DESIGN AND IMPLEMENTATION OF INTEGRATED LABORATORY ACTIVITIES WITH MEASUREMENTS, DATA ANALYSIS AND MODELLING

Maria Tsakiri, Euripides Hatzikraniotis

ABSTRACT
The Lab-based course, that is described in the present work, is offered to first year university students of Physics, mainly aiming to introduce students to the basic concepts and familiarize them with the use of Computers in Physics and with efficient Lab-reporting. It consists of a series of lab sessions, structured in a coherent way, where students perform activities that gradually guide them from taking data measurements and graphing them to advanced data analysis tasks and to mathematical modeling. The in-Lab sessions consist of measurements using the VideoJavaLab, a web-based software for the study and measurements of video based phenomena. Students, take measurements of various types of motions, and subsequently analyze them either by performing a curve-analysis or by mathematical modeling.

KEYWORDS
Web-based learning, modeling, Lab design

INTRODUCTION

Over the past two decades there has been a constantly increasing interest in investigating the role of models in physics education research. Several authors highlighted the importance of modeling activities during instruction for all levels of physics education. A number of studies have also been carried out on the combined use of experimentation and modeling activities during instruction, and the impact on meaningful learning in physics (Schecker, 1998; Rogers, 2003).

Application of theory principles for model building and their extension (mathematical modeling) that constitute the substance of scientific thought and work can become the key to an effective Physics teaching (Harrison & Treagust, 2000). As results of such application of modeling show, the physical content of laws seems to be thus better understood ("I learn Physics"). Furthermore, a combined use of modeling and experimental process can serve all three axes that Physics teaching has to face: learning of science, learning about science and learning to do science (Hestenes, 1987; Mäntylä & Koponen, 2003).

Research on the long-term effects of computer-aided modeling for an improved qualitative understanding of key concepts has so far given promising results. Several studies across Physics curricula showed that modeling can help accentuate the conceptual structure of a physical domain (Schecker, 1994; Schecker, 1996). Though it enlarges the set of phenomena that can be dealt with in school towards more complex and realistic examples, Newtonian mechanics is presented as the ideal selection to test the effectiveness of teaching with modeling, while other thematic areas require students' high scientific perception (Hestenes, 1992; Schecker, 1993).

According to Stratford (Stratford, 1996), research on learning processes through computer-aided modeling is directed in three types of learning via modeling: use of simple simulations, creation and use of mathematic models using suitable software and finally creation of simulations using special computer language.

It appears therefore from the bibliography, that students' interaction with models of real phenomena, whether we refer to the simple use of simulations or to the creation and application of new models, gives them the chance to confront their misunderstandings and to build on the comprehension of Physics concepts.

Bearing in mind the importance of the combined use of experimentation and modeling an Introductory Physics Laboratory course was designed introducing students to modern ways of doing physics. The course consists of a series of lab sessions, structured in a coherent way, where students perform activities that gradually guide them from data collection/measuring and graphing to advanced data analysis and mathematical modeling. The course involved first year university students of Physics and provides evidence on the impact of the use of laboratory activities that incorporate data measurements, data analysis and modeling on Introductory Physics.

The scope of our work was to investigate if students can accomplish integrated laboratory tasks that combine experimentation, data analysis and modeling

STRUCTURE OF THE COURSE

The course "Introduction to Computers Applications in Physics" is a Lab-based course given in the department of Physics-AUTH. It is addressed to 1st year students and aims to introduce students in the basic concepts and familiarize them with the use of Computers in Physics. The course is one semester long and covers the topics:

- On the structure and compute operation
- Windows and Internet
- Word processing (MS-word)
- Data processing and scientific graphs
- Data analysis and mathematical modeling (Mathematica)

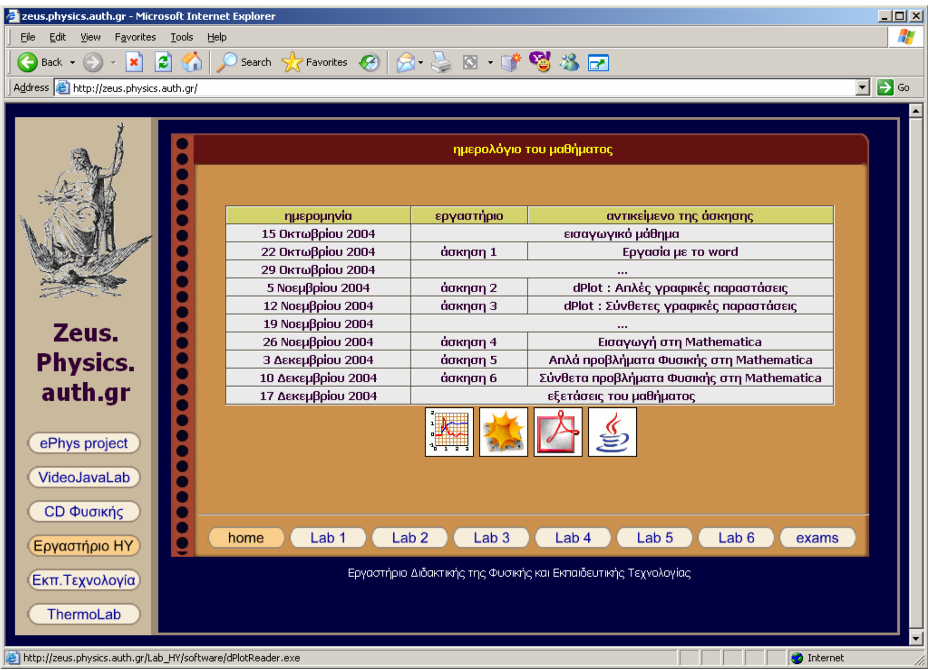

Figure 1: Home (calendar) page of the courseware material for year 2004-2005

The course, recently re-structured within **"ePhys project"** makes intensive use of ICT; VideoJavaLab (VJL) platform, developed within ePhys, has been adopted. In the new course-structure, students are gradually introduced from data-measurements to data graphing, data-analysis and finally to mathematical modeling. Re-structuring of the course has been done two-fold, with blended learning approach and context-based structure:

- A course web-site has been developed, and courseware material made available to students over the internet
- VJL, a web-based application for video measurements, enabled students take their own measurements during each lab session. Student exercises have been re-structured based on the actual data (measurements) collected.

Blended learning combines online with face-to-face learning. The goal of blended learning is to provide the most efficient and effective instruction experience by combining delivery modalities. One obvious advantage of blended learning is its ability to maximize effectiveness by matching the best medium for each learning object, the course segment (Singh, H., 2003).

Courseware material, delivered electronically, consists of two parts

- ***VJL-lab***, a web based lab exercise on video measurements (fig.2), along with a short text description of the Lab activity
- ***Lab Instructions***, in pdf file format (fig.3) which can be accessed through the "instructions" tag

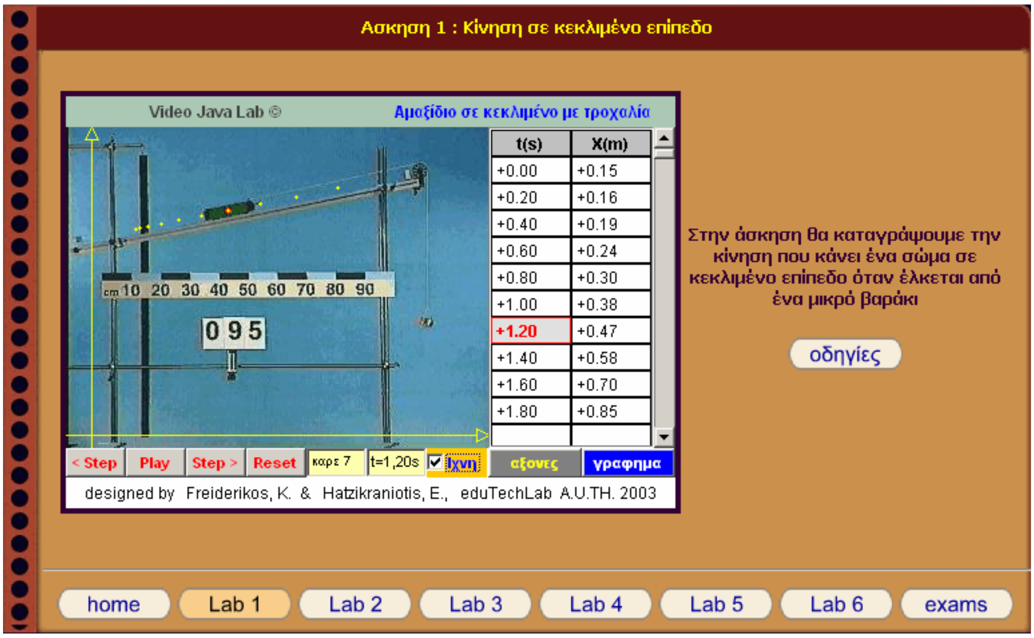

Figure 2: Typical screenshot of a lab activity in VJL (Lab-1).
Students take measurements for the motion of a cart on inclined plane.

Courseware requirements for blended learning applications

There is an increasing demand for university and college courses to be made available online and 'delivered' electronically, taking advantage of the time and place flexibility this approach offers (Collis & Moonen, 2001; Van Schaik et al, 2003). Appropriate online activities are provided to enable students work as individuals and as members of a team (Salmon, 2000; Salmon, 2002). These activities often involve problem solving, creation of essays and/or web-reports, and participation in computer-conferencing events. In order to assess students' progress and to certify the skills and knowledge they have acquired, a range of different assessment metrics has to be put into place.

For a realistic blended (home and in-Lab) learning application and course on-web delivery, the design should take into account factors like low speed Internet connections and the size of transferable data. Courseware material is structured in html pages, and instructions are in pdf format. Since the core of the course is based on Video Measurements, an innovated approach has been taken to handle and deliver the required videos

A typical video, even at a few seconds has several MB size in **avi** format; even if converted into **mov** format, size still is too high for any realistic application. Though several techniques –like streaming media methods- may be applied, and much advance has been made in educational use of streaming media, this technique is totally inappropriate for video-measurements. A main characteristic of video-measurement lab, is the option available to the students to move back and forth in frames, repeat and correct measurements, and correlate measured points with data graph-representations (Beichner, 1990; Gamboa et al, 2001). These requirements, call for a new approach in the design of a web-based video measurement lab.

- The interface has to be kept simple and developed in java language, to be accessible by students at remote access, through java-aware browser from their home PC.
- Videos for measurements have to be kept as small as possible. The selected 320x240 pixels video size gives adequate resolution to measurements leaving enough space for comments and short instructions in the html page.
- Video **avi** (or **mov**) format has been converted into filmstrip (sequence of individual frames); the VJL applet advances the frames at given frame-rate to simulate motion. Changing a typical video format into filmstrip has reduced video size to typically 50KB, which is realistic for web-delivered courseware material
- VJL applet had to be scriptable, to easily incorporate different videos, according to teaching/learning requirements.

COURSE APPLICATION, RESEARCH METHODOLOGY AND RESULTS

The course is being fully implemented since 2004, and more than 120 students have attended it so far. Initial tryouts were first applied in previous years to identify the critical conditions for a successful implementation. VJL and courseware materials were installed to an apache-based server where students had free access. During the 4-h long lab sessions students used:

- The VJL web video-measurements to collect data
- Data graphing and Data analysis software, available as stand alone applications
- MS Word to structure their report

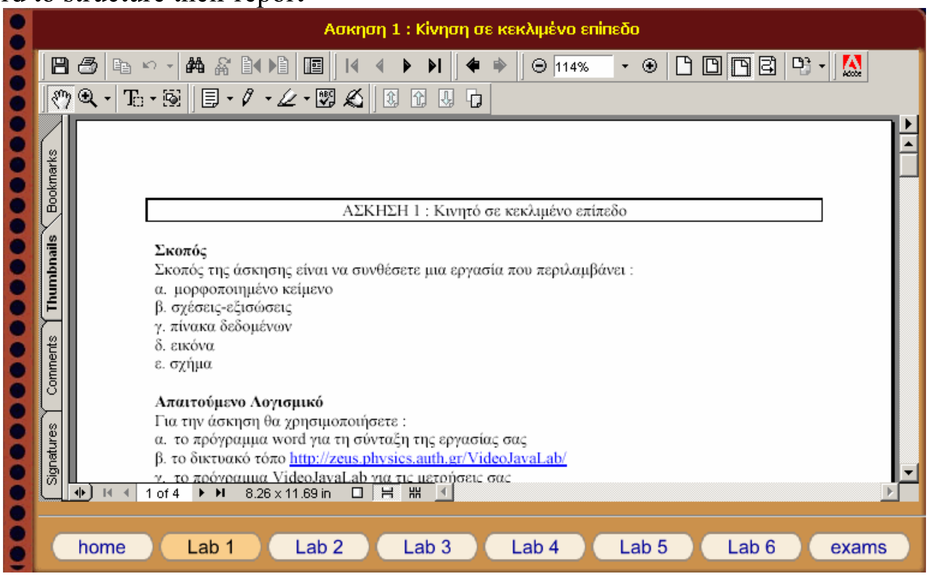

Figure3. Typical screenshot of lab instructions (Lab-1) in adobe-pdf.

The course that consists of 8 lab sessions, namely an introductory lab, a 6-step modeling process upgrading from measurements to advanced modeling, and a final lab-exams session, is summarized bellow:

- Introductory Lab: introduction to the Lab and Lab-facilities. Students work in simple problems (free body diagrams) and are also introduced to measurements in VJL.
- Lab 1 (fig. 4a): Familiarization with MS-word and report writing. Students study the motion of a cart on inclined plane. In their report they include measurements (table), and a screenshot of their VJL experiment. They are also asked to draw the forces on the cart and the falling body.

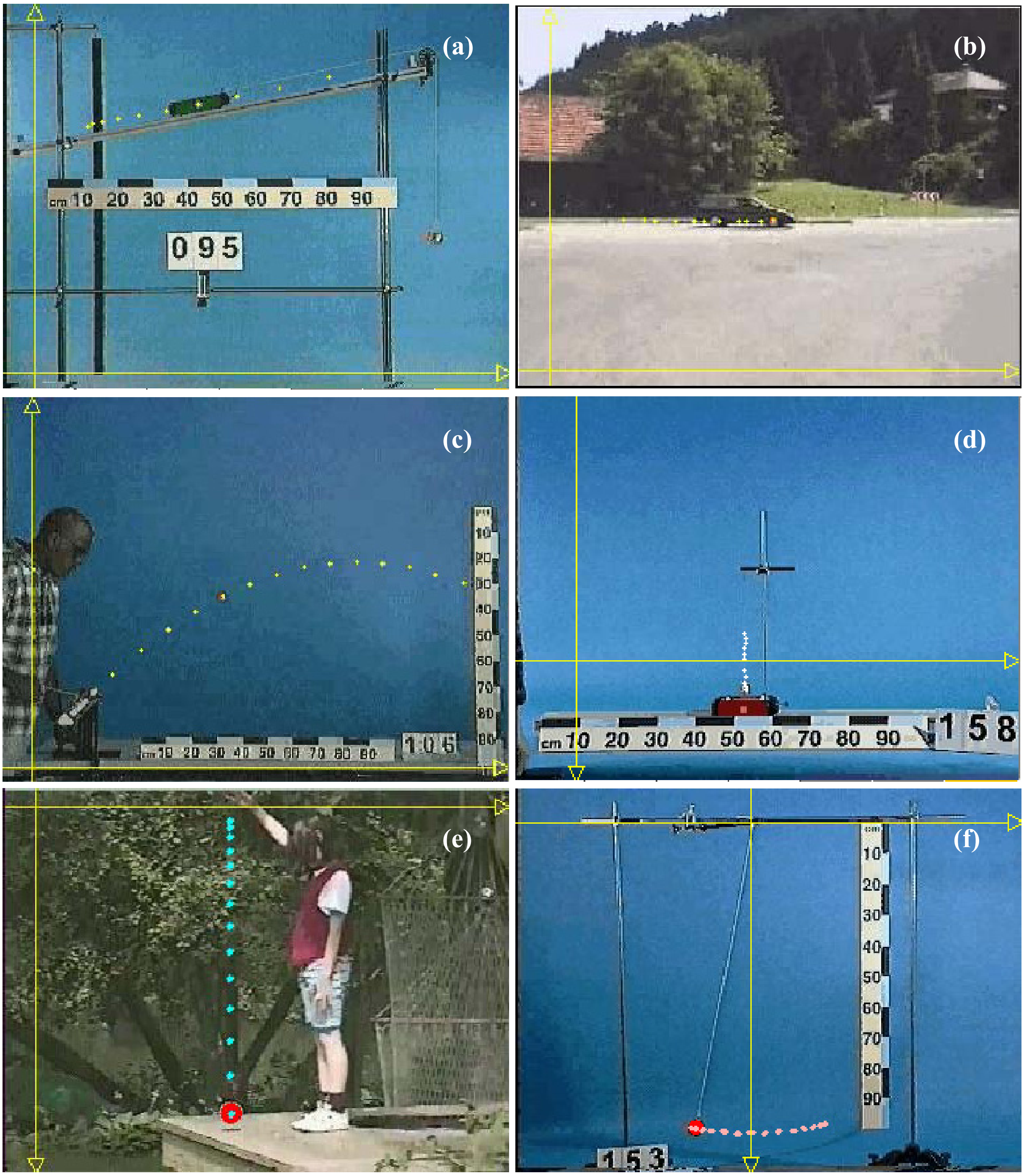

Figure 4. The 6 Labs. Dots indicate the points of measurement in each lab

- Lab 2 (fig. 4b): Introduction to data graphing. Students study the motion of a real car in the street, introduce their data to data-graph software and get X(time) graph. In their report they include measurements (table), a screenshot of their VJL experiment and the X(t) graph.
- Lab 3 (fig. 4c): Introduction to data analysis. Students study a projectile motion and make the X(time) and Y(time) graphs of the motion. They introduce their data to data-analysis software (dPlot) to evaluate the equations of motion. In their report they include measurements (table), a screenshot of their VJL experiment, the X(t) Y(t) graphs and data analysis to extract the equations of motion in the two directions.
- Lab 4 (fig. 4d): Introduction to data simulation. Students study the oscillatory motion of ball attached to a spring, and make the Y(time) graph. They introduce their data to Mathematica, and simulate the motion numerically. They calculate the equation of motion, based on the mass of the suspended ball and the spring constant. They apply this equation iteratively, changing the phase, until theoretical curve simulates their measured values. In their report students include measurements (table), a screenshot of their VJL experiment, the Y(t) graph data and numerical simulation.
- Lab 5 (fig. 4e): Introduction to data modeling. Students study the motion of a ball in free-fall, and make the Y(time) graph. They introduce their data to Mathematica, and model the motion in first principles. They apply their model iteratively, changing the initial velocity, until theoretical curve matches their measured values. In their report students include measurements (table), a screenshot of their VJL experiment, the Y(t) graph data and numerical model of the motion.
- Lab 6 (fig. 4f): Introduction to advanced modeling. Students study the motion of a pendulum, and process data to make the Theta(time) graph. They introduce their data to Mathematica, and model the motion in first principles. They apply their model iteratively changing the initial angle of launch, until theoretical curve matches their measured values. In their report students include measurements (table), a screenshot of their VJL experiment, the Theta(t) graph data and numerical model of the motion.
- In lab-exams, students are asked to study the motion of falling body in air. Exams have two parts At the 1st part, students are asked to take measurements, graph and analyze their data. At the 2nd part, students are asked to model the motion of a parachutist and calculate the limiting velocity. Students are also asked to produce a short (2-3 pages) report in MS-word.

Description of research methodology

Lab sessions are scheduled weekly on a 4-hours basis, for 8 weeks and are held in two ICT-labs of the Department, equipped with 16 networked PCs each. While each student works at his own PC (1 student – 1 PC scheme), the arrangement of PCs is in clusters of 2 or 3, in a way that facilitates student-student interactions. During lab-sessions, the instructor at first gives an introduction to the subject, mainly pointing out the problem students have to deal with, and the strategy to apply. Students are then left to work alone, deal with the problem, take measurements, make the graphs and analysis required, and pre-structure their report. They have to finish their lab-report and handle it printed on next lab session. The main instructor and a lab assistant are always present during lab work. They discuss with the students and help them with any issues raised regarding the physics of the subject, taking and analysing data and so on. Students are strongly encouraged to discuss any raised subject with their peers while instructor or the lab assistant act as moderators. All sessions were recorded.

Our research data was collected by voice recording all in-lab sessions and taking notes on spot. Additional sources of research data consisted the written reports of the teams and their performance during final exams session.

Results and discussion

Regarding the use of the blended learning approach that has been adopted for the course we observed that during the lab sessions student-student interactions had an increasing pace throughout the course, as each student became more aware from one lab session to the next that he/she could help, guide or get help and learn from his/her peers. Although each student had a domain account and could use any PC-terminal in either of the labs even outside the official lab time, soon after the first labs students preferred to group up, and work together as informal teams. This collaboration and groupware work was also extended to cases outside the lab, when students had to work-on and finish their lab-report. The ways that student adopted for out-of-lab collaboration were mail exchange and in-person meetings. Web-available courseware material enabled students to examine the lab activities for next lab well in advance; they were thus prepared for the problem they had to handle and made better use of the time during lab session in order to finish their tasks. This approach much helped students to achieve better scores, and motivated them a lot.

Analysis of the data gathered by the written reports handed in by the students after each lab session gave us evidence that they all performed successfully and in time all required lab tasks and gathered the adequate data necessary to produce the written reports.

On spot observations and long discussions with the students have shown that regarding their attitude towards the lab work they were asked to perform and the way they worked during lab time, two main categories of students can be described. A part of the students (almost half) focused mainly on the difficulties of the tool (software) they had to use without paying much of attention to the problem of physics they had to handle and the procedure they had to follow. Another part of the students was able to distinguish between the use of the tool and whatever difficulties it might create on one hand and the physics problem and procedure to solve it on the other. Both these categories of students handed in a written report after each lab session following quite satisfactory the rules "how to create a lab report". However the reports of the second category were more complete and with an increasing level of maturity in the way they presented and supported the analysis of their data, their results and their evaluation.

CONCLUDING REMARKS

Students –at least in Greece– when entering University they have a very limited, if any at all, experience in lab, lab work, lab measurements, and lab-report writing. Situation appears similar in many other countries and, in several projects (eg. LabWrite 2003), students need guidance and support in their steps to effective and efficient lab-report writing, data evaluation, and drawing of sound conclusions from the performed analysis. Based on the evaluation of lab-reports, we noticed a positive effect of the various steps of modeling, successively enhanced from Lab-report 1 to Lab-report 6. Even though the experience of "report writing" should not be neglected, it is noticeable the "maturing" on writing and clearness in argumentation that is often found in students on later years of their studies. Laboratory activities integrated with Measurements, Data Analysis and Modeling in an Introductory Physics course, may prove as a valuable pathway for helping students' scientific literacy, communicating facts and ideas, and, most important, stimulating them for the rest of their studies.

REFERENCES

Beichner, R. (1990). The effect of simultaneous motion presentation and graph generation in a kinematics lab, Journal of Research in Science Teaching 27, 803-815.

Collis, B. & Moonen, J. (2001). Flexible Learning in a Digital World - Experiences and Expectations, Kogan Page, London, UK.

Courseware site http://zeus.physics.auth.gr/ (visited continuously since Oct 2006).

ePhys: Towards an effective use of ICT for Open Learning in the Teaching of Physics in Europe, project supported by European Community in the framework of SOCRATES action (99817-CP-2202-1-GR-MINERVA-M)

Gamboa, F., Pérez, J. L., Lara, F., Caviedes, F., & Miranta, A. (2001). A student cantered methodology for the development of a physics video based laboratory, Interacting with Computers 13, 527-548.

Harrison, A.G.& Treagust, D.F. (2000). A typology of school science models, INT. J. SCI. EDUC., VOL. 22, NO. 9, 1011- 1026.

Hestenes, D. (1987). Toward a modeling theory of physics instruction, Am. J. Phys. 55 (5), pp 440-454.

Hestenes, D. (1992). Modeling games in the Newtonian World, Am J Phys 60, 732-748.

LabWrite project site http://labwrite.ncsu.edu/ (visited on Sept 2004).

Mäntylä, T. & Koponen, I.T. (2003). Understanding the character of physical laws through the intertwined epistemic roles of experiments and models: An example from physics teacher education, ESERA.

Rogers, L.T. (2003). Integrating modeling with datalogging - a new approach, Logotron educational software (www.logo.com).

Salmon, G. (2000). E-Moderating - the Key to Teaching and Learning Online, Kogan Page, London, UK.

Salmon, G. (2002). E-tivities the Key to Online Learning, Kogan Page, London, UK.

Schecker, H. (1993). Learning physics by making models, Physics Education, 28, (2), 102-106.

Schecker, H. (1994). System Dynamics in High School Physics, Published in: Proceedings — Education — of the 1994 International System Dynamics Conference, Stirling, Scotland, 74-84. System Dynamics Society.

Schecker H. (1996). Modeling Physics System Dynamics in Physics Education, Published in the “Creative Learning Exchange” Newsletter.

Schecker, H. (1998). Integration of Experimenting and Modeling by Advanced Educational Technology: Examples from Nuclear Physics. In: Tobin, K. & Fraser, B.J. (eds.): The International Handbook of Science Education. Dordrecht: Kluwer, Part I, 383-398.

Singh, H., (2003). Building Effective Blended Learning Programs, Issue of Educational Technology, 43 (6), 51-54.

Stratford S.J. (1996). A Review of Computer-Based Model Research in Precollege Science Classrooms.

Van Schaik, P., Barker, P.G. & Beckstrand, S. (2003). A Comparison of On-Campus and Online Course Delivery Methods in Southern Nevada, Innovations in Education and Teaching International, 40(1), 5-15.

Maria Tsakiri
Department of Physics
Aristotle University of Thessaloniki
Thessaloniki
54006 Greece
Email: mtsak@physics.auth.gr

Euripides Hatzikraniotis
Department of Physics
Aristotle University of Thessaloniki
Thessaloniki
54006 Greece
Email: evris@physics.auth.gr