Analysis of a Web Based Engineering Undergraduate Course

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Abstract

This paper discusses some of the tools being used to enhance learning of the undergraduate Heat Transfer course offered at the Mechanical Engineering Department of PUC-Rio. Based on the Internet, students may follow the curriculum at their own pace, although there is always a lecturer or a tutor in class. Student motivation and learning are improved in consequence of several simulation codes specifically written to overcome past students' difficulties, observed in their examinations. Such codes are produced using visual tools, java applets, spreadsheets, Matlab and similar tools. Collaborative work is motivated through the use of short term projects to be made in a competitive environment and through the whole class discussion of simple open ended questions. Examples of those are given herein. The results obtained so far indicate the advantages of the Internet to improve engineering classes through the combination of web pages, downloadable software and group work.
Introduction

Internet based education and training are being used in many colleges and universities in two conceptually different ways: distance learning and presential classes. For distance learning, Internet offers many interesting ways to deliver learning material intended to educate more people anywhere, any time. On the other way round, in presential classes, Internet may be seen as a source of new and innovative technology capable to offer better learning for basically the same people or so. This paper is concerned mainly with the second possibility due perhaps to the present author's experience in teaching presential engineering courses using Internet facilities.

The availability of technical courses and the number of faculty members concerned with such uses are increasing throughout the world, as shown on last year topic meetings such as CALISCE'98 [1] and ICEE'98 [2], among many others. It may be argued that the attractiveness of such courseware is high for several reasons, such as the fact that the developing efforts for these virtual books are smaller than the ones for the production of a plain text book. There are already several commercial software to convert document files (plain text) to html (hypertext markup language) files, including equations, improving the autonomy of faculty members to make anytime text corrections and have always updated notes. For instance, editing is mainly a simple "cut and paste" process.

However, it has been the current author's experience that web based training needs more attention if better understanding of the physical situations involved and enhanced learning of engineering courses are to be obtained. This paper describes the tools developed for an undergraduate Heat Transfer course [3]. The observations and conclusions, however, may be easily shifted to others technical disciplines. This paper's objective is to present an analysis of a well-tested design of a virtual course, offering some insights on its development.

Course Methodology

As mentioned in [4], the course notes, converted to html files, are projected on a screen but students are also able to follow them through their own computer's monitors or by the printed material, reducing handwriting to a minimum and offering them options. Blackboard usage is reduced but not eliminated, being used only for additional discussions or to exercises being done by students. After offering web based classes for some years, the author considers that they are generally more pleasant, being also able to enhance significantly class interaction as compared to a standard overhead projection + copies of the overheads given to the students combination. The main advantage is the possible use of simulation codes as often as necessary and following each student's own pace. Besides that, adding or correcting information is quite simple, avoiding the known limitations and the difficulties with the production of new overheads or correcting old ones (not counting the involved costs).

Notwithstanding the lecturer presence at all times, there isn't a classical lecture style class where all students follow the lecturer's rhythm. In other words, although there is still
someone who provide information (i.e. the teacher) and those who receive information (i.e. the students) the classes are more oriented to the specific needs of the individual student. He/she, following general guidelines loosely defined but clearly stated, may choose at any time the most interesting resource to help him/her learn, discuss and test his/her knowledge. There are also many advantages to the teacher interested on learning how students learn the materials as the number of hits per page is easily counted. So, in a nutshell, the course is focused on the learner, students or teacher.

This methodology is more effective than standard lectures due to the combination of tools used, not only in the author's view but also according to the students general evaluation of the resources offered to them that, as discussed below, are developed in order to enhance students difficulties observed in their exams.

**Developed Material**

All lecture notes are available in html (web) and pdf (Adobe) formats. Although lectures are now given on a computer equipped room (one computer per student) linked to the Net, past students asked for the correspondent doc files to let them study anytime they wish, even if an Internet connection is not working, a not uncommon situation in 3rd world countries with poor telecommunications lines. Up to last year, these doc files were available in both Microsoft Word 6.0 and Word 7.0 formats. Making small editing was quite a burden due to the needs of producing two versions of the same text files. In the new version of the course, portable document format, pdf, from Adobe, is going to be used, solving the previous compatibility problems. Reading and printing such files are quite easy, using the Adobe Reader, available as a free software.

For this coming term, students will also get a CD-rom containing all material to be used at home, for those lacking Internet connection at a sufficiently high speed. Besides the previously mentioned lecture notes, the CD under production will contain all computer aided learning (CAL) software, including spreadsheets, visual basic software, java software, Matlab (or similar) files, Internet links to related materials, all colection of solved past exams, solved exercises, frequently asked questions (offering other explanations to terms or situations that presented difficulties to past students), student self evaluation tests and the class syllabus, discussed below.

**Class Calendar and Syllabus**

After teaching the undergrad courses for several years, with the last two using Internet resources, it was noticed the importance of having a clearly stated agenda, where the course description including grading information, exams dates are described. Most praised by students is the description of the discipline curriculum on a daily basis from where the students, through hyperlinks, may reach the html and pdf files, and everything else available for the academic topic being investigated. Material from missed classes, solved exercises, self evaluation tests so on, are readily localized through such links. The next figure shows briefly the possibilities.
Development of non-html materials

As mentioned in the first section of this paper, the usage of Internet resources for enhancing the quality of technical courses offer a few more attractions, such as the possibility of downloading simulation codes specially prepared to the students and executing them as needed. However, developing such codes is very time consuming and in order that this become cost effective, they should add something to the whole educational objective. Assuming the impossibility of developing such codes to each and every topic of the course, there are two ways for doing so: following the lecturer's view of the most difficulty topics and listening students opinion.

In the present paper, the second approach was used, supported by the author past experience and by authors such as Lelouche [5]. However, is not a simple task to listen to the students and it was decided, instead, to learn from their results. For already some time, a critical evaluation of the most severe mistakes made by the students in their examinations were conducted in order to help them to avoid repeating the mistakes and prevent others from doing so. Such evaluation was usually offered to them but not really used towards the understanding of the current or to the following term students. For instance, in the Heat Transfer course under description, it has been observed that quite often students, at the beginning of their 4th year (from a total of 5 years), make some mistakes that are easily traced back to a poor understanding of the 1st Law of
Thermodynamics (energy balance) and distinction between heat and temperature, even after taking a Thermodynamics course in the previous term (usually).

It was not difficulty to obtain a reasonable reason for such mistakes. Following Bizzo [6] and others, there are two types of general knowledge: the common sense and the scientific one (already called as the uncommon sense [7]). During their first studies (till high school), the teaching of science is usually based on making simple non-related chemistry and physics experiences, memorizing many "technical" terms and others tasks that do not develop a critical and logic reasoning, most needed to engineering courses. It is quite common, for instance, to listen students using heat (path dependent) instead of temperature (local property), to use \( Q = m \Delta T \) (mistake between general and specific laws), and similar mistakes. Consequently, students go to university level courses without understanding the importance of scientific terms.

Naturally, in no way is to be expected that a computer code will, by itself, produce an upgrade in the students poor understanding of such terms. However, a carefully prepared code may explore different situations and help students challenge their own understanding. As example, a couple of java applets were written for the Heat Transfer course to evaluate energy balances on interfaces and on the boundaries. The next figure shows one of such codes. Students may choose the type of interaction on the left and the right boundaries and the level of the contact resistance between two slabs of user-selectable materials and dimensions. The many situations possible to be simulated are believed to help students understand energy balance.

**Collaborative Training**

It is already quite known the advantages of using multimedia in education, as previously stated. However, as nowadays it is being considered important to train students to develop collaborative projects, it was decided to use Internet to do so. In the course being discussed, this is done in two ways. Short term group projects are assigned to the whole class and grades are given in a competitive basis. Among others, students have been asked to present papers on a solar energy collector, in boiling heat transfer, thermal insulation and others. Recently, it was decided to propose questions such as estimating the evaporation time for a small amount of water and the melting time of an iceberg that are open to the participation of all students at the same time. The objective is not only to answer the specific question being asked (whenever possible) but mainly to discuss how to project and conduct an experiment to obtain the answer.

Student participation may be done using web resources and are easily posted in the Net, allowing group discussion at topics related to the curriculum but not covered during regular class. The final result is a written report with many contributions on how the answers may be obtained. Most important, students learn to participate in a lengthy discussion on topics where the answer is not readily available. Internet resources seem to be powerful to handle such situations.
Self Evaluation Methodology

Even considering the many solved exercises available throughout the material, students have complained that during exam hours, they have doubts on topics they took for granted or they have supposedly mastered. To help them investigate such doubts, several self evaluation materials were developed. Among others, it is worth mentioning the chapter questionnaires, to be taken any time but certainly at the last lecturer covering each chapter, with selected questions prepared to evaluate student awareness on the given topics and the specially commented solved exercises. One example of this last situation is given below.

Consider, for instance, a simple 1-D slab that receive 100 W / m² in the left boundary. Assuming steady state and neglecting any heat generation inside it, the student is asked to obtain the energy leaving the right boundary. If the student answers correctly, he is praised and a harder question is suggested. However, if the student answers differently, a discussion follows, questioning his understanding of terms such as steady state and heat generation. After that, the student is allowed to proceed with the evaluation. Through a series of similar simple exercises but having answers containing elaborated comments, students may check their understandings and very often they find out where they should
According to the students that took time to go through such quizzes, developing them is very effective as they are beneficial to them.

Conclusions

This paper analysed the application of Internet resources in the framework of a Heat Transfer undergraduate course. Using it not only as a multimedia source but also as collaborative space centered on the student needs seems to be effective.

Although the evaluation of the material presented herein is done in a permanent way as its results are used to enhance the whole learning process, it was not possible, at this point, to evaluate the full potential of Internet training. This happens as the approach used in the Heat Transfer course is essentially an isolated experience, unfortunately not yet fully integrated into the Mechanical Engineering Program. However, from the experience so far obtained, it seems that a student oriented and carefully designed web course may enhance education as it is able to challenge more deeply students, due to their more active participation. Perhaps, the most important lesson to be learned from the experience reported herein is that learning from the student mistakes in order to develop new educational material is a reasonable way to use properly information technology resources to enhance engineering and science education.

References