# INFORMATION TECHNOLOGIES IN STRUCTURAL ENGINEERING: A PAPERLESS COURSE

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This paper presents the structure of an undergraduate course entitled “Programming Techniques and use of specialised software for Structural Engineering” which is offered to the 5th year students of the Civil Engineering Department of Aristotle University Thessaloniki in Greece. The aim of this course is to demonstrate the use of new Information Technologies in the field of Structural Engineering and to teach modern programming and finite element simulation techniques that the students can in turn apply in both research and everyday design.

Apart from demonstrating the programming and simulation techniques and tools currently available, the course focuses on the physical interpretation of structural engineering problems as they are discussed in class, in a way that the students become familiar with the concept of computational tools without losing perspective from the engineering problem studied. For this purpose, a wide variety of structural engineering problems are studied in class, involving problem solving related to structural statics and dynamics, earthquake engineering, design of reinforced concrete and steel structures as well as data and information management.

The main novelty of the course is that it is taught and examined solely in the computer laboratory ensuring that each student can accomplish the prescribed hands-on exercises on a dedicated computer, strictly on a 1:1 student over hardware ratio. Significant effort has been put so that modern educational techniques and tools are utilised in order to offer the course in an essentially *paperless* mode. This involves electronic educational material, student information in real time and exams given electronically through an ad-hoc developed, personalised, electronic system. The feedback received from the students, also in the form of an automatically processed web-based questionnaire, reveals that the educational digital media used and the structure of the course itself, meet the main course objective to familiarize the students with modern technologies without losing focus to the physical engineering problem studied.

**KEYWORDS**

computer applications; engineering education; e-learning; programming techniques; finite elements; structural engineering; information technologies.

## 1. INTRODUCTION

Major advancements have been made during the last decades primarily due to the revolution in Information and Communication Technologies (ICTs) that resulted from the rapid increase of computational power and internet speed and have drastically reformed the way engineers are educated and trained [1]. Educators on the other hand, are faced with an ongoing challenge of creating engaging, student-centered learning situations that can relate problems presented in the class to the tools developed for their solution. This transition from traditional educational means and processes to the use of modern Information and Communication technologies has not only reformed the educational experience but also drastically changed the educational objectives themselves: the students and now required to study both the physical problems *and* the tools currently available for their study. During the last few years, the above ICTs are widely used in the field of structural engineering education, primarily for [2]: (a) improving the visualization and demonstration equipment in class, (b) developing interactive educational tools and software for distant and life-long learning related to structural and earthquake engineering applications [3-9], (c) utilizing "hands-on" experiments for demonstrating basic concepts in structural dynamics and earthquake engineering, (d) setting up and executing bench-scale shaking tables at a lower scale, and (e) training students through "virtual" experiments in a self-learning environment [10].

An important role in the education of structural and earthquake engineering through ICTs is also being played by the Network for Earthquake Engineering Simulation (NEES) Academy for Education and Training which is a web-based, open university to students, teachers, researchers and professionals. This Academy utilizes cyber-technology for delivering NEES-related, primarily to the graduate level, resources such as complex computational simulations, learning modules, visualizations, multimedia presentations, video resources and interactive games, all serving the purpose of knowledge dissemination to the structural engineering educational and professional community [11-12] and thus providing a continuous link between the students, educators and researchers.

From an academic perspective, numerous courses are currently offered worldwide within the context of their respective university curricula, in a variety of structural engineering fields, utilizing modern technologies to assist students visualize, comprehend and solve complex physical problems in a completely new way. In many cases, these courses are offered in a so-called, "paperless" mode; however, quite typically, "paperless" is essentially limited to the replacement of hardcopy material by educational tools which are provided in various electronic forms (i.e., documents, spreadsheets, presentations) and delivered primarily through the web or even through new hardware devices such as tablet PCs and ipads.

To this end, the scope of this paper is to present the effort made at the Department of Civil Engineering of Aristotle University of Thessaloniki in Greece to offer to the undergraduate students a comprehensive experience of an entirely paperless course on structural informatics, that not only involves hands-on training and a set of electronic visualization and educational tools, but also a novel structure for conducting the final examinations and evaluation within the computer laboratory. To the best of the author's knowledge, the particular course must be the only one currently provided within the Departments of Civil Engineering in Greece and most probably elsewhere in Europe in a purely electronic manner, for a large group of enrolled students which typically exceed 100. The course structure, syllabus and main features of this course are presented in the following.

## 2. COURSE STRUCTURE

"Programming Techniques and use of specialized software for Structural Engineering" is an optional course offered to the fifth year undergraduate students of the Civil Engineering Department of Aristotle University Thessaloniki in Greece since the academic year 2004-2005. It is aimed to promote the use of new Information Technologies in the field of Structural Engineering and to teach modern programming and Finite Element simulation techniques that the students can apply both in research and design. The course curriculum is structured in two main parts:

(a) software and application development for structural engineering problems with the implementation of visual programming (Visual Basic.NET and Matlab). Utilization of the fundamental programming skills developed for the management of database systems (MS Access), spreadsheets (MS Excel) and drawings (Autodesk Autocad) using built-in programming languages such as Visual Basic for Applications (VBA).

(b) Implementation of widely used commercial finite element (FE) packages for the simulation and analysis of structural engineering problems. Emphasis is given in the fundamentals of FE simulation, while specific cases of structural non-linearity and 3D simulation are also demonstrated. Applications are performed using the FE program ANSYS utilizing both the Graphical User's Interface and the Ansys Programming Design Language.

An important component of the course is the distinction between the problem studied and the tools used or developed for its solution. Therefore, the course focuses on the physical interpretation of structural engineering problems discussed in class, so that the students become familiar with the concept of computational tools without losing perspective of the engineering problem studied each time.

**Figure 1:** Overview of the computer laboratory

## 2. COURSE SYLLABUS

The course syllabus is divided into thirteen classes of three hours duration which are in turn split to an hour of theoretical background and two hours of step-by-step hands-on exercise during which the students reproduce what is demonstrated (projected) on board. As already mentioned, emphasis is also given in explaining the theoretical background behind the engineering problem studied each time, in order to ensure that the students comprehend the fundamental aspects of the physical problem before implementing the specific programming techniques taught. A wide variety of structural engineering problems are studied in class, involving statics, structural dynamics, earthquake engineering, design of reinforced concrete and steel structures as well as information management. It is noted that since most of the students are enrolled to the Structural Engineering Division, they are already familiar to the fundamental concepts of the above scientific fields.

The exact content taught in each class, the programming skills developed and the engineering problem solved are presented in Table 1.

**Table 1**: Summary of the course syllabus and physical problems studied

| Lecture ID | Topic | Programming Skill | Physical problem |
|---|---|---|---|
| #1 | Introduction | Accounts creation. | - |
| #2 | Visual Basic | Introduction to Visual Basic structure and GUI | Area of reinforcement longitudinal bars and hoops |
| #3 | Visual Basic | If-else statements and for-next, do-loop structures | Design of an RC beam to flexure |
| #4 | Visual Basic | Matrices | Static analysis of a simply supported beam with varying point loads |
| #5 | Visual Basic | I/O and string handling | Building evaluation through string handling of a SAP2000 input file |
| #6 | Visual Basic | Functions and modules | Dynamic analysis of structures |
| #7 | Visual Basic for Applications (VBA) | Optimization of Excel using VBA | Response spectrum resampling |
| #8 | Visual Basic for Applications (VBA) | Optimization of Access using VBA | Pre-earthquake assessment of structures |
| #9 | Visual Basic for Applications (VBA) | Optimization of Autocad using VBA | Design and drawing of RC slabs |
| #10 | ANSYS | Introduction to finite elements and ANSYS | Static analysis of a steel truss |
| #11 | ANSYS | Introduction to 3D modelling | Static and modal analysis of a steel beam-column joint |
| #12 | ANSYS | Introduction to nonlinear analysis | Nonlinear static analysis of a concrete column |
| #13 | Matlab | Introduction to Matlab | Dynamic response of flexibly supported buildings |


**Figure 2:** Official Course Website: http://nisida.civil.auth.gr/tp

## 3. COURSE PAPERLESS MODE

A significant aspect of the particular course is that since its initial development in 2004, significant effort has been put so that modern educational techniques and information technologies resources are utilized in order offer the course in an essentially *paperless mode*. In particular, this is achieved by the following:

(a) Course consists of 13 interactive lectures all given in the Civil Engineering Computer Laboratory. Classes are organized in 2 or 3 groups of 30 students, which are obliged to log in using their personal accounts.

(b) All educational material (handbooks, notes, source code, solved examples, tutorials, presentations) is provided in electronic form.

(c) Additional educational material (Figure 3) is provided in the form of video tutorials (freely available at www.civil.auth.gr/tp,), which essentially act as a step-by-step guide of all the examples solved in class [9].

(d) Sample, fully functioning educational software developed and demonstrated in class is provided through the Virtual Laboratory Official Website (www.edusoft.civil.auth.gr) for motivation purposes (Figure 4).

(e) The course time table and schedule is available on-line through the Official Course Website (http://nisida.civil.auth.gr/tp) and is automatically updated using the Google Calendar Service. Students can subscribe to the service to receive notifications related to the course schedule.

(f) Announcements are published on the course website where the students can subscribe through RSS tools for immediate information. The students can also comment through the relevant blog.

(g) Students interested in Diploma Theses to be conducted in the framework of the course can refer to the subjects offered online and apply also online through an open call procedure which takes place twice a year.

(h) The examination takes place at the Computer Laboratory in a similar manner as the hands-on demonstration experiments. The students store their examination papers online using their personal accounts while the electronic papers are gathered using specific software developed for this purpose. All examination papers are automatically tagged with the students' IDs and are stored in the server for asynchronous evaluation by the tutor. The final assessment grades are sent to the administration using the web-based e-class system of the Department.

(i) Students' feedback and evaluation of the course is made electronically on a provisional basis right after the completion of the exams, through an online questionnaire which is available at the following address: (http://freeonlinesurveys.com/rendersurvey.asp?sid=n7f2e2ld99vahwd864628). All evaluation statistics are performed automatically and are officially submitted to the Civil Engineering Departmental Committee that is responsible for course evaluation. The evaluation results are published on the course website.

The entire structure of the course is illustrated in Figure 5. Additional information related to the evaluation of the course is provided in the following section.

## 4. STUDENTS' FEEDBACK

Upon accomplishment of the educational process, feedback from the students' experience is obtained regarding all aspects of the course. In particular, a detailed, anonymous, online questionnaire is completed on a provisional basis on the day of the course exams. Only students attending the exams are asked to fill-in the questionnaire. It is noted that the statistics of the evaluation is performed automatically by the web-based application and that it is impossible for the tutor to investigate or modify the response

provided, hence ensuring confidentiality and credibility of the evaluation process. The results of this evaluation are publically displayed at the official course website immediately after the feedback deadline is expired.

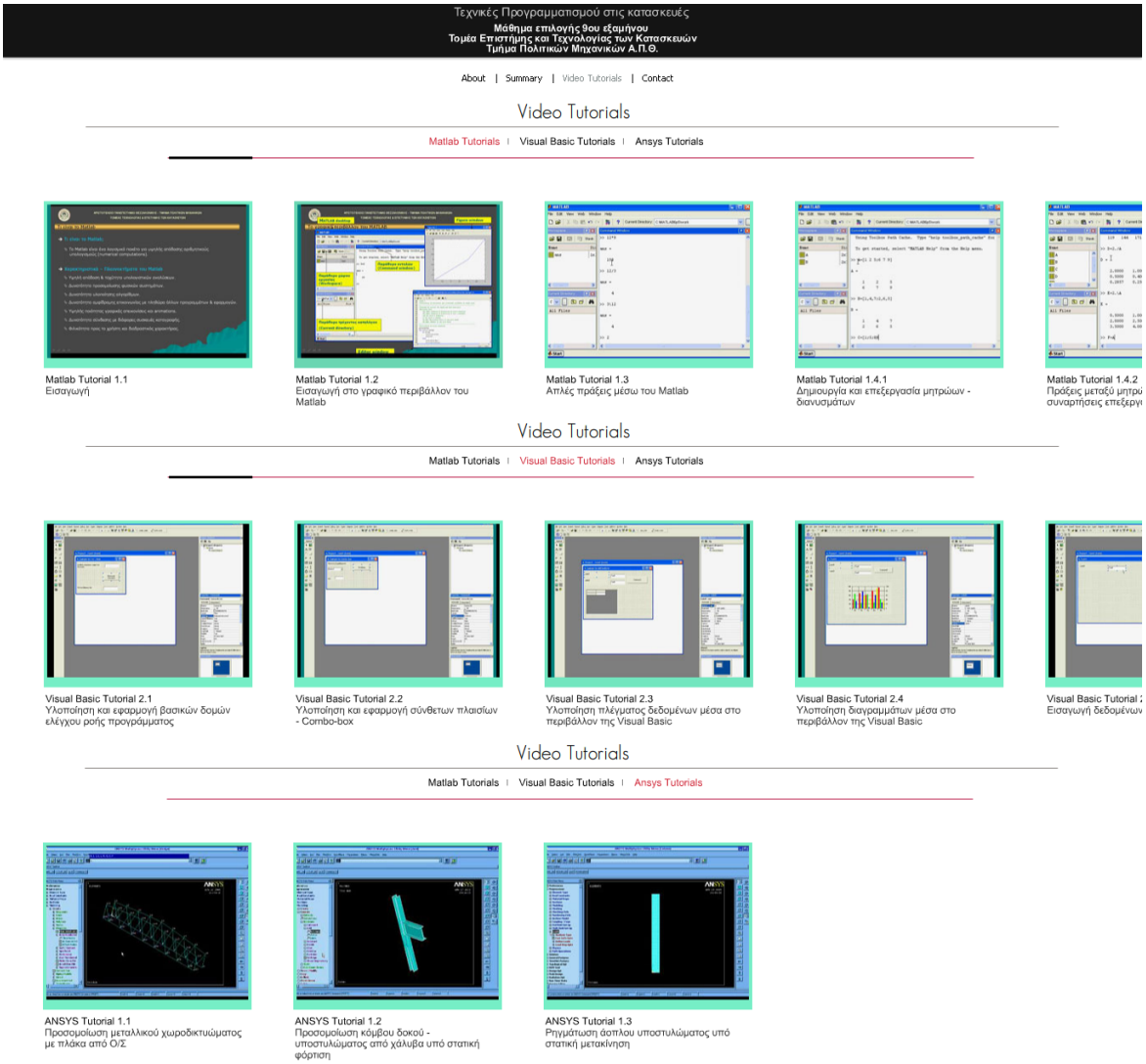


**Figure 3:** Online flash video tutorials of the course content (http://www.civil.auth.gr/tp)

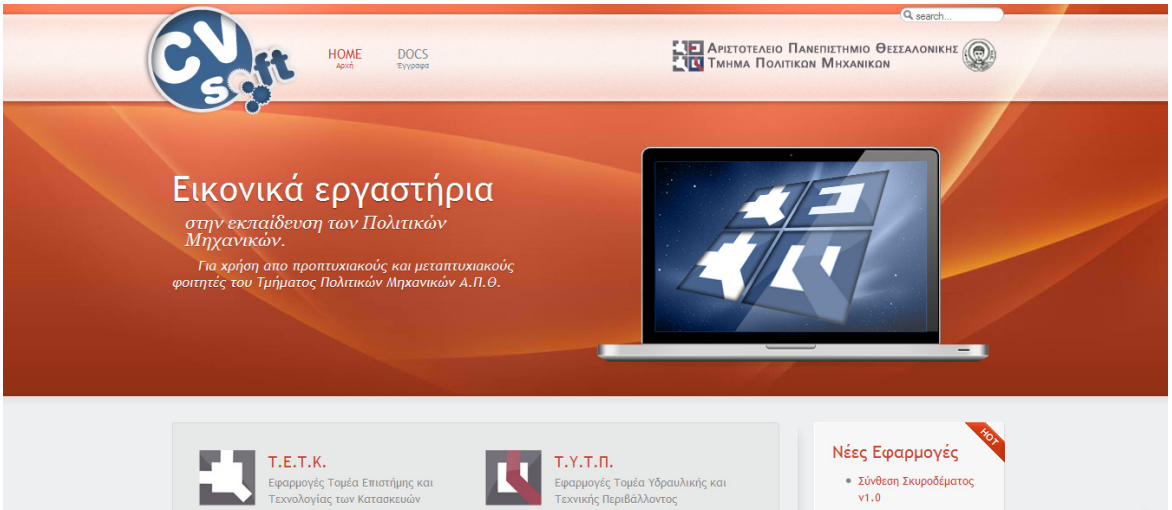


**Figure 4:** Educational freeware developed in class and released as freeware (http://it-structural-engineering.weebly.com/abel.html, http://cvsoft.civil.auth.gr/)

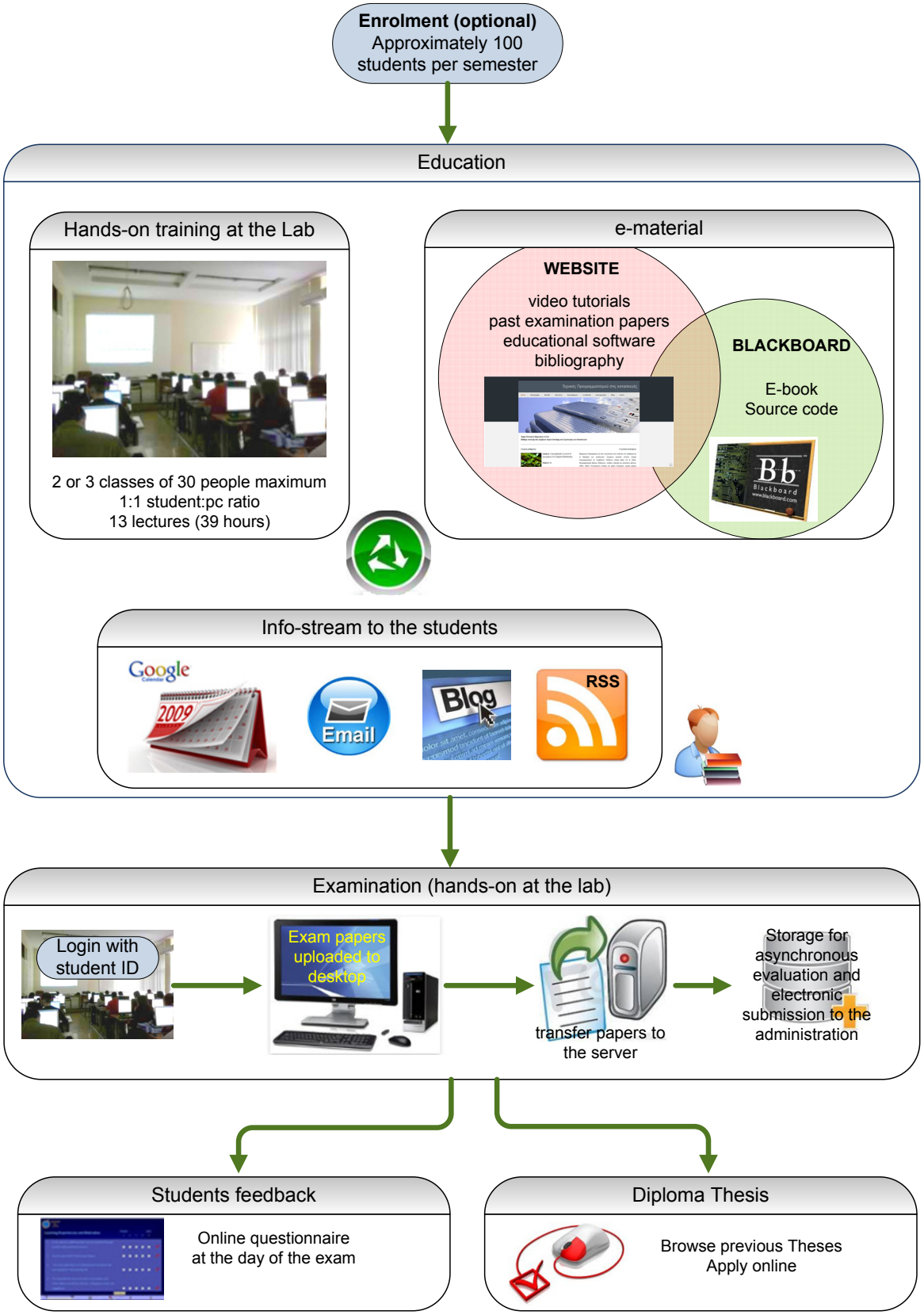


**Figure 5:** Structure of the course in a paperless mode

It is not the scope of this paper to reproduce any positive feedback that has been provided by the students. It can only be stated that in principle, the educational digital media used and the structure of the course itself seems to meet the main course objective to familiarize the students with modern technologies without losing focus to the physical engineering problem studied. It is also mentioned herein that some concern is often expressed that the time given for solving the examination problems is significantly reduced compared to the ample time span within which the problems are solved during demonstration. Some concern has also been expressed that despite the inherent interactive nature of the course and the fact that the students comprehend the problem studied and the tools developed, there are cases where they find it hard to take the initiative and immediately start programming another problem from scratch. From the tutor's perspective, it is deemed that these concerns are valid and well spotted. However, these issues arise naturally due to the wide variety of the content covered and they are planned to be tackled through additional homework and hands-on exercise on dedicated computers during the course. Most importantly, the students are encouraged to break the ice of the "white" programming screen by repeating the commands projected on the wide screen but very soon, even within day one of the course, they are asked to deviate for the prescribed command lines and experiment with alternative programming structuring.

## 5. CONCLUDING REMARKS

This paper presents the structure of an undergraduate course offered at the Civil Engineering Department of Aristotle University Thessaloniki in Greece with the aim to demonstrate the use of new Information Technologies in the field of Structural Engineering for teaching modern programming and finite element simulation techniques to the last year undergraduate students. The above are taught using examples from a wide variety of structural engineering problems related to statics, structural dynamics, earthquake engineering, design of reinforced concrete and steel structures as well as data and information management.

The paper describes the modern educational techniques and tools that are utilised to offer the course in an essentially *paperless* mode, involving electronic educational material, student information in real time and exams given electronically through an ad-hoc developed, personalised, electronic system. It is believed that the particular course is a case study that demonstrates the significant potential for implementing the most modern information technologies in the educational process. It is also believed, based on the experience already gained in class, that the students are more than keen to obtain knowledge through new educational methods independently of the course content taught, apparently without underestimating the impact of a modern scientific topic in the first place. Therefore, ICT tools offer a number of advantages in terms of attracting the interest of the students and enhancing their deeper understanding of the problems studied. However, it has to be made clear to the students that although teaching and learning can be indeed made easy, the physical problems should not be perceived as easier than they really are. Effort has to be put by the tutor so that when the students become familiar with modern tools for teaching and solving engineering problems they don't develop the false perception that the problems themselves can only be solved by magic, user-friendly interactive black boxes. On the contrary, it is the responsibility of the tutor to develop their ability to distinguish between the parameters involved in a physical problems, the fundamental concepts of their solution, the required mathematical background and, at the very end, of the necessary advanced electronic tools that can be adopted or developed to facilitate the above solution. Time will show at what extent this difficult balance will be eventually achieved by the future engineers between developing both their engineering judgement and computational skills.

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