledge.

EIKON is based on and exploits the following pedagogical principles:

- Mastery learning for the acquisition of basic knowledge
- Prerequisite knowledge and skills through the knowledge organization in a new spiral form
- Secondary learning through the retrieval and usage of additional information
- Direct instruction via free navigation in the virtual environments, exploration of the multimedia material, and immediate feedback
- Direct experience through the student involvement in processes in virtual environments
- Cooperative learning through the work over the network
- Learning styles through the individuation of exploration
- Transfer of learning through the interdisciplinary approach of the content
- Student and classroom management by the teacher.

The didactic objectives of EIKON include:

- Knowledge construction on the agricultural technology through the ages and its cultural contribution
- Skill development for the classification and usage of information concerning agricultural tools, machines, and processes
- The relation of the educational process with the technological physical world, experiences and interests of the students
- The development of communicational and collaborative skills.

The proposed educational software is for individual use for high school class A, and collaborative use for high school class B, according to the national curriculum. It can be also used in elementary level. A reason for choosing agricultural technology as the topic of EIKON, is that Greece is a mainly agricultural country, and every student, specially those living at urban areas, has to know about all implications (economic, cultural, environmental) of that particular type of technology. Moreover, agricultural technology is offered as a topic for an interdisciplinary study through the time based on historical revolutions.

Empirical study

A first pilot evaluation of EIKON had been conducted with a sample of 94 in-service elementary school teachers. The research axis were the study of the teachers' attitude towards the virtual learning environments, as well as towards the specific application for its exploitation in the educational process. All the teachers were familiarized with the software very quickly, and they agreed that EIKON substantially contributes to the educational process (Mikropoulos et al., 1999).

The present study concerns a different sample, of 19 high-school teachers. They are information technology teachers having a degree in computer science. They manage the computer lab at their school, and contribute to any discipline supported by computers. During the time of the study all the teachers were attending a further education program on didactics. The teachers worked with EIKON for two hours each, and after that they filled a questionnaire. The research axis are described by four indices, namely content evaluation, pedagogical evaluation, software quality evaluation, and attractiveness of the application. Table 1 shows the results concerning content evaluation. The majority of the subjects found content well organized, and the tree structure of hypermedia information easy to explore even by novice users. Concerning the competence of multimedia information, more than half of the subjects found it adequate, with the exception of video. This result was anticipated, since EIKON is a pilot project dedicated to six academic hours only. The volume of the information content of the current version of the application is limited, and it will be increased in the future version.

Table 2 shows the pedagogical issues evaluation. The majority of the subjects had a positive acceptance for all the variables, indicating that EIKON has the potential to support the educational process. Two important results indicating the acceptance of a constructive

Table 1. Content evaluation

Variables	F (%)
Satisfactory chapters' organisation	88.2
Existence of unknown technical terms	41.2
Competence of multimedia information	64.7
Accretion of video	73.7
Accretion of text	33.3
Accretion of pictures	36.8
Accretion of sound	38.9

Table 2. Pedagogical evaluation

Variables	F (%)
Suitability for interdisciplinary work	94.7
Linkage between old and new information	93.8
Motivation for continuity of work	94.4
Motivation for collaborative work among students	72.2
Motivation for collaborative work among students and teachers	94.4

Table 3. Software quality evaluation

Variables	F (%)
Software reliability	70.6
Efficient on-line help	100.0
Efficient information inquiry and retrieval	77.8
Convenience in navigation in virtual environments	26.3
Convenience in multimedia information management	31.6
Software friendliness	89.5
Convenience in scenarios management	68.4
Convenience in notepad usage	83.3
Convenience in orientation in virtual environments	100.0
Realism of virtual microworlds	68.4
Understanding of manuals	92.3

and collaborative artificial educational environment, are the 93.8% for the linkage between old and new information, as well as the 94.4% concerning the motivation for collaborative work among students and teachers.

Concerning software quality, Table 3 shows that this is very good, except the convenience in multimedia information management. An important factor is that all the subjects had no problems with the orientation inside the application. This is partially because of the existence of a navigation map showing the ground plan of each microworld. This is a strong indication that virtual environments can be used in the educational process.

A subject under investigation is the hardware interface for the navigation in virtual environments, since only 26.3% of the sample found it easy to navigate using the controls provided by the software. A possible solution might be the use of the mouse, as data have shown that this is the most familiar device for navigation in virtual worlds (Mikropoulos et al., 1998). Finally, 63.2% of the sample found the application attractive to be used by students and teachers. Moreover, almost all of the subjects (94.1%) found a great deal of interest in the ability to compose essays using the tools of EIKON (notepad, student portfolio), by dragging and dropping multimedia elements into general purpose software packages.

As a conclusion, the results of the present study indicate competence of multimedia information, very good instructional design, and very good software quality.

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