Use of Multimedia and the World Wide Web in Civil Engineering Learning

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Abstract: The case study method, which has been proven to be a very useful learning tool, can be further enhanced with the use of multimedia and the World Wide Web. This paper demonstrates multimedia and Web-based enhancement with the design and construction of a port, a large-scale civil engineering project. The main purpose was to create an educational tool that brings into the classroom a "real-life" design and construction problem, including the construction field, operation of equipment, and details of construction methods. This enables civil engineering students to better understand the details of the planning, design, and construction of a complicated project. Furthermore, through the use of evaluation tests, feedback on the students' understanding of the case study can be provided to both the students and the educator. This application can be expanded beyond an academic environment for use as a learning tool in a business environment, which may be especially beneficial for new engineers.

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Introduction

Today's society faces an immense proliferation of all aspects of knowledge. In order to keep curricula from becoming dated, current research results and applications to "real life" must be incorporated into today's classrooms. This integration implies a need for instructor awareness of the latest advances in engineering education. More and more students wish to obtain higher education. Technology is moving fast in some areas so educators need additional training every few years. Both of the above lead to a deficit of available educational resources. Technology is moving fast in some areas, so educators need additional training every few years; this demand leads to a deficit of available educational resources. Additionally, adult and part-time learners are becoming important consumers of higher education, requiring methods of educational delivery addressing space and time separation and student diversity (Vouk et al. 1999).

Engineering educations specifically has to address creativity, teamwork, hands-on learning, and interdisciplinary issues (Davis 1998). Creativity and critical thinking can be stimulated with teaching techniques such as problem-based learning and cooperative learning (Johnson 1999). It is important to help students understand basic principles but also to develop their skills to acquire more specialized knowledge as required (Beder 1999).

Emphasis should be given in (1) helping students integrate knowledge across courses and disciplines; and (2) teaching more about real-life engineering and operations, and on how to acquire knowledge from a variety of sources (Woods et al. 2000). Exposing students to real-life problems and other important issues can be addressed with the use of case studies. A comparison between case-based teaching and traditional teaching is given in Angelides et al. (2000).

The written format of the case study method used in business institutes has been augmented in engineering instruction with the use of time-lapse video technology (Oglesby et al. 1989). This approach is limited to "linear" data access and retrieval capabilities; that is, the tape must be linearly advanced or rewound to the location of interest. This obstacle is removed with the use of digital multimedia approaches to support engineering instruction with the case study method (El-Bibany and Schuld 1995; Webster 1996; Chinowsky 1998). In particular, Chinowsky developed a prototype for an electronic library that includes civil engineering case studies using Web-based technologies. Navigation in the electronic library can be direct item viewing or sequential learning.

In addition to multimedia, several other information technology (IT) capabilities, such as e-mail, white boards, chat rooms, and the Internet, can support new trends in engineering instruction and further enhance a student-centered learning environment. The concepts of a student-centered learning environment and the supporting role of IT have been discussed by Cook and Cook (1998), Richards et al. (1995), and Kessler et al. (1999).

Angelides et al. (2000) enhanced the case study approach using multimedia and focusing on project flow and integration of design and construction.

The case study method, which has been proven to be a very useful learning tool, is further enhanced in this paper with the use of the World Wide Web. The main purpose of this work was to create an educational tool that brings to the students a real-life

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design and construction problem including the construction field, operation of equipment, and details of construction methods. Special effort was made to create a tool that the students could operate by themselves, can facilitate interaction among the students, promote collaborative learning, and provide easier access and a cross-organizational view of a project's analysis-design-construction processes.

Furthermore, through the use of evaluation tests, feedback about the understanding of the case study was provided to both the students and the educator. The students' opinion about the application and its use is presented at the end of this paper, followed by statistical analysis of the data provided by questionnaires answered by the students. Finally, the tool could be expanded beyond the academic environment, companies' environment, especially for the benefit of new engineers.

Table 1. Advantages and Disadvantages of Web versus Multimedia CD-ROM Versions

Multimedia	Advantages	Disadvantages
CD-ROM	• Quality of multimedia	• Difficult distribution
	• Faster browsing	• Versioning problem (for updates)
	• No special software required	• Shipping of CDs
	• Internet connection not required	• No feedback on statistics of use
Web	• Worldwide availability	• Connection to Internet
	• Easily upgradable	• Internet software
	• Communication capabilities	• Quality lower than multimedia
	• Cooperation capabilities	• Limited bandwidth for video/audio
	• Use of existing information on other Web sites	
	• Feedback on statistics of use	
	• Security control	
	• Feedback to instructor	

Case Study Method with the Use of Multimedia and the World Wide Web

The engineer of the twenty-first century needs to be familiar with the concept of a projects' life cycle and its subprocesses (Angelides et al. 2000). The planning, design, construction, and maintenance phases of the life cycle and their mutual influence are highly dynamic and require teams of engineers with creativity in decision making, communication, and teamwork skills.

The case study method is a step forward in providing training in critical and creative thinking skills and real-life problem solving. Case studies are derived from actual experience and combine knowledge and techniques from several disciplines taught in several engineering courses. The limitation of this teaching approach is that it requires prior student background in several disciplines, and is therefore more suited to upper-level students.

The case study method is enhanced with the support of IT. The new computer and communication technology could revolutionize the way that the students, instructors, and researchers access and use information. The integration of IT in the education system enhances students' access to knowledge (Boy 1997) and can facilitate interactive and cooperative learning where the students can learn from each other, and the instructor can learn from the students and receive feedback on the students' learning level and process.

In the recent past, use of IT innovations into the educational process was a major undertaking technically and economically; this was primarily due to hardware setup and maintenance and the need for software environments specific to the individual educational tools. Presently, there have been many impressive achievements in the application of IT to education; however, some of these can still be characterized as "point solutions" (Vouk et al. 1999) targeted to solving a particular problem (e.g., a set of courseware modules for teaching structural analysis/design issues). The focus on point solutions could be primarily attributed to constraints imposed by technical system requirements, and lack of appropriate familiarity of educators with the rather sophisticated technology. New technical capabilities that are easy to implement were provided with enhancements of the World Wide Web. The World Wide Web was a breakthrough in defining a standard for decoupling information/content and hardware/software delivery systems. The Web browser is now an "appliance" (Vouk et al. 1999).

A Web-based learning environment enables interactions between teachers and learners, through e-mail or forums, outside the teaching hours; opens the class toward the real world and to wide views, facilitating contacts with professionals through relevant links; enables personalized learning (students often have heterogeneous levels of learning; also, it is possible for students to control their own rhythm of learning); and includes not only written materials, but also voice, video, and image materials, which are sometimes more efficient for knowledge transfer (Tassin and Deutsch 2000).

The case study of the port construction in this project is presented through two different pieces of software that cover most educational needs. The first software product is a multimedia application, which is distributed through CD-ROMs, and is most suitable for stand-alone use in a personal computer or for a classical presentation in a classroom. The second product is a Web site containing most of the information included in the CD-ROM, but with enriched functionality utilizing the communication capabilities provided by the Internet. This version is most suitable for cooperative learning, dynamic presentation in a classroom, or even for distance learning.

Although the two software products are aimed at different educational needs, their scope is not easily distinguishable. Apart from the educational needs, the choice of which one to use must be also based on other factors such as network availability, expected quality of multimedia, frequency of updates, etc. Table 1 gives an overview of the advantages and disadvantages of the two approaches.

The multimedia CD-ROM version and the Web version of the tool developed in this work blend information based on text, graphics, photos, drawings, and videos to support engineering case studies. The text becomes dynamic through the use of hypertext that provides the user with links to modular information. The architecture of the structure of this project follows the flow of the real-life project. The IT-supported modular and integrated information brings together teaching methods from several instructors specialized in different disciplines with field experiences in real-world projects. The tool presents several key characteristics:

- Hypertext structure that enables information to be stored and viewed in manageable sections, which are linked together and can be searched in different ways;
- Information structured into smaller units than in a printed document to facilitate reading comfort;

- Flexibility that encourages the user to take active control of the learning process;
- Balance between guidance and freedom of the user;
- Text "linking," rather than scrolling, and
- Electronic index that facilitates reaching a specific page.

The classroom arrangement does not differ from the traditional case study method; however, the creation of the Web version makes the case study more dynamic and easy to use for the students outside the classroom, while promoting collaboration and interaction among them. The Web version of this tool provides various advantages for the future way of academic learning, including imminent access to information by the students in their own environment, schedule, and pace; facilitation of interaction among students; possible collaboration among students in different geographical locations (the Web version provides remote access capabilities that the CD-ROM version is unable to supply); active participation of students to assume responsibility for their education; enhanced retention (due to high interactivity); and stimulation for effective learning.

Case Study Description

The multimedia CD-ROM and the Web-supported case study developed in this project describes in great detail the design and construction of the first phase of a major project—the Port of Mykonos, in Greece (phases B and C are currently under construction). This case study is part of the senior-year course on marine structures in the Department of Civil Engineering at the Aristotle University of Thessaloniki. The first part of the course is taught with the traditional lecture-type approach, while the second part focuses almost exclusively on the use of case studies. Three case studies are presented, two with lectures and discussions in the classroom, and one, the Port of Mykonos, with the use of CD-ROM and Web versions both by the instructor in the classroom environment and by the students studying individually. The Port of Mykonos case study described in this paper has been developed within the framework of a senior thesis with the close involvement of the project manager of the actual project.

The system architecture of the CD-ROM and Web versions of the tool is shown in Fig. 1. The flow of information follows that of the real project, while integrating several disciplines of civil engineering—hydraulics, structures, geotechnical, marine, and project management. The processes of the project are presented in several levels of detail. There are three levels in the hierarchical structure of the software. In the top level there are six sections: main page, introduction, technical studies, project construction, financial data, and time schedule. The nodes at the second level are identified by numbers formatted as $X.Y$, where X is a number between 1 and 6. For example, nodes 3.1 Hydraulic, 3.2 Geotechnical, and 4.2 Bridge are second-level nodes. Similarly, nodes 3.2.1 Introduction and 3.2.2 Initial Study belong to the third level. Note that the navigation map is not complete, that is, there are nodes (e.g., 3.1, 4.1, 5) that can be further expanded, but this is omitted due to space limitations.

The number of moves needed for a transition from one node to another is equal to the number of nodes in the path minus one. For example, the path from node 4.2 to 4.5 contains only these two nodes, and thus the number of moves is equal to one; the path from 4.2 to 3.2.1 contains four nodes (4.2, 3, 3.2, 3.2.1) and therefore this transition needs three moves.

The planning and design of the CD-ROM and Web versions of the tool follow the structure of an ordinary Web page. Multiple hyperlinks, photographs, drawings, video clips, active documents, text, and graph data are blended so that the user can access the information that he or she needs. Furthermore, the use of software agents (denotation and definition agents [Boy 1997]) reduces the complexity while at the same time improving, managing, accessing, and interpreting the provided information. A denotation agent associates text descriptions to corresponding graphical objects, while a definition agent establishes a correspondence between a text description and a mathematical formula. For instance, when the mouse is dragged over a highlighted sentence, a denotation agent shows the relevant sketch or graphic.

The combined use of text, graphics, video, and drawings make the case study dynamic, providing detailed information that covers the field of all the previously mentioned disciplines of civil engineering. The CD-ROM and Web versions of the tool facilitate

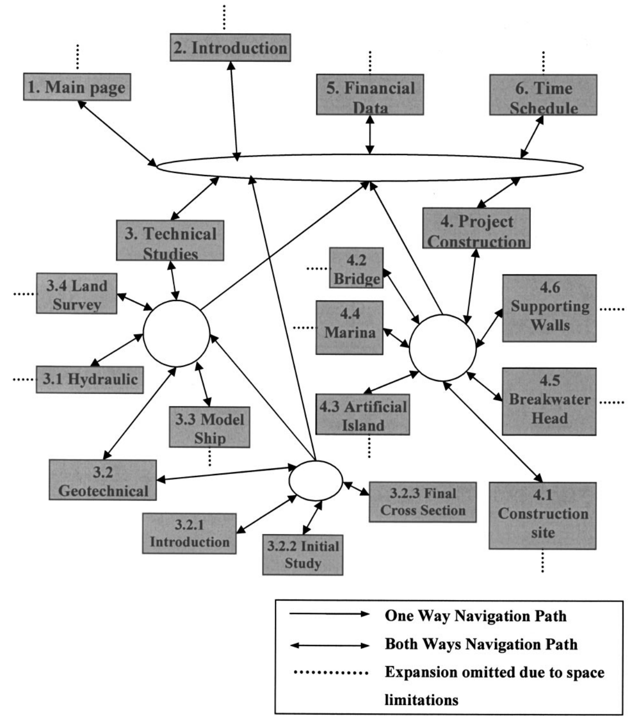


Fig. 1. System architecture and navigation map

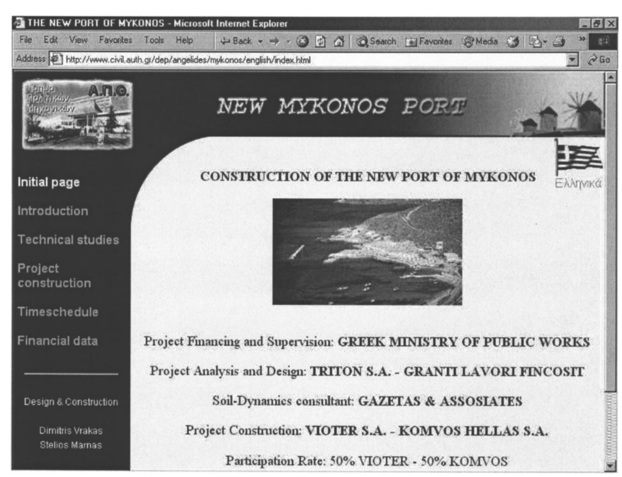


Fig. 2. Main page (Web version)

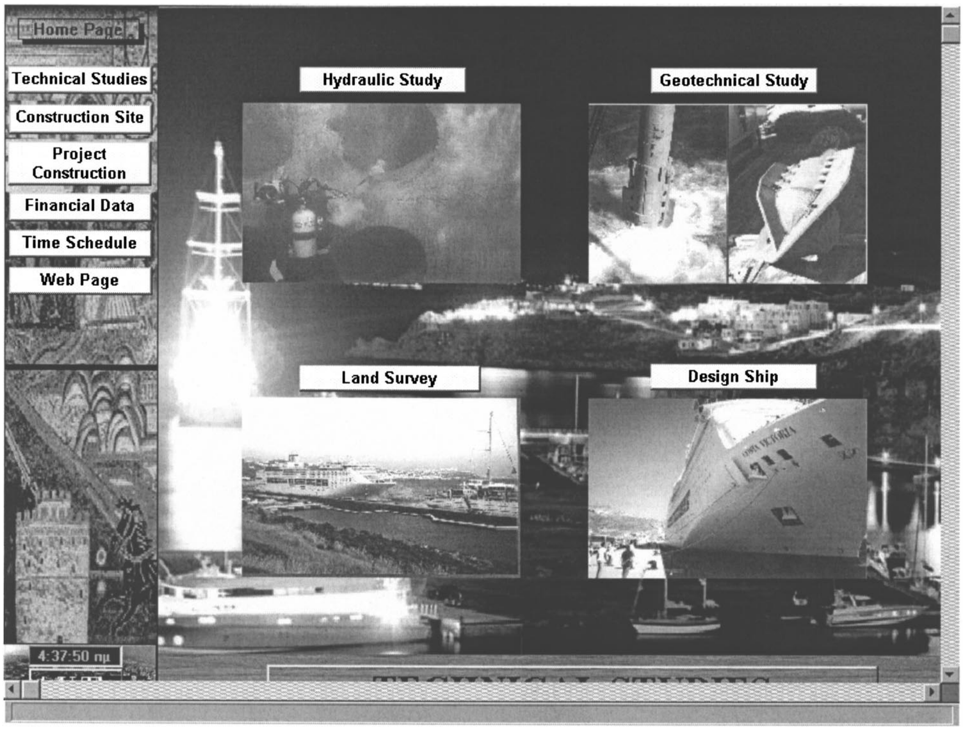


Fig. 3. Main page, technical studies (CD-ROM version)

a modular environment where expertise from different disciplines, different instructors, and different project managers can be brought together.

The user enters the main theme page, shown in Fig. 2. On the left side of each page links have been included that lead to each of the five basic thematic units of the case study—introduction, technical studies, construction, financial data, and time schedule. Entering any main page of the five thematic units, the user has the ability to choose any of the subthematic units that comprise the main one. For example, if the user clicks on the technical studies link, he will obtain a page that has links to each of the four subthematic units—hydraulic study, geotechnical study, design ship, and land survey (Fig. 3).

On the first page of the construction unit there is an interactive map of the project, shown in Fig. 4. As the user moves the mouse over an area of the project, a denotation agent reveals the title of that area; by clicking on the area the user obtains the page of that area. For example, if the user clicks over the bridge then he will obtain the main page of the thematic unit of the bridge section (subthematic unit of the construction section). This describes with every detail the analysis/design and construction of the bridge. While creating the case study application, there was an effort to extract each part of the actual project and present all the information that was needed. For example, when the user enters the bridge section, there are links to units on the left part of the page that cover several items of the bridge's design and construction (Fig. 5).

As was previously mentioned, the case study integrates several disciplines of civil engineering while following the logical flow of the physical project. Hydraulic engineering was used extensively. Two examples of text, diagrams, and drawings are presented in

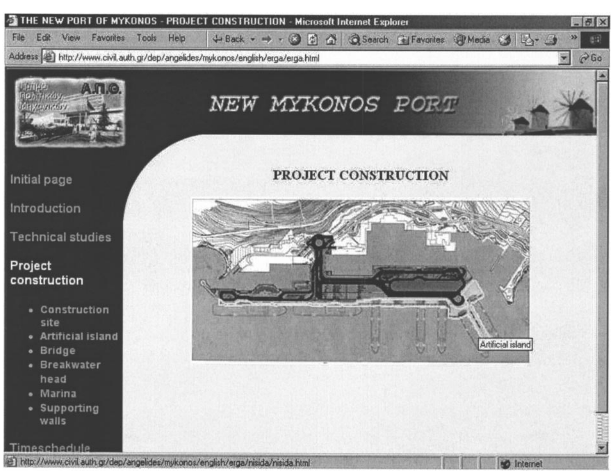


Fig. 4. Main page, project construction (interactive map Web version)

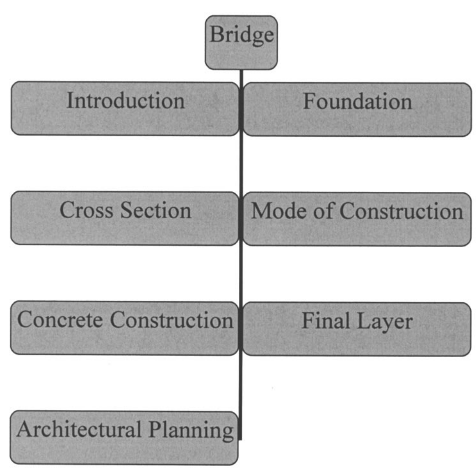


Fig. 5. Subthematic unit, construction section (bridge) and its units

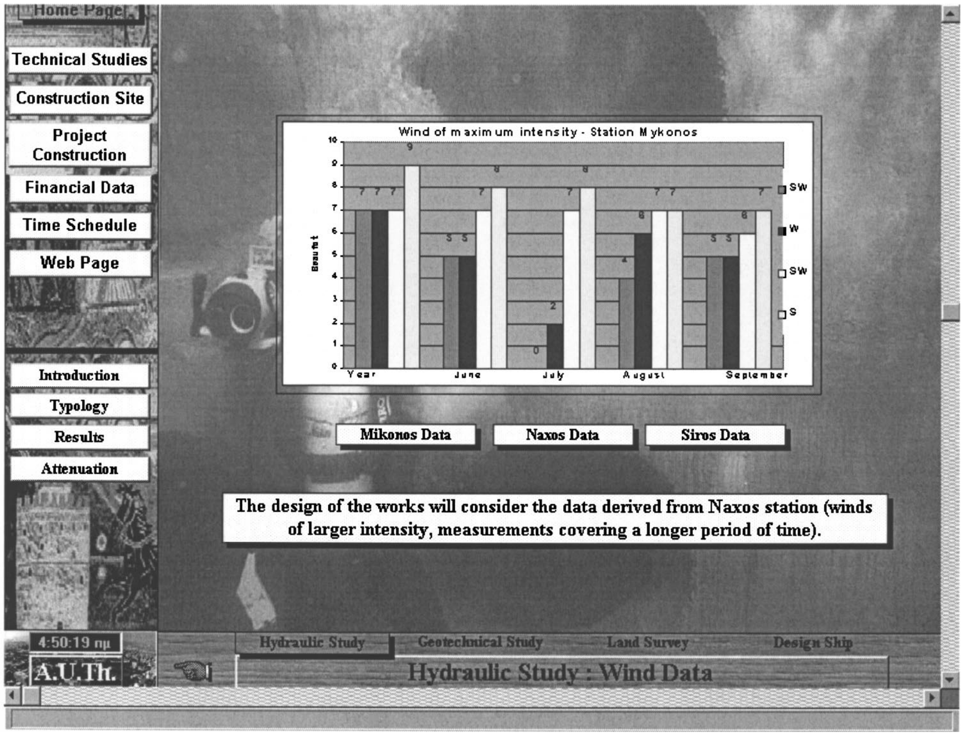


Fig. 6. Wind intensity charts (CD-ROM Version)

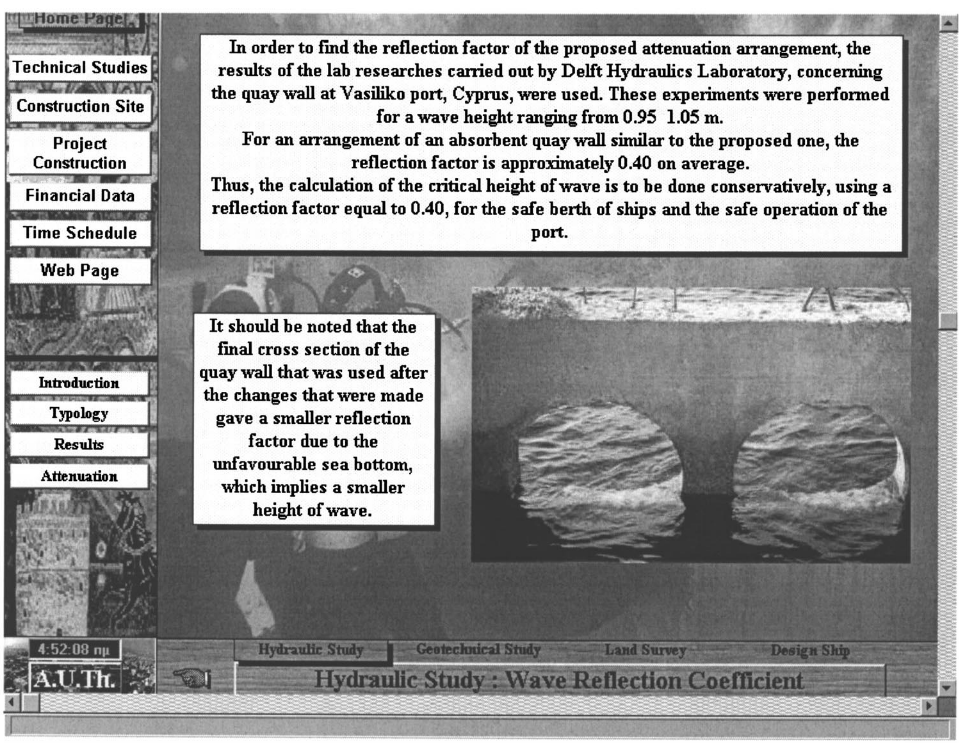


Fig. 7. Combination of text and photograph (hydraulic study, attenuation holes) (CD-ROM Version)

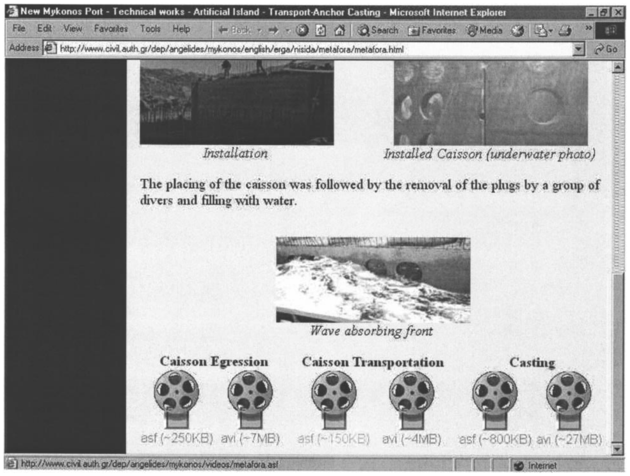


Fig. 8. Video buttons

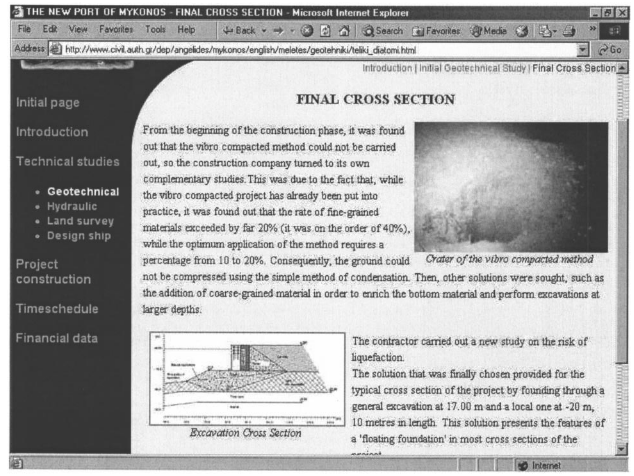


Fig. 10. Geotechnical study (final cross section)

Figs. 6 and 7. Construction methods and construction details were of great importance in this project. Again, the combination of text, drawings, photographs, and video (Figs. 8 and 9) represent an effort to improve the presentation of the construction methods and details. Finally, geotechnical engineering considerations for settlement, landslides, and liquefaction, as well as project management, are presented with text, graphics, and photos (Figs. 10 and 11).

Evaluation of the Software

The improvement in the teaching process with the CD-ROM and Web-based software tools (particularly the Web-based tool) was evaluated with (1) a statistical analysis performed on examination results used to assess the students' performance on the port design course (which contains as subset the Port of Mykonos software-based case study), and (2) student questionnaires aimed at the evaluation of the case study application itself. The statistical analysis on the examination results aims to assess the level of contribution of the software in enhancing the knowledge acquisition and comprehension. The results from the questionnaires illustrate the level of student satisfaction with the use of the software.

For the statistical analysis, data was used from the examinations for two years before and after the introduction of the software to the teaching process. In each year, there were approximately 40 students attending the class. The examinations included two components: first, two quizzes and an oral exam on the whole of the material covered in the course; second, an electronic test comprising questions relevant to generic knowledge included in the port case study, and specific knowledge directly related to the

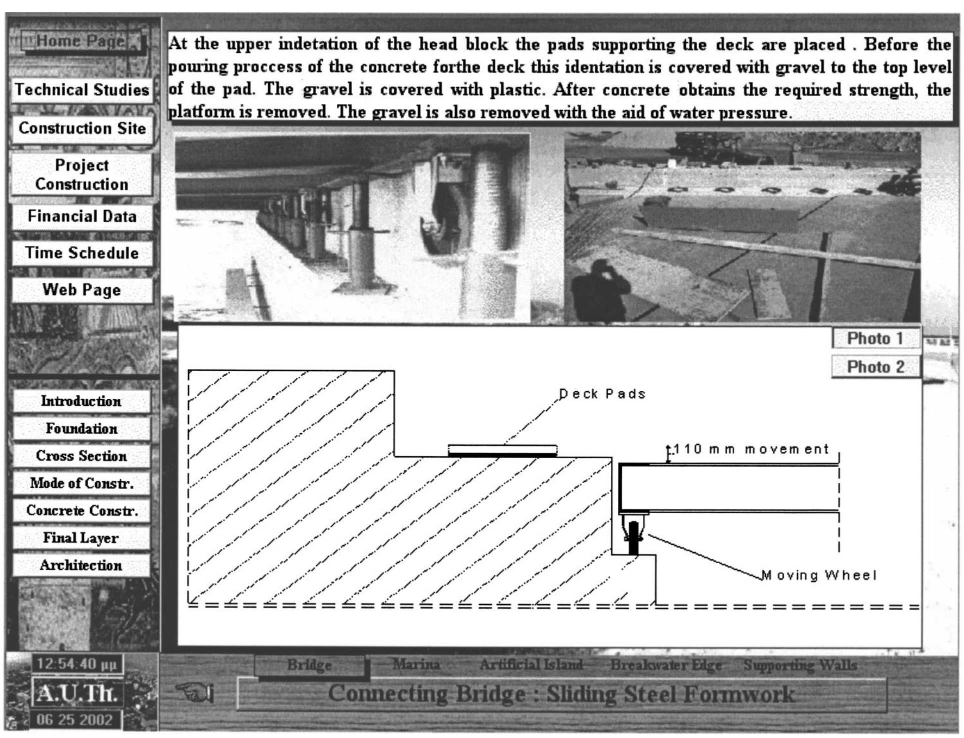
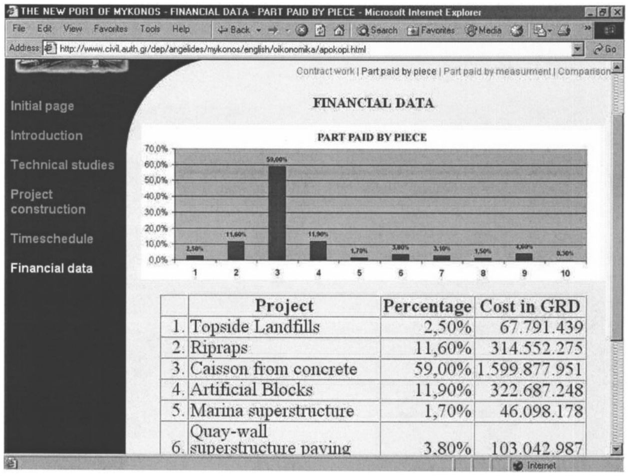


Fig. 9. Combination of photographs and drawings (CD-ROM Version)



	Project	Percentage	Cost in GRD
1.	Topside Landfills	2,50%	67.791.439
2.	Ripraps	11,60%	314.552.275
3.	Caisson from concrete	59,00%	1.599.877.951
4.	Artificial Blocks	11,90%	322.687.248
5.	Marina superstructure	1,70%	46.098.178
6.	Quay-wall superstructure paving	3,80%	103.042.987

Fig. 11. Financial data

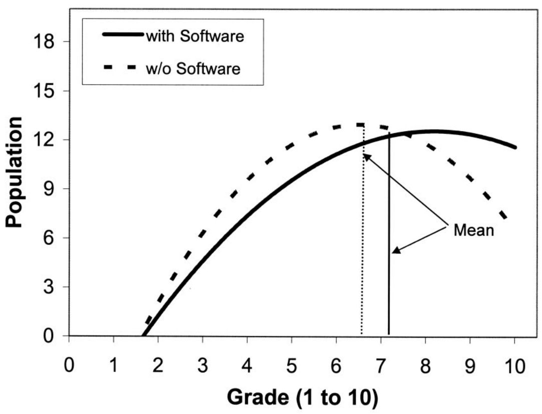


Fig. 12. Overall student performance (with and without software)

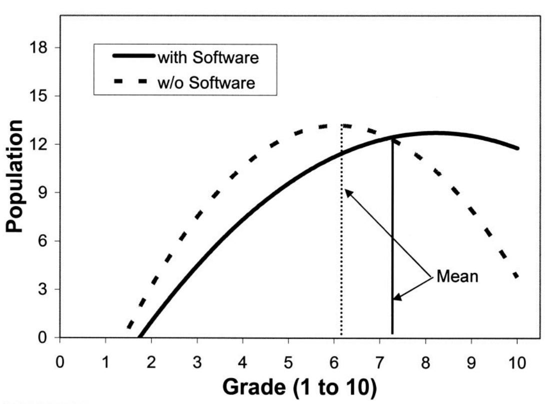


Fig. 13. Student performance: Generic knowledge addressed in the case study (with and without software)

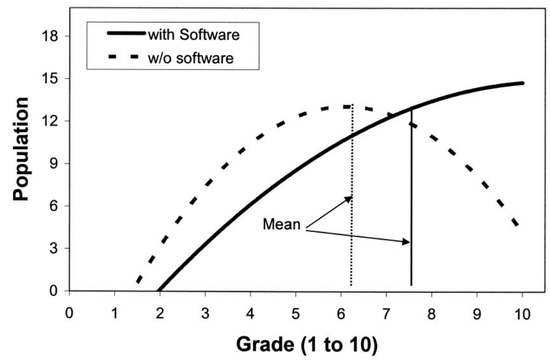


Fig. 14. Student performance: Knowledge specific to the case study (with and without software)

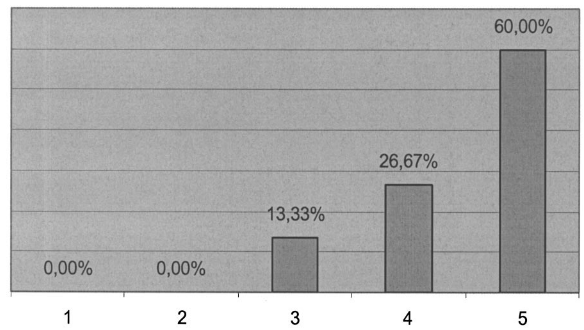


Fig. 15. Question 1: "How well did you manage to comprehend the presented design and construction methods?" (1 = not good, 5 = excellent)

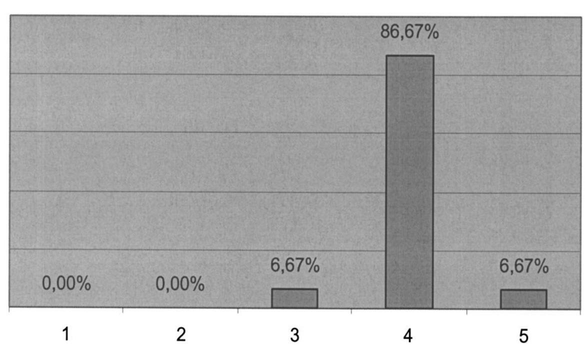


Fig. 16. Question 2: "Did the tool give you a good understanding of the relationship between the design and construction of a large project?" (1 = not good, 5 = excellent)

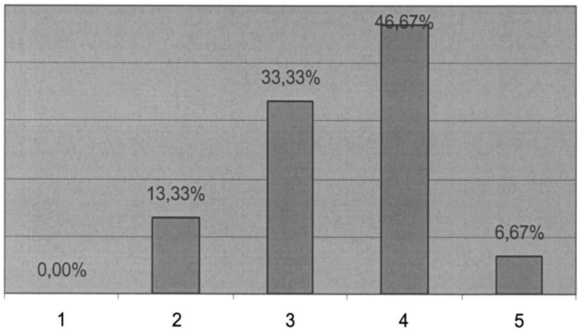


Fig. 17. Question 3: "Could someone use the CD-ROM and the Web version without having attended the presentation?"

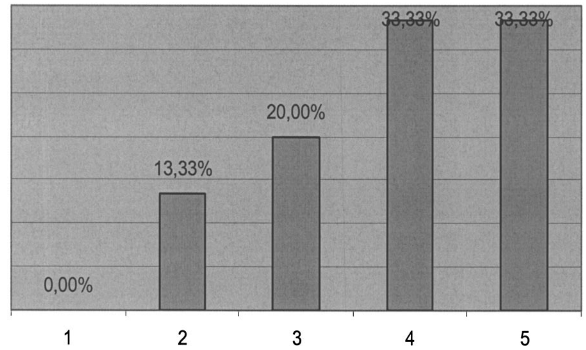


Fig. 19. Question 5: "What was the degree of difficulty of the questions in the electronic test?" (1=very easy, 5=very difficult)

port case study. The students' performance is assessed below.

Fig. 12 depicts the overall course performance of the two groups of students. As it can be seen, students who had the software at their disposal performed better. Fig. 13 shows the performance of the students in the electronic test questions relevant to the generic knowledge included in the case study. It is clear that the software tool enabled the students to learn and understand relevant generic issues quite better. Finally, Fig. 14 shows the performance of the students in the electronic test questions on knowledge specific to the port case study. It can be easily seen in Fig. 14 that the software tools assisted the students to better comprehend the details of the case study.

The results of the questionnaires handed out to the students are presented in Figs. 15–20. A limited number of graphs on the analysis of the questionnaires are presented in this paper, but as it can be seen in Figs. 15 and 16, the students managed to comprehend difficult design and construction methods, such as the construction of caisson cellular boxes (Fig. 15), and understand the relationship between the design and the construction (Fig. 16).

By examining Figs. 17 and 18, it can be deduced that the students can use the software tool to retrieve information even without having attended a presentation of the tool. Furthermore, they have the flexibility to go back to the information presented by the tool, an advantage that does not exist when the case study is told exclusively with traditional approaches. The differences between the CD-ROM and the Web versions depicted in Fig. 18 can be explained by the students' difficulty in accessing to Internet (Internet usage outside the university has many problems, such as low speed when downloading graphs and videos; problems of this nature do not occur with the CD-ROM version).

By examining Fig. 19 in combination with Fig. 15, and considering the fact that the students managed to achieve a high score in the electronic test (Fig. 14), one can draw the conclusion that both versions of the tool were sufficient in terms of knowledge transfer and retention, though the students thought the test questions' level of difficulty was rather high.

It should be mentioned that the students found that navigating the tool was a process rather swift and straightforward (Fig. 20); this proved that the selection of the particular navigation map (Fig. 1) was successful.

Technical Characteristics

For the development of the software products (multimedia CD-ROM and Web-based) of this work, a large number of tools and applications were used. The photographs that were shot by analog camera had to be scanned and processed with imaging applications (Adobe Photoshop) to extract suitable electronic versions. The videos from the construction of the port were also in analog format and had to be digitized, retouched, and compressed. For these purposes, several software tools were used, such as shareware A/D converters, VirtualDub, and Indeo/AVI codecs. Adobe Image-Ready and Premiere were also used to produce animations and special effects to the video clips. The pieces of multimedia were stitched together with Asymetrix Toolbook Instructor II for the CD-ROM version and Macromedia Dreamweaver for the Web version. The CD-ROM version required one CD of 650 MB capacity. The dynamic character of the presented material (hypertext, hypermedia) and the extended communication capabilities of the Web version were realized through Java Scripting Language.

The Web site can be accessed from the following URL: http://www.civil.auth.gr/dep/angelides/mykonos.

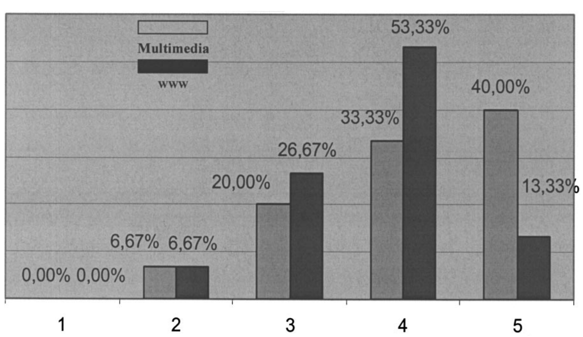


Fig. 18. Question 4: "Could you use the CD-ROM and the Web version of the tool as a source of information?" (1=no, 5=entirely)

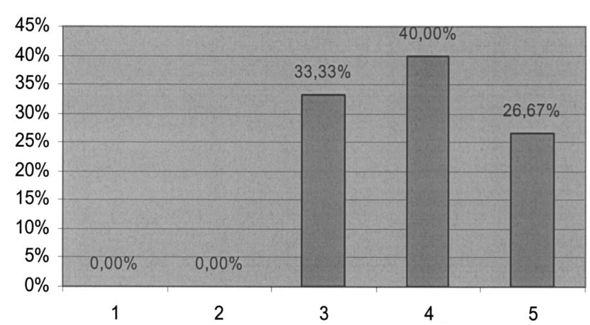


Fig. 20. Question 6: "Was the navigation through the tool uncomplicated and swift?" (1=very confusing, 5=not confusing)

Conclusion: Future Expansion of the Multimedia/Internet Tool

The multimedia CD-ROM and the Web supported case study presented in this paper have been confirmed by the students' feedback to be a very successful project. The IT-supported (and particularly the Web-supported) case study method has been demonstrated to be a very promising student-centered learning tool toward the enhancement of the engineering education.

Some of the additional enhancements that are planned in the future include the following:

- Incorporation of a database for providing more flexibility in including additional photographs, video, and textual information;
- Development of electronic libraries that use case studies to illustrate experiences and lessons learned, and stimulate new ideas;
- Inclusion of a dictionary of technical definitions supported by text, pictures, and videos;
- Enhancement of the electronic case study test to include a database for automatic grading of students, automatic calculation of statistics, and electronic feedback to the students on their relative performance in the class;
- Inclusion of a timer to record how long a student has been in the system and how long he/she takes to complete the test;
- Inclusion of a search engine to provide easier access to information; and
- Intelligent feedback mechanisms to assess the students' qualifications and learning styles for proper future adjustment of the software.

By creating electronic interactive case libraries of similar projects, the lessons learned from the past can enhance the knowledge required for future projects. This creates a direct benefit for the designers, construction contractors, suppliers, owners, and users of the construction facilities. Such a system would facilitate the organization, indexing, classification, content, and digital assets (video-photographs) of a project class. This would be a piece in the puzzle toward the new era of the projects' life-cycle philosophy.

It should be recognized that educational systems, as the one presented in this paper, imply development of a new culture and establishment of communication framework among the stakeholders of the system. These stakeholders are students, instructors, authors, and system developers. Instructors and authors could be the same person or different persons depending upon the situation and individual skills. The requirements, responsibilities, and relationships of the above four types of individuals ensure the marriage between pedagogy and technology. The Web-based educational framework should ensure a balance between "directed" and "exploratory" learning (Vouk et al. 1999). In "directed" learning the system controls the flow of information, while in the "exploratory" learning the student participates in directing the learning activities.

Finally it should be recognized that Web-based learning should not replace the in-class interaction. A hybrid approach is the best recipe.

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