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Bologning in the Wind

1. Introduction

The idea of the creation of a European Higher Education Space was formally presented for the first time in the Sorbonne Declaration (Allègre *et al.*, 1998).[1] It represented the political wish to go further, beyond a mere economic union. Education and knowledge were recognized as vital for Europe's development. There were significant differences between the existing higher education systems inside the different countries of the union. It was time to create the mechanisms to allow convergence, easing mobility for students and teachers in order to share knowledge and experiences.

The Bologna Declaration (Einem, 1999)[8] established a strong commitment between governments aiming at building a common educational area and improving transparency and compatibility. It is important to understand that this Bologna Process is the result of multiple reflections and analysis promoted by national and supranational work groups and personalities. From these the need of a paradigm change arises, not only in educational structures, but also in thought and knowledge creation.

The learning process will lead students to acquire personal, academic and professional skills. These skills will play a fundamental role for the individual and for his integration in society. The focus of the learning-teaching process will shift towards the student and his particular progress will serve as a point of reference. This learning and training process is meant to continue throughout life.

The definition of the academic and professional profiles will be related to the identification and development of students' acquired skills.

Actually, the Bologna process is aimed at creating a new higher educational paradigm centred on student work, skill importance and preparation for professional life.

2. The adaptation process

As a result of the challenges proposed by this new higher education paradigm, the Mechanical Engineering and Industrial Management Department have undertaken efforts to design a Mechanical Engineering Course that could respond to the new orientations.
Over the last fifteen years, the life span of the Mechanical Engineering and Industrial Management course, there were several measures taken in order to give students the best education for their future professional lives as well as to contribute towards successful promotion of the course.

These measures such as integration, tutorial and socio-pedagogical programs, team working projects, curricula and methodology revisions were taken with very interesting results.
The design and implementation of a new curricular structure as a consequence of the Bologna process was a pretext for a broad discussion within the department. After a period of some expectation regarding the duration of the different study cycles, it was decided by the

government to establish the first cycle (the former bachelor graduation), 180 ECTS (European Credit Transfer System Units), corresponding to six semesters.

This credit system takes into account all the student's work hours: classes, tutorials, preparation and lab experiments and study. In order to have an accurate reference so as to distribute credit units fairly, both students and teachers answered questionnaires. Their opinions about the different kinds of work hours were fundamental to the attribution of the new subject's credits. Consequently, the new degree has five subjects each semester, one less than the former degree. This new course is centered in the student's need to develop the necessary professional skills, namely in areas like production, industrial maintenance and industrial management. Curricular structure is strongly based on Mathematics and Physics. The adequacy of the course revealed the need to reinforce practical knowledge application, to intensify the use of problem based learning, to design new laboratorial strategies, to promote team work and to develop the fundamental skills in engineering formation.

The new course design also resulted from the analysis of similar courses in reference countries in engineering, such as Germany, the United Kingdom, the United States, France, Swiss, Spain, Denmark, Sweden and Finland. It was compared mainly in terms of duration, curricular plans, credit system units and strategies adopted. The new Mechanical Engineering degree is comparable in structure with the foreign courses analyzed (see Table 1). General skills, critical for professional future, such as analysis and ability to summarize, communication skills, practical and critical sense, time management and team work were also considered activities to be coached and developed throughout the course.

Table 1. General structure of the new Mechanical Engineering degree

SCIENTIFIC AREA	**CREDITS**	
	Obligatory	**Optional**
Maths	17	
Information Technologies		4
Engineering Sciences	127.5	5.5
Industrial Management	11	
General competences	12	3
TOTAL	**167.5**	**12.5**

3. The new Mechanics subjects

As a result of the adaptation process two new subjects, Mechanics I and Mechanics II became the heirs of the former Physics and Mechanics. Their syllabi were modified and reorganized, in order to allow the necessary skills to be acquired in this important support field. Mechanics I directs to the analysis of mechanical systems based on concepts in kinematics and dynamics. Mechanics II is dedicated to the study of static. It begins with an analysis of the equilibrium of a particle, followed by the study of single rigid body equilibrium and gradually reaches the analysis of more complex structures. Compared to the syllabi of the former subjects, the most relevant modifications at this level were the decision to concentrate the entire static syllabus in Mechanics II and introducing the study of structures, namely regarding internal forces and methods of structural analysis.

Table 2. The new Mechanics classes scheduling

		Mechanical Engineering and Industrial Management (hours/week)	Mechanical Engineering (hours/week)
1st semester	Physics	6	
	Mechanics I		4.5
	Tutorials		2
2nd semester	Mechanics	4	
	Mechanics II		4.5
	Tutorials		2

Important changes were also made in class scheduling, like shown in table 2. During the new tutorials hours students are totally free to present topics, questions or problems related to their particular difficulties. This strategy is conducive to the possibility of individual progress in study. Each student can establish his own way to develop the required skills.

Despite the new educational context, there is some teaching experience at this level, because developing different strategies to promote success has always been a primary concern (Marques and Paiva, 2000).[13] These are usually difficult subjects and the students have to be motivated and accompanied closely.

It has been possible to identify students' major difficulties and misconceptions. One important gap is related to Newtonian mechanics, mainly in kinematics and dynamics. These difficulties arise when students have their first contact with physics at the age of 13 or 14. They manage to pass through all of the following years adopting a symbolic resolution of physics problems, recognizing patterns more than thinking about situations and applying laws and concepts. Rather than other physics subjects, mechanics is a subject which people come into contact with from birth, leading to a set of spontaneous and intuitive theories, which are for the most part completely divorced from scientific reality. This gap is related to the abstract and non-intuitive nature of mechanical concepts and to its commonly associated complex formality. In a Mechanics course, the student faces a conflict between two different ways of observing the world around him: one constructed from spontaneous observations and intuitive explanations; the other which is a scientific and rational construction that, most of the times, is not at all 'logical' (Neto, 1998).[17] Each student has his own difficulties and misconceptions, which lead to a distinguishable learning-teaching path that must be identified.

Daily examples and simple conceptual questions during classes have been used to clarify some ideas, but they were shown to be insufficient. It was necessary to create sets of questions for the students to work on. These questions had to be very objective and the goal is to test basic concepts, giving students the chance to 'think' physics. During tutorial sessions students are invited to share their experiences related with those sets of questions. Some interesting discussions revealed common misconceptions. Among others, those related to kinematics concepts and their relation with forces as well as understanding the forces involved in the interaction of bodies.

Another step to promote conceptual changes is lab work. The students are distributed in small groups of 2 or 3. For each laboratorial class each group has to prepare one of the proposed experiments. During class the groups perform the experiments and the corresponding reports are due in the next class.

The experiments were conceived and set up with the goal of developing lab skills and leading the students to think about simple phenomena, that they can easily observe and measure. The search for explanations for these lab situations is an important contribution to understanding mechanics.

As an example, they are well-known student difficulties with graphs of position, velocity, and acceleration versus time. These include, among others, graphs interpretation, the inability to understand the meaning of the area under different graph curves or to establish a correct relation between kinematics quantities and applied forces.

For the purpose of creating an interaction with these concepts in a stimulating and practical context, it was designed to be a very simple experiment (Fig. 1). It consists of a path along which a vehicle can be displaced due to the action of a mass suspended by a string and a pulley system. A sensor fixed at the beginning of the path, connected to an acquisition system and a computer, allows the registration of position, velocity and acceleration. Data can be worked in distinct ways highlighting a set of concepts and measurable values. Using different suspended masses there are a lot of possibilities to explore.

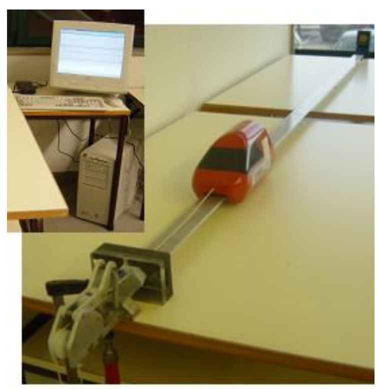


Figure1. Kinematics experiment.

Along the semester all of the groups worked on all of the experiments. At the end, each student had to make a public presentation about one of the experiments. Each one was totally free to choose how to do it. This is an important issue because, on the one hand, students have to reflect about the concepts involved, the results obtained and conclusions drawn. On the other hand, they can develop skills related to analysis, synthesis and communication such as, the correct use of language, behavior in front of an audience, to name only a few.

As far as lab work is concerned, the goal in the near future is to abandon directed experiments, for which there are plans with the various steps to be executed. The students will have relative freedom (depending on existing material) to design the experiment in order to understand and explain the different phenomena analysed.

4. The Case of Thermodynamics

Formerly distributed in three 2-hour classes hours per week, Thermodynamics classes were rearranged to two 3-hour classes (Paiva, 2005)[19]. The reason for this rearrangement was to be able to have three consecutive 45-minute periods, for each subject. It was then possible to have an initial 45-minute period where teachers presented the subject that ensured that the nominal 13 weeks enabled students to cope with the syllabus for a semester course:

I. Introduction, Concepts, Units and Definitions
II. Thermodynamic Properties
III. First Law for Closed Systems
IV. First Law for Open Systems
V. Second Law and Entropy
VI. Second Law for Closed Systems
VII. Second Law for Open Systems
VIII. Power and Refrigeration Cycles
IX. Gas Mixtures and Air Conditioning

4.1. Structure of the classes

Following the initial 45 minutes of classic exposition, using OHP transparencies and power point slides, as well as the board to illustrate practical cases and exercises, students had a 45-minute period to review their notes, to read the book and to ask questions or to clear up any doubts. At the end of this stage, there were oral questions addressed to individual students (such as those illustrated in Fig. 3). The correctness of the answers was registered in each individual file, assessed by that same individual at any moment at the beginning of class, as it was part of the daily sheets distributed and circulating among students for signing in. Then there was a 20-minute break. The next and final part of the class was used for cooperative work on assigned exercises and problems. During this last stage of the class, the teacher was always available to clear up any doubts and to help students to make their own way through the resolution. Anything is acceptable but solving that particular exercise or problem (Mazur, 1997).[14]

In the end, oral answers accounted for 15% of the final mark, thus providing a reward for attending classes regularly since, naturally, only those who had not missed were there to answer. The assigned exercises and problems (these were identifiable by a letter J at the beginning of the text J for Joker) accounted for another 15% of the final grade. Problems had a higher value. The same groups formed for collaborative work handed in an assignment on fuel cells. Marks for both the paperwork and exercises and problems were credited globally. As the paper was presented in public, different marks were given to each of the group members, based on previously outlined criteria (Paiva, 2003).[18]

4.2 Examples (quizzes and tests)

A set of questions was previously prepared for use during classes. In the end, those questions were seen more as guidelines than a precise textbook, as the dynamics of the class quite often directed the form and subject of the questions, but not the contents, in different directions. Nevertheless, there was an obligation on the part of the faculty to report the questions actually asked. They served not only as a way to ensure an acceptable level of homogenization but they will also be used as source of data for a future class database. Figure 2 shows an example of a set of questions that guided the oral assessment at the end of the first period of class number 8.

Class nr 8: Mass and energy balance for steady flow systems

1. How can energy be transferred from or to an open system?
2. Is an isothermal evolution the same as an adiabatic one?
3. How can you make a distinction between a steady and an unsteady-flow process?
4. Which advantages come from working with mass flow rates rather than with volume ones?
5. State the Conservation of Mass Principle.
6. State the Conservation of Energy Principle, for closed systems.
7. State the Conservation of Energy Principle, for open systems.
8. The total energy carried by a flowing fluid is composed by which parts?
9. On a warm summer morning a student turns on a fan in his room; coming back at the end of the day he's expected to find the room warmer or fresher?
10. Do you know any situation where any of the Conservation Principles do not apply?

Figure 2. Example of an oral set of questions.

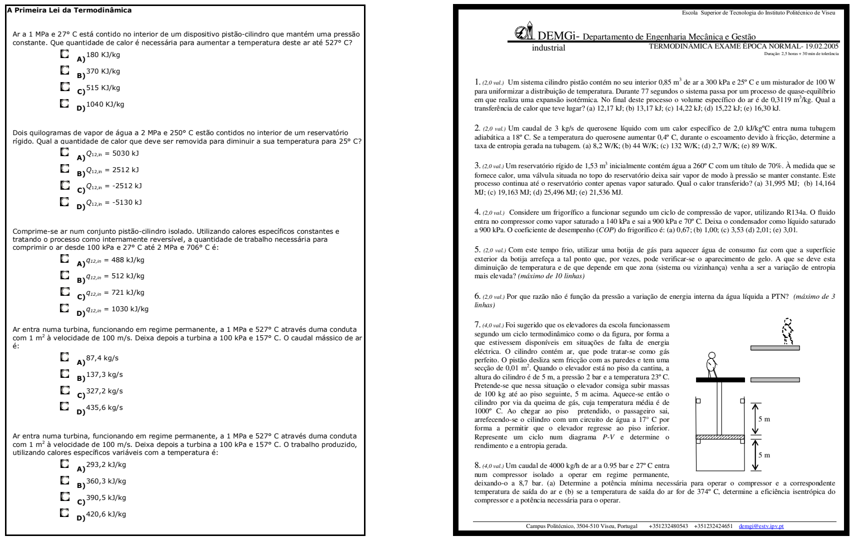
The set of oral questions shows a distribution of questions with either an immediate answer, capable of being addressed correctly by normal conscientious students, as some simple topics intended to develop some straightforward analysis.

As for the quiz, it is supposed to reward knowledge, comprehension and application, obtained by means of regular study in class. The level of achievement will be in direct relation to extra study time at home (or, more generally, outside classes), and will be the reward for those students aiming at an above average final mark. But the bottom line is, working regularly and staying on top of things is worthwhile and enables a normal student to progress.

Generally speaking, students arriving at the end of the semester may fall within one of the following conditions: One, they studied far in advance, took good notes, raised any doubts they had with their teachers; two, they studied regularly and had the same attitude towards doubts; three, left considerable amounts of material to be covered and had irregular attendance; and four, did not even take a look at the course material/work.

Were any adviser asked what the most important thing that contributes towards good preparation is, the answer would be: time management. This advice is given before at freshmen orientation, during the first year classes and at appointments with advisers integrated in GóisII activity (a program that seeks to integrate freshmen). The fact still remains that learning how to prioritize and manage time appropriately makes things a lot easier (Marques and Paiva, 2003)[13]. Procrastination does not really allow much time for cases one and two and that is why it is recommended from the beginning that preparation must start as soon as possible.

Another well known and repeatedly stressed reason for starting preparation early is that students tend to retain large amounts of information better if it is obtained over an extended amount of time rather than crammed over a few hours. Thermodynamics is a good example of this, as students are required to obtain good skills from the beginning of substance property calculation. A message is also sent out that the school realizes that students are adjusting and that is why it offers the introductory programs to help them to adjust.



A Primeira Lei da Termodinâmica

Ar a 1 MPa e 27° C está contido no interior de um dispositivo pistão-cilindro que mantém uma pressão constante. Que quantidade de calor é necessária para aumentar a temperatura deste ar até 527° C?

- A) 180 KJ/kg
- B) 370 KJ/kg
- C) 515 KJ/kg
- D) 1040 KJ/kg

Dois quilogramas de vapor de água a 2 MPa e 250° C estão contidos no interior de um reservatório rígido. Qual a quantidade de calor que deve ser removida para diminuir a sua temperatura para 25° C?

- A) $Q_{12,in}$ = 5030 kJ
- B) $Q_{12,in}$ = 2512 kJ
- C) $Q_{12,in}$ = -2512 kJ
- D) $Q_{12,in}$ = -5130 kJ

Comprime-se ar num conjunto pistão-cilindro isolado. Utilizando calores específicos constantes e tratando o processo como internamente reversível, a quantidade de trabalho necessária para comprimir o ar desde 100 kPa e 27° C até 2 MPa e 706° C é:

- A) $q_{12,in}$ = 488 kJ/kg
- B) $q_{12,in}$ = 512 kJ/kg
- C) $q_{12,in}$ = 721 kJ/kg
- D) $q_{12,in}$ = 1030 kJ/kg

Ar entra numa turbina, funcionando em regime permanente, a 1 MPa e 527° C através duma conduta com 1 m^2 à velocidade de 100 m/s. Deixa depois a turbina a 100 kPa e 157° C. O caudal mássico de ar é:

- A) 87,4 kg/s
- B) 137,3 kg/s
- C) 327,2 kg/s
- D) 435,6 kg/s

Ar entra numa turbina, funcionando em regime permanente, a 1 MPa e 527° C através duma conduta com 1 m^2 à velocidade de 100 m/s. Deixa depois a turbina a 100 kPa e 157° C. O trabalho produzido, utilizando calores específicos variáveis com a temperatura é:

- A) 293,2 kJ/kg
- B) 360,3 kJ/kg
- C) 390,5 kJ/kg
- D) 420,6 kJ/kg

Escola Superior de Tecnologia do Instituto Politécnico de Viseu

DEMGi- Departamento de Engenharia Mecânica e Gestão industrial

TERMODINÂMICA EXAME ÉPOCA NORMAL- 19.02.2005

Duração: 2,5 horas + 30 min de tolerância

1. *(2,0 val.)* Um sistema cilindro pistão contém no seu interior 0,85 m^3 de ar a 300 kPa e 25º C e um misturador de 100 W para uniformizar a distribuição de temperatura. Durante 77 segundos o sistema passa por um processo de quase-equilíbrio em que realiza uma expansão isotérmica. No final deste processo o volume específico do ar é de 0,3119 m^3/kg. Qual a transferência de calor que teve lugar? (a) 12,17 kJ; (b) 13,17 kJ; (c) 14,22 kJ; (d) 15,22 kJ; (e) 16,30 kJ.

2. *(2,0 val.)* Um caudal de 3 kg/s de querosene líquido com um calor específico de 2,0 kJ/kgºC entra numa tubagem adiabática a 18º C. Se a temperatura do querosene aumentar 0,4º C, durante o escoamento devido à fricção, determine a taxa de entropia gerada na tubagem. (a) 8,2 W/K; (b) 44 W/K; (c) 132 W/K; (d) 2,7 W/K; (e) 89 W/K.

3. *(2,0 val.)* Um reservatório rígido de 1,53 m^3 inicialmente contém água a 260º C com um título de 70%. À medida que se fornece calor, uma válvula situada no topo do reservatório deixa sair vapor de modo à pressão se manter constante. Este processo continua até o reservatório conter apenas vapor saturado. Qual o calor transferido? (a) 31,995 MJ; (b) 14,164 MJ; (c) 19,163 MJ; (d) 25,496 MJ; (e) 21,536 MJ.

4. *(2,0 val.)* Considere um frigorífico a funcionar segundo um ciclo de compressão de vapor, utilizando R134a. O fluido entra no compressor como vapor saturado a 140 kPa e sai a 900 kPa e 70º C. Deixa o condensador como líquido saturado a 900 kPa. O coeficiente de desempenho (*COP*) do frigorífico é: (a) 0,67; (b) 1,00; (c) 3,53 (d) 2,01; (e) 3,01.

5. *(2,0 val.)* Com este tempo frio, utilizar uma botija de gás para aquecer água de consumo faz com que a superfície exterior da botija arrefeça a tal ponto que, por vezes, pode verificar-se o aparecimento de gelo. A que se deve esta diminuição de temperatura e de que depende em que zona (sistema ou vizinhança) venha a ser a variação de entropia mais elevada? *(máximo de 10 linhas)*

6. *(2,0 val.)* Por que razão não é função da pressão a variação de energia interna da água líquida a PTN? *(máximo de 3 linhas)*

7. *(4,0 val.)* Foi sugerido que os elevadores da escola funcionassem segundo um ciclo termodinâmico como o da figura, por forma a que estivessem disponíveis em situações de falta de energia eléctrica. O cilindro contém ar, que pode tratar-se como gás perfeito. O pistão desliza sem fricção com as paredes e tem uma secção de 0,01 m^2. Quando o elevador está no piso da cantina, a altura do cilindro é de 5 m, a pressão 2 bar e a temperatura 23º C. Pretende-se que nessa situação o elevador consiga subir massas de 100 kg até ao piso seguinte, 5 m acima. Aquece-se então o cilindro por via da queima de gás, cuja temperatura média é de 1000º C. Ao chegar ao piso pretendido, o passageiro sai, arrefecendo-se o cilindro com um circuito de água a 17° C por forma a permitir que o elevador regresse ao piso inferior. Represente um ciclo num diagrama *P-V* e determine o rendimento e a entropia gerada.

8. *(4,0 val.)* Um caudal de 4000 kg/h de ar a 0.95 bar e 27º C entra num compressor isolado a operar em regime permanente, deixando-o a 8,7 bar. (a) Determine a potência mínima necessária para operar o compressor e a correspondente temperatura de saída do ar e (b) se a temperatura de saída do ar for de 374º C, determine a eficiência isentrópica do compressor e a potência necessária para o operar.

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Figure 3. Examples of (a) a quiz on the First Law of Thermodynamics and (b) a test/exam.

Within this strategy, procrastinating students are therefore encouraged to realize the goals of such an approach, particularly in Thermodynamics. They are alerted from the very beginning of the course to the benefits of avoiding, the unfortunately quite common, passive attitudes, as right from the very beginning there is a record of efforts made to keep up with the subjects. Procrastination is also fought as students are coached by both faculty and peers who are constantly there to answer questions or overcome a difficulty.

Another effort that is consistently made consists in making it clear to students that, within all subjects, there are things that they must know how to deal with precisely, and that those aspects turn out to be evaluated on a sole basis of a final result. And a distinction is made in what concerns other approaches to the same subjects, deeply complex approaches, for instance, where their evaluation is based on the quality of the analysis carried out. These two aspects are regularly illustrated by means of exercises and problems, respectively, using these designations to endorse each one of the two referred angles.

Throughout the classes, once a subject is presented, the first part of the work performed is directed to the first three levels of Bloom's well-known taxonomy, *i.e.*, knowledge, comprehension and application. The first oral questions address knowledge and comprehension, and the first exercises, application. In advanced classes, oral questions keep addressing knowledge, but some questions are introduced to exercise analysis.

Students are encouraged to come to the conclusion that knowledge is not the same thing as information, that information is accessed instantly but knowledge is a construction which takes time. The next step is to show that an individual is only capable of solving complex situations after being very well-acquainted with solving common situations.

As the previous experience of nearly all students mixed these two levels (especially those coming directly from k-12), and it is a tradition to consider that anything that was written has to be accounted for, a strong emphasis is placed on solving multiple choice questions, stressing that, as the knowledge involved is called upon for a low level use, those questions are evaluated on a right or wrong basis. That same approach is illustrated in the exam structure in Fig. 3(b). That structure is kept for all tests, the mid-term, the normal and the final exam.

Therefore, the tests demonstrate that on a scale of twenty points the first eight are earned by answering multiple choice quizzes. Those quizzes are made up of simple questions, exercises such that having practiced conscientiously, an average student is supposed to be able to answer quickly and easily. Questions 4 and 5 address conceptual understanding of daily phenomena and account for four points, i.e., 20% of the overall mark, thus stressing the importance given to understanding the physics of processes. Problems 7 and 8 will be the object of a 'constructive' correction, giving a good deal of credit to developing reasoning and not only the final result. They are worth 40% of the final mark.

4.3. Results

A first evaluation was made during the last week of classes. Students were asked to give their opinion on how things had worked out. The survey addressed several issues but the more important ones, within the scope of this paper, were those related to the impact that the fact of providing regular study, within class time, had been appreciated. Students were requested to answer identifying themselves as first time or repeating Thermodynamics students. In order to enhance and develop this initiative in the best way possible, there was a continuously driven effort to ensure a regular follow up, either by recording attendance, or by registering marks on oral quizzes and cooperative exercises and problems solved cooperatively.

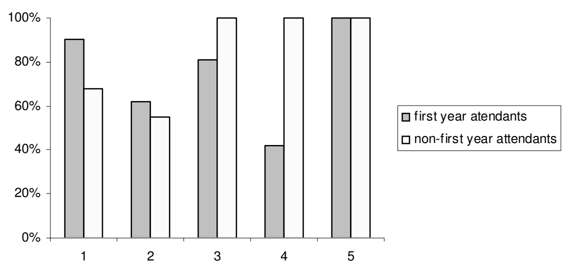

Figure 4. End of Thermodynamics course survey; Key: 1- Difficulties in keeping up; 2- Considered the period of study in class positive; 3- *Idem* oral questions assessment; 4- *Ibidem* multiple choice; 5. Considered using a TIC interface for homework correction favorable

These are some of the questions answered by students shown in Fig. 4. To prove that there are no miraculous solutions in education, a great majority of answers, both from first and non-first year students, indicated that it was difficult to keep up, even after being accompanied so closely.

Difficulties in keeping up must be understood as being closely related to insufficient practice (and demonstrates that class work alone is insufficient). The fact that the in-class study was considered positive is an indication in the same direction: students appreciated the results of studying in due time and recognized that having stabilized some information and acquired some knowledge; but they also think that the solution would come a slower pace which would allow them to address the oral, multiple choice and, eventually, tests, with greater success rates. The 'TIC interface for homework correction' was introduced to assess their willingness to have homework corrected through an intranet terminal in future.

The number of students attending classes increased appreciably. This was made possible due, in part, to those who were not necessarily required to do so, because being second year students, they could miss classes if their records in the first year proved a minimum of 75% attendance.

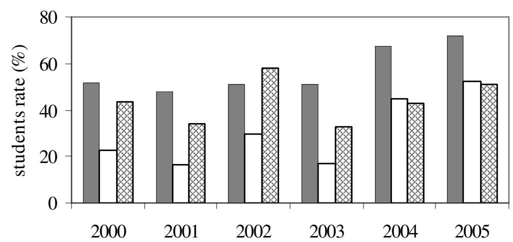

Figure 5. Students' attendance (filled) and evaluation (blank) rates, calculated on a total registered students number; success rates (cross off columns) calculated on the number of attendant students (2000-2005).

The increased rate of students who attended evaluation (tests and exams) shown in Fig. 5 is also the result of answering quizzes as well as solving exercise during class time. That gave them increased self-confidence beyond some knowledge application.

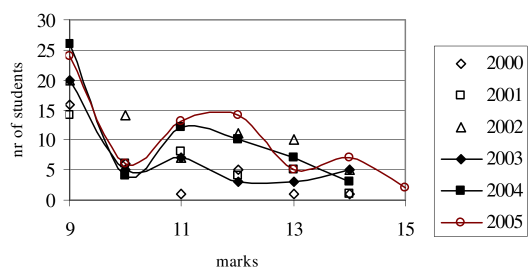

Figure 6. Marks distribution with the number of students.

Many of them, even after failing that assessment, told faculty that they knew what 'had gone wrong' or 'was missing' and that they would know better next time. This was a significant difference regarding former years, when many students did not even try to attend tests because they simply had no idea whatsoever of what to do to start studying.

Figure 6 represents the number of students who achieved marks below 9.5 out of 20 and 10 to 15. As there was a change in 2004 in contributions from assignments and attendance, and the introduction of oral questions, the relative percentage of tests and paper assignments changed. Nevertheless, comparisons can be made and they show that there are no significant changes concerning higher marks, but they show a slight trend in the 11-13 and 13-15 intervals.

5. The Case of Heat and Mass Transfer

This course followed the same pattern as Thermodynamics in terms of weekly class distribution: two 3-hour classes. The semester course also has a classic syllabus:

I. Introduction, Basics of Heat Transfer
II. Heat Conduction Equation
III. Steady Heat Conduction
IV. Transient Heat Conduction
V. Fundamentals of Convection

VI. Forced Convection
VII. Natural Convection
VIII. Fundamentals of Thermal Radiation
IX. Radiation Heat Transfer
X. Mass Transfer
though not necessarily taught in this sequence.

5.1. Structure of the classes

The main structure was similar to Thermodynamics. The first 2 chapters, *i.e.*, until finishing the topic of the General Heat Conduction equation, classic exposition, using OHP transparencies and slides was used, along with increased usage of the textbook.

At the end of the 45-minute review period individual students were asked questions orally. Special attention was given to understanding heat transfer phenomena, simultaneous heat transfer mechanisms and boundary energy balances, particularly those involving the notion of heat flux and its continuity in steady state conditions, using hydraulic analogies.
Once Chapter II was completed, things changed. Now we would begin to apply the new paradigm: we were right in the middle of the implementation of the Bologna Process.

5.2. Problem-Based Learning

A MacDonald's fry was the object chosen to start this new phase. The question placed was "Do you think you could improve McDonald's fries and to deliver a textbook to successfully fry the best French fries?" The discussion on what was a good French fry began, and after a while the good fry was defined as a simultaneously interiorly baked and externally crispy fried regular sized piece of potato. Students were assigned to search for more detailed information on that subject and to give an oral presentation during the next class. Meanwhile, the problem proposed was, in order to bake a piece of potato with the same dimensions as the French fry, to investigate the possible use of the Lumped System Analysis. Next, some convection fundamentals were taught and students used them to look into the subject and eventually calculate, by means of a semi-empirical correlation, an approximate value of a natural convection coefficient.

This subject was worked on until the end of classes. It was the anchor of the remaining topics; it was used to address bi-dimensional conduction, to use the Heisler and Gröβer charts (Incropera and DeWitt, 1996)[9], to deal (and understand the attractiveness of that usage) with semi-infinite solids, to calculate different convection heat transfer coefficients to cope with the fact that a rectangular prism like fry, has horizontal and vertical panes; to simulate fin behavior, with the same dimensions, exposed to a high temperature fluid.

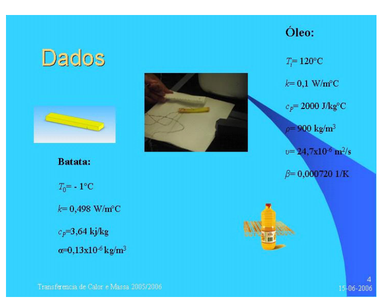

Figure 7. A presentation slide concerning the French fry study.

Every two weeks students, previously (and almost routinely) organized in groups of two or three, had to give the whole class a presentation. This regular activity proved to be an excellent choice to bring down the stress levels. In the end, the last version of the presentation was the assignment which was handed in and evaluated, not only as a final project but also as the result of continuous learning and assessment. It was used as a way to foster independent and autonomous property search for both vegetable oil and potatoes (density, thermal conductivity, thermal diffusivity, specific heat and volume expansion coefficient).

This problem-based learning process continued with another "just-in time" case study- the forest fires that have been one of the major concerns these last couple of years due, on the one hand, to the importance this economic sector has on several paper related industries, and on the other hand, to the fact that the dimension those fires have been taking put lives and property at risk. So, the case was trying to study one pine tree exposed to fire, thus calculating all the parameters needed to find a forced convection coefficient, at the same time they had to evaluate how long the pine surface would take to reach ignition temperature.

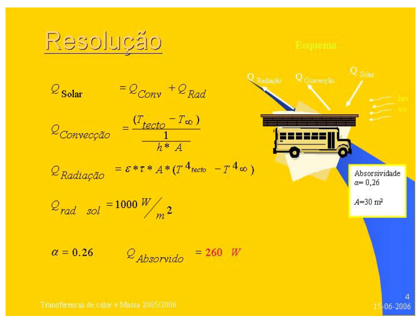

Figure 8. A presentation slide concerning the bus ceiling temperature.

The third case had to do with a bus that was travelling on a given summer day at a precise moment, so that students were forced to search for ASHRAE files and use direct and diffuse radiation values for that particular moment (Fig. 8).

Finally, the school's boiler was visited, its different dimensions actually measured and surfaces and environment temperatures evaluated by means of an infrared proximity probe. Radiation view factors were calculated and the hydrodynamic and thermal entrance regions evaluated so that a value of heat losses from the waste hot water exit could be calculated. Due to an exceptional time schedule for 2005/2006, the topic "Mass Transfer" was not covered.

5.3. The Experimental Part

The theoretical/semi-empirical results were compared to experimental data gathered with a data acquisition system. After realizing that vegetable oil was not an electrical conductor (through an internet search were a German student was proving the point by totally immersing a motherboard into an aquarium filled with vegetable oil).

Significant superficial temperature decrease, when in comparison with the data being recorded by the inner thermocouple, was autonomously interpreted as an effect of the latent energy used for phase change as water inside the potato was evaporating at the surface, merged into hot oil.

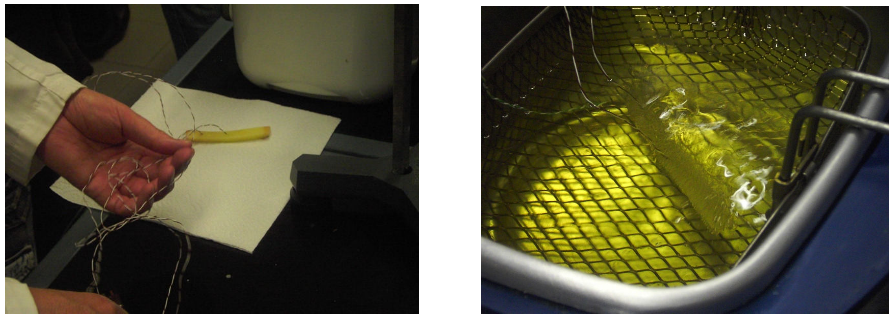

Figure 9. Wiring and frying the French fry.

The natural convection hot horizontal surfaces hexagonal pattern, which description was always a bit “fluid”, was identified during the frying experiments (Fig. 10(a)).

(a) (b)

Figure 10. (a) Upper surface of a hot plate, natural convection; (b) Heating the oil.

The transient heating process of the electric frying pan was also used to determine electric consumption and the amount of energy needed to fry 500 g of initially frozen potatoes.

In the end, the data was compared with the theoretical results, in order to assess the amount of time needed to bake and fry the potatoes. And though this was an atypical situation, the order of magnitude involved was quite satisfactory.

Due to an exceptional time schedule for 2005/2006, the topic “Mass Transfer” was not covered.

5.4. Results

A survey was conducted just after the classes were finished and the first exam was taken three days later. The positive issues referred were:
i) improved quality of language usage;
ii) concern with what presentations looked like and with quality of editing and appropriate use of symbols;
iii) improvement in communication skills;
iv) improved knowledge;
v) improved skills when dealing with esoteric or unusual situations;
vi) increased personal feeling towards the need to develop regular study habits.

As for the negative ones:

i) lack of time to study after classes;
ii) non-similar problems dealt with regarding those that are expected appear in tests.

6. The Case of Operations Management

Referring now to the Management area in the Mechanical Engineering graduation, an example that will show the innovative teaching methods used in Operations Management course, under the guidelines of Bologna reorganization process will be described, as well as some of the results that have been achieved so far.

Within the previous five-year graduation in Mechanical Engineering and Industrial Management, the Production and Operations Management area was explored in two different semester courses: Inventory and Production Management and Operations Management. The first one appears in the 3rd year of the course and concerns 'production' in the classic sense of the word, i.e., production of goods, complemented with inventory management. Specifically, the contents of the Inventory and Production Management included issues like strategy, design of productive systems (including size, location and plant layout), aggregate planning, production scheduling and control and inventory management.

The Operations Management course appeared in the 4th year of the graduation with the purpose of looking at production management from a broader perspective. In other words, the term *production* is now applied for both goods and services. However, for the Operations Management course the need to establish more ambitious goals in order to follow the present-day reality that demands increased innovation in enterprises so as to face global competition was felt. The introduction of entrepreneurial skills has been an established goal since 1999, but, only after a first external evaluation process was momentum created that enabled this to take place under the guidelines of the Bologna Declaration on the European Space for Higher Education. Therefore, in the 2002 academic year, a reorganization in the Operations Management curriculum took place, bringing together the (not so) classic contents of designing productive systems (both products and services), organizing and implementing operations strategy, carefully managing the processes to distribute those products and services, doing all of this in an innovative way, and through entrepreneurship.

After the implementation of the new Mechanical Engineering graduation curriculum under the guidelines of the Bologna Declaration, the Operations Management and Production and Inventory Management courses merged into just one called Production and Inventory Management, appearing in the 3rd year, bringing together the goals of the previous two.

The teaching methods used in Operations Management course can now be applied to this new single course, since the results obtained so far with this method are very encouraging. The teaching methods used in Operations Management course will be described in some detail in the following section. The new curriculum was divided into three distinct parts, as described below.

6.1. Using Case Studies

In order to apply this teaching method, it is absolutely necessary for classes to take place in labs with internet access. During the first couple of weeks students are expected to propose their own teams of two to three elements, which will work together until the end of the semester. Solving the case studies presented in class is the first team work of this course. The four/five initial weeks are used to approach the main subjects and to discuss them based on case studies (Zara, Optimus, Vulcano/Bosch, Benetton, Birmingham Airport, Marks and Spencer; Johnston *et al.*, 2003).[10] It is a fact that the decisions that operations managers take each day in their organizations cannot easily be studied by simply listening to or reading texts. Certainly these will give students important and helpful insights, but it is also a fact that the subject does not come to life until it is practiced. That is why case studies are essential to teaching practical and applied subjects such as operations management.

Case studies allow students to understand what operations managers actually do and how they work, as well as the issues they have to face. Most importantly, case studies also provide students the opportunity to deal with the situations that operations managers face in a safe environment, giving them a chance to analyze and evaluate those situations and to develop and discuss possible solutions with peers.

All cases studied in the Operations Management course are real, based on real situations, and real organizations which make them especially interesting. Case studies have the ultimate goal of helping students to develop a range of skills that could be of great importance in their professional lives, as operations managers or as entrepreneurs (Johnston *et al.*, 2003).[10] Some of those are: analytical skills, application skills, creative skills, critical thinking skills, decision-making skills, interpersonal skills, time management skills and written communication skills. These skills do not just appear out of nowhere, they must be worked at, and it is the students' responsibility to develop their own skills through an adequate approach of case analysis, treating them as problem-solving opportunities.

6.2. Introducing Entrepreneurship

In the second part of the Operations Management curriculum, a short 10-hour Entrepreneurship course is given, following the "Getting Started as an Entrepreneur" (NCIIA, 2002).[15] It addresses the following issues: creativity (finding and evaluating an idea), opportunity, teambuilding, planning work and business planning, evaluating legal constraints and finding money. Those general issues are deeply analyzed and discussed in class with students.

Entrepreneurship education is a way to teach students to embrace changes rather than fear them. It is the teacher's duty to help students to understand their options in a free market economy, and to encourage them to look for entrepreneurial opportunities themselves.

Entrepreneurs look at "risk" and see opportunity for their expertise rather than opportunity for failure. In the Entrepreneurship course, students are also taught how to analyze opportunities available to them.

Opportunity-focused entrepreneurs must always start with the customer and the market in mind and that is how students are encouraged to think. This course also teaches how to analyze some important market issues like market structure, market size, growth rate, market capacity, attainable market share, cost structure, strategy issues, breakeven point, opportunity costs and barriers to entry. To sum up, the Entrepreneurship course has an ultimate goal of helping students answer the following questions, which any entrepreneur should use to evaluate his business ideas and plans (Ashmore, 2005):[2]

- What is the need you fill or problem you solve (value proposition)?
- Who are you selling to (target market)?

- How would you make money (revenue model)?
- How will you differentiate your company from what is already out there (unique selling proposition)?
- What are the barriers to entry?
- How many competitors do you have and of how good are they (competitive analysis)?
- How big is your market (market size)?
- How fast is the market growing or shrinking (market growth)?
- What percentage of the market do you believe you could gain (market share)?
- What type of company would this be (lifestyle or high potential, sole proprietorship or corporation)?
- How much would it cost to get started (start-up costs)?
- Do you plan to use debt capital or raise investment? If so, how much and what type (investment needs)?
- If you take on investment, how much money do you think your investors will get back in return (return on investment)?

By using these questions students should be able to do a thorough job of analyzing the business ideas they come up with.

This type of entrepreneurial education has numerous benefits. The most important are: community understanding, business management skills, orientation to change, individual personal growth, expanding creative thinking, decision-making skills, sense of career choices and application of technical skills and experiences.

6.3. Written Projects

The third part of the Operations Management course appears as a natural sequence of the Entrepreneurship short course. Previously, during the first week, students are well informed about how the course is structured. Therefore, by the end of the fourth week each group is expected to state their own idea of an innovative service within an existing enterprise (including the one they are working at) or of an enterprise itself. So, after the Entrepreneurship course, groups start to develop their own projects, based on the idea they have presented, applying concepts acquired up to that point.

The operational contents (planning and control) that follow the unfolding course are approached in a highly applied manner, i.e., applied to their very own case. Those contents could vary depending on students' specific needs, following their work in class. It is important to say that projects are mainly worked on during class. Nonetheless, students still have to get together out of classes to work on their projects.

Considering that in their projects students make an effort trying to create as real a business as possible; the final assignments handed in by students are expected to approach the three basic functional areas of any business organization: Finance, Marketing and Operations (Stevenson, 2005).[16] The Operations function is primarily responsible for producing goods or services offered by the organization, which is obviously the main issue in the Operations Management course. Therefore, the Operations functional area should be the one which is most highly-developed in students' final assignments, allowing them to apply their knowledge and demonstrate how much they have learned.

The final week of the Operations Management course is usually reserved for the presentation and discussion of the assignments. Each group prepares a ten-minute Power Point presentation, followed by a brief discussion where students are questioned about their work. All presentations are open to classmates.

6.4. Assessment

Assessment of the Operations Management was established in order to motivate students to attend classes regularly. It is divided as follows:

Table 3. Operations Management course assessment.

Issues	Value (%)
Case studies	10
Public presentation	35
Participation quality	10
Written test	45

Case studies were worked out in class; public presentations involving an application assignment of theoretical concepts taught in the scope of the Operations Management course, particularly as an entrepreneurship application, in an existing enterprise (including the one they were working on) or of an enterprise itself; the quality of classroom participation was taken into account considering the level of student attendance (50%, and students should attend a minimum of 75% of the classes) and the effective quality of classroom participation, measured by answers and comments produced.

Beyond motivating regular attendance, this assessment allows students to increase their chances of successfully completing the Operations Management course, since passing does not depend exclusively on a single assessment moment.

The assignments handed in over the past two years have been very interesting and, in some cases, the ideas that students have come up with are quite original. Some examples of those assignments are:

- Creating a new mobile phone operator – this new company appears in the market with competitive prices and a set of innovative services to compete with those already in place.
- Creating an institution that provides, in a unique space, a complete set of student services – this institution provides all sorts of information that students need; it is also a study centre, with a library, an internet room and a coffee shop, all this in a single, open space.
- Creating a fresh vegetable export enterprise– the main goal was to provide to some European countries with fresh vegetables out of season.
- Creating an enterprise law consulting firm – this enterprise would provide consulting services, legal support and standardization services.
- Creating an enterprise that provides fire prevention services – this enterprise provides training courses to fire fighting corps, analyzes risk situations and provides enterprises with safety inspections.
- Creating a professional school.

Those assignments, along with all the work developed during the semester are proof that students have acquired some operations management and entrepreneurial skills and that they have learned how to explore and develop those skills.
At his point, one can say that there are some key points or main goals with this curriculum that have been achieved so far:

- The first is to make students take an active role in their own learning and to make them understand that they should take personal responsibility for their own learning and development, as required by Bologna;
- The second is to provide students with entrepreneurial abilities and exercise skills so they can more easily create their own job or to empower them to make a valid contribution to increase innovation and competitiveness in the enterprises where they will either work or are currently working.
- Finally, it is teachers' belief that this course and this particular teaching method have been contributing to provide students with professional skills based on individual learning processes.

The results obtained so far are insufficient to establish some final and definite conclusions. Nonetheless, there is some evidence of positive trends directly related to this approach, making it appear to be a valid way to further implement this teaching method on the new Production and Inventory Management course, following the Bologna guidelines.

7. Conclusions

Implementation of the Bologna process has been, so far, an excellent opportunity for all those who feel that teaching is finding ways to deliver, to use their ability to put into practice the unified complete set of engineering laws applied to graduated engineers: being able to solve problems independently.

Teaching subjects related to physics, the faculty always complains about the background level and the lack of student commitment. The goal has never been to accept fatalities or recurrent excuses for failing to teach ordinary students. An opportunity exists to give students a major role in their own learning process, making them responsible for following subjects, creating situations that carry with them important motivating potentials.

An issue has yet to be addressed independently– students' own time management, especially when studying subjects which require more dedication, more extended in time. Helping them to find a way out is an issue that begins being addressed throughout the course. For the time being, reduced class time is a window of opportunity for independent learning. Still, the fact that the Bologna process is resulting in an increased pressure for the rapid growth of student entrance into the work force, at the same time as it increases the need for a complete and precise set of professional abilities and skills. This must not give any illusions as to what is expected from faculty, especially in polytechnics. The times, definitely, they are a-changin'.

Come gather 'round people
Wherever you roam
And admit that the waters
Around you have grown
And accept it that soon
You'll be drenched to the bone.
If your time to you
Is worth savin'
Then you better start swimmin'
Or you'll sink like a stone
For the times they are a-changin'.

Robert Zimmerman, 1964

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