A COURSE OF THERMODYNAMICS FOR AN INDUSTRIAL ENGINEERING DEGREE USING NEW METHODOLOGIES AND TECHNOLOGIES

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Abstract

This paper presents the experience carried out at the Industrial Engineering School (ETSII) of the Universidad Politécnica de Madrid (UPM) for teaching Thermodynamics science using new methodologies and technologies.
During the last two years a special course on Thermodynamics has been given to those students who failed to pass the ordinary examination. This group was made of around thirty students with some level of knowledge of the subject. Nontraditional teaching methodologies have been applied to this group stretching the potential of new technologies to the maximum possible extent.
A complete e-learning system developed by our University called AulaWeb was used to produce a weekly schedule for each individual student.
AulaWeb consists of several modules. News and Forum channel the communications with the student. "Contents" is a repository holding various types of learning material such us presentations, theoretical texts and problems with solutions. "Activities" assigns homework to the student who can submit it electronically. Finally, "Self-assessment" composes bespoke self-assessment tests resorting to a wide database of questions and short problems.
A totally personalized long problem was programmed using MATLAB. The problem is structured in ten steps that help the student to progress towards his/her learning target. Upon conclusion of the learning program the student should have acquired all foreseen knowledge of the subject.
Observed results are very satisfactory. Throughout the whole process the level of motivation of the students has been very high.
The Universidad Politécnica de Madrid supports education innovation experiences through special programs whose main target is the convergence at the European Higher Education Space.

Keywords
Teaching/learning Thermodynamics, interactive learning environments, web self-assessment tool, educational innovation, e-learning

1. INTRODUCTION

In this paper we are going to describe an e-learning experience for the subject of Thermodynamics-II, given in the degree of Industrial Engineer at the Escuela Técnica Superior de Ingenieros Industriales (School of Industrial Engineering - ETSII) of the Universidad Politécnica de Madrid (UPM). The experience has been carried out for academic years 2006-07 and 2007-08 with positive results.

This experience consists in the application of an e-learning teaching procedure which we shall call *Complementary Teaching* (CT), for a semester. It is directed at pupils who have failed their exams after taking normal lectures. It consists of web-based activities. The normal subject is lectured in 42 hours and does not necessarily involve interactive learning.

The idea of trying e-learning for CT emerged after unsatisfactory results in past years. It seemed an efficient way of overcoming the two main difficulties of the course: pupils who had previously failed the subject and a reduced number of teaching hours.

The subject Thermodynamics-II assumes that the pupils are already familiar with the application of the First and Second Laws of thermodynamics to pure substances and simple systems. In summary, it covers: knowledge and use of thermodynamic diagrams of pure substances, analysis of open systems, mixtures, chemical reactions and industrial cycles (Rankine, Linde, Claude, Brayton...) It is a broad subject in which many known difficulties in teaching engineering appear [4]. This made that finding a suitable compromise between pedagogy, number of teaching hours and e-learning activities resulted especially challenging, and that it required several adjustments during the first stages of the experience.

We realized that the e-learning platform selected would be critical towards the results. We wanted not only certain Computer Adaptive Testing (CAT) features [5], but also dynamic assessment [3] and a complete framework enabling different kinds of teacher-pupil interaction. The Moodle platform provided many of these features [7]. However, we finally selected Aulaweb [6] [1] [2], for it is entirely developed within ETSII, allowing us to eventually customize it through direct access to the developers if necessary, and because it is adapted to the administrative procedures and databases of the School.

2. DESIGN OF THE EXPERIENCE

Pupils following the CT course took the same exam as normal students. Their final mark was the sum of the exam mark plus a maximum of two extra points depending on their performance in e-activities. Normal students also have the opportunity of achieving extra points through class participation. Nevertheless, in order not to bias the conclusions, the comparative data offered in this paper are referred only to exam marks.

2.1. Infrastructure: Aulaweb

Detailed descriptions of AulaWeb can be found in the bibliography [6], including detailed comparisons with other web self-assessment tools [1]. We have chosen AulaWeb for being a powerful, reliable tool with years of successful operation in our University. We have also an easy access to their developers, who are professors in our School. This last point allows us to make suggestions for further developments to adapt the system to our needs.

AulaWeb is a modular platform. The teacher may activate or deactivate modules in order to use only a specific subset of features. In our study, the following modules were selected:

- **Communication with the student:** Both through a forum, accessible for everyone, and through personal messages
- **Download area:** For additional didactic material
- **Self-assessment tool:** Allows the execution of exercises that once concluded are corrected automatically and immediately.

Exercises are built upon a database of questions proposed by the teachers of the subject. It includes questions of several types, but in our study only these were present:

- **Simple-choice:** A single answer must be chosen from a list.
- **Multiple-choice:** Several true answers can be selected of a list. The number of valid answers is not known.
- **Whole Number:** The answer is an exact integer value, without error margin.
- **Real Number:** The answer is a number with or without decimals. The pupil is allowed a certain error (the interval is set by the teacher).
- **Variable problem definition:** The definition of the exercise is generated by a computer program in which a parameter randomly generated is included. The resulting question can being of closed answer, where the program selects randomly among several options those that appear in each case, or of open answer, where the parameter is part of both the definition of the problem and the solution.

It has been observed that the choice of the type of question has significant influence in the results students obtain [2]. Most questions in our study were of the type variable problem/open answer.

2.2. e-Activities

As it has been mentioned in advance, CT consisted pupil-customized e-activites. These were structured around a global project: a long problem conveniently structured in a sequence of smaller parts following a didactic order. Coherence between order, pedagogy and problem solving requirements was achieved after several iterations at the beginning of the 2006-07 year (pupils were not affected by this).

The global project consisted in analyzing the different thermodynamic parameters of a given thermodynamic cycle that covered all the topics of the subject. Specifically, the cycle was a cogeneration system with gas and steam turbines which included calculation of properties in a multi-component reactive subsystem. Although the layout of the cycle was the same for all pupils, the given data were customized for each student (i.e. fuel mass flow and pressure immediately after the compressor). Thus, the expected results were different in each case.

The e-activities were the following:

- Self-assessment questions. These questions were designed to test the overall comprehension of a particular topic by the pupil. Passing a question enabled the block of activities related to the corresponding topic (i.e. exercise).
- 10 exercises with 10 questions per exercise. Each exercise was focused on a different part of the global project. Exercises were set so that results from the previous would be needed for the next.

All activities had an associated deadline for completion. In case of deadline failure, the pupil was automatically expelled from CT. Within the allowed interval, the pupils were allowed to answer the questions any number of times, although self-assessment questions were programmed to change each time to prevent guessing. Also for this purpose, wrong answers counted a negative half-point.

In order to allow some kind of feedback to the teacher during the course, the global project and the questions were programmed in Matlab before starting and each pupil variant solved, so that intermediate performance could be tracked through Aulaweb reports of question trials, results and self-assessment performance.

3. COMPLEMENTARY TEACHING IN PRACTICE

The participation in CT can be summarized as follows:

2006-07: 32 students started in CT. 18 completed the course.
2007-08: 61 started. 21 completed.

3.1. Objective Results and Discussion

Only the students that took the February exam were considered for this study. This population was divided in two subsets: CT group (indicated by “A” in Table 1) and the rest of the students (B). Only pupils that finished CT are counted in (A).

In the comparison, in order to avoid bias due to the additional points associated to e-learning performance, the exam mark is considered (not the total of the subject). The summary of the main statistics is shown in Table 1.

Course	Group	Total	Range (over 20)	Mean	Median	Standard deviation	Pass	pass/tot.
2006/07	A	18	6.25-15.75	11.714	12.25	2.700	16	89%
	B	69	1-19	9.264	8.75	3.489	34	49%
2007/08	A	21	6.3-18.2	12.274	11.9	2.735	20	95%
	B	130	2.5-17.5	10.331	10.45	3.100	86	66%

Table 1. Sumary of statistical data.

We may clearly observe that the difference between the numbers of passed exams is statistically-significant, higher in the CT group than in the rest of students. These results are in correspondence to other similar experiences found in the literature [8]. However, we consider that larger series of data and time-series analyses would allow building stronger and more precise conclusions.

3.2. Subjective Results

After the first course (2006-07), an opinion poll about the experience was carried out. A form was posted in AulaWeb, to be filled in by the CT students in an anonymous and voluntary way. They were asked to rate some aspects about their experience in CT from 1 to 5 points. The completed forms were placed in the Thermodynamics mailbox. 11 out of 18 forms were collected.

The different aspects treated in the questionnaire obtained from 3.0 to 4.1 (all of them exceed the central value, 3), and two thirds of them obtained more than 3.5.

The better rated aspect was "I consider that the experience has helped me in my learning", with 4.1 points, followed next by the global valuation of the experience, with 4.0 points. The worse valued aspect was "The level of the exercises is adequate" with 3.0 points, which indicates a medium agreement of students with the difficulty or the level of demand they found.

Although the opinion poll necessarily represents a subjective opinion, it is remarkable that all aspects (except the one about the level of the exercises) were positively marked by the students.

4. CONCLUSIONS

From the results shown in table 1, we understand that Complementary Teaching is successful in helping to learn Thermodynamics. As it has been mentioned, Thermodynamics-II involves a wide spectrum of concepts, many of them known to be especially difficult for the pupil, as well as developed problem-solving capabilities. However, further samples are required before establishing the exact extent of the influence of CT in student success.

We also understand that the strategy of designing a unique global project comprising all topics of the subject in combination with a learning schedule was essential for CT success. The adaptive learning and communication facilities provided by Aulaweb were critical for generating a proactive attitude in the pupils. The global project scheme (including time deadlines and self assessment questions) guided students to study the parts required for each exercise. In normal classes, students passively receive knowledge first, and are asked to apply it later. We understand that the CT experience managed to develop both conceptual and problem-solving capabilities better and in less time than normal classes due, in part, to the proactive attitude of pupils induced by the global project scheme.

From the experience of years previous to the 2006-2007 course added to the CT courses described here, we conclude that the design phase of an e-learning course is basic for its possibilities of success. We understand that the medium (the computer and the web) requires a new approach, different to that of conventional lessons, possibly demanding from the teacher a higher effort prior to the course and lower throughout.

We leave for future analysis, both statistical and with surveys, establishing the causes for what we consider a high number of expulsions from CT (44% in 2006-07 and 66% in 2007-08). Given that most expulsions took place during the first stages of CT, and in absence of further data, we suspect it is due to the demanding agenda that CT puts on the students, possibly in conflict with studying other subjects.

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