Proceedings of the 11th Brazilian Congress of Thermal Sciences and Engineering -- ENCIT 2006
Braz. Soc. of Mechanical Sciences and Engineering -- ABCM, Curitiba, Brazil,- Dec. 5-8, 2006

Paper CIT06-0974

BOLOGNA PROCESS: FOR THE TIMES THEY ARE A-CHANGIN'

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Abstract. *Changing winds are blowing through the European higher education systems. The so called Bologna process brings new horizons, new challenges and new hopes. But it mainly brings a new paradigm: to change the focus from knowledge transmission to student's competence acquisition. Improving the quality of the provided education through an assessment of the professional skills. Moreover, it pretends to promote mobility of students and teachers, creating portable curriculum designs, reinforcing the European cultural and educational space. The implementation of different educational strategies transfers to the students the important role. This paper describes the new adequate subjects of Physic/Mechanics and Thermodynamics and Heat and Mass Transfer, the measures that allow the construction of a sufficient basic conceptual structure in applied situations, trying to fill the gap between theoretical and professional areas, bringing and thoroughly describing the particular didactic cases used in teaching. The ultimate goal is to provide the means to fulfil a competent life, assuring the acquisition of professional skills based on individual learning processes.*

Keywords. *Active Learning, Engineering Education, Bologna Process*

1. Introduction

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

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

The learning process will conduct the students to acquire personal, academic and professional skills. These skills will have a fundamental role for the individual itself and for his integration in society. The centre of learning-teaching process will be shifted towards the student and his particular evolution as reference. This learning and formation process is meant to continue during the all time life.

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

Actually, the Bologna's process is aimed at creating a new higher educational paradigm centred in student work, skill's importance and adequate preparation to professional life.

2. The adequation process

As a result of the challenges proposed by this new higher educational paradigm, the Mechanical Engineering and Industrial Management Department made efforts to design a Mechanical Engineering Course that could answer to the new orientations.

During the last fifteen years, lifetime of the former Mechanical Engineering and Industrial Management course, there have been several measures applied in order to give the students the best education for their future professional lives as well as contributing to success promotion.

Measures like 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 Bologna's process was a pretext for a broad discussion inside the department. After a period of some expectation which concerned to the duration of the different study cycles, it was decided by the government to establish to 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 a reference to make a fair distribution of the credit units, inquiries were presented to both students and teachers. Their opinions about the different kind of work hours were fundamental to the attribution of the new subject's credits. In consequence, the new degree has five subjects each semester, one less than the former bachelor. This new course is centered in the student need to develop the necessary professional skills, namely in areas like production, industrial maintenance and industrial management. Curricular structure is strongly based in Mathematics and Physics. The adequacy of the course made apparent the need of reinforcing practical knowledge application, to intensify the use of problem based learning, to design new laboratorial strategies, promoting team work and developing the fundamental skills in engineering formation.

The new course design also resulted from the analysis of similar courses in reference countries in engineering domains, such as Germany, United Kingdom, United States, France, Swiss, Spain, Denmark, Sweden and Finland. It was mainly compared in terms of the duration, the curricular plans, the credit system units and the adopted strategies. The new Mechanical Engineering degree has a comparable structure with the analyzed foreign courses: basic sciences (Maths and Physics), engineering sciences (Mechanics, Materials Strength, Fluids and Energy, Electricity and Electronics, Automation) and industrial management. Generic skills, critical for professional future, such as analysis and synthesis capacity, communication ability, practical and critical sense, time management and team work, were also thought as activities to be coached and developed during the course.

3. The Physics/Mechanics case

The new adequate subjects of Mechanics I and II will be the heirs of the former Physics and Mechanics. Their syllabus will direct to the analysis of mechanical systems based in kinematics, dynamics and static concepts. Although in a new educational context, there exists some teaching experience at this level, because there always has been the concern of develop different strategies to promote success. These are usually difficult subjects and the students have to be motivated and followed with particular attention.

It has been possible to identify students' major difficulties and misconceptions. One important gap is related with Newtonian mechanics. This might be related to the abstract and non-intuitive nature of mechanical concepts and also 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 that is 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'. Each student has his own difficulties and misconceptions, which lead to a distinguishable learning-teaching path that must be identified.

Daily examples and simple experiments have been used to clarify some ideas, but they were noticed to be insufficient. It was necessary to create sets of questions for the students to work on. These questions must be very objective and the goal is to test basic concepts, giving the students the possibility to 'think' physics.

Introducing the use of a computer supported experimental learning-teaching program, the goal is to have a more interesting and efficient model, improving students' motivation through the use of an ICT, allowing the immediate assessment of their own results. This way the student can work and have an idea of his progress, without teacher's presence, leading to a self responsibility and some autonomy following Bologna's ideal.

In a very near future the idea is to have a considerable number of exercises in a repository available on the web, with easy access to the students. For the moment and in order to test the students' reactions to this new tool, the computer provides a set of mechanics problems related to the different subjects studied. The students try to solve each problem and they write a solution. The system corrects and returns the system's answer to the student in real time. In case of error it is possible for the student to find a new solution. This procedure could be repeated as many times as necessary until the correct answer is found, though the system in place only allows three attempts. After that, the solution is disclosed and a new problem is presented.

Example 1− A box has a mass of 8 kg. The static friction coefficient between the box and the floor is 0.50. Calculate the maximum value for F which makes the box stay at rest. Consider g= 10 m/s^2.

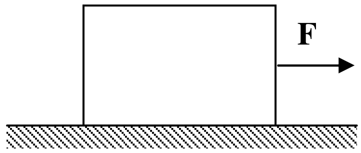


Figure 1. Schematic for Example 1

In the resolution of this kind of problems it is very common to observe students' difficulties related with the depiction of free body diagrams, namely concerning normal reactions and friction forces. There is also a common misconception between mass and weight; the establishment of the equilibrium equations is also accountable for some wrong answers. The correct resolution shall be:

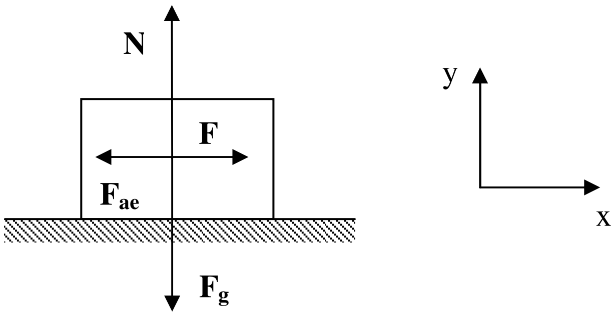


Figure 2. Free body diagram of the box in Example 1.

Establishing the equilibrium vector equation:

$$\mathbf{F_g + Fa_e + N + F = 0} \quad (1)$$

and writing the corresponding scalar expressions, along xx

$$F - Fa_e = 0 \quad (2)$$

and yy

$$N - F_g = 0$$

(3)

From Eq. (3)

$$N = F_g \quad (4)$$

and remembering the static friction force concept

$$F - \mu_e N = 0 \quad (5)$$

From Eq. (4) and (5), we have

$$F - \mu_e F_g = 0 \quad (6)$$

that, using this example values, is

$$F - 0.50*8*10 = 0 \quad (7)$$

and finally

$$F = 40 \text{ N} \quad (8)$$

Some of the possible errors delivered by the system are:

F = 40 (*units are not referred*) (9)

F = 4 N (*mass was used instead of the weight of the box*) (10)

F = - 40 N (*incorrect formulation of equilibrium scalar equations*) (11)

An important feature of the system is the possibility of identifying errors committed while the problem is being solved incorrectly and provide, if requested, a report. This report is a very important basis of work for the student because it can show the points that need to be worked on harder. This is done in a context of multiple-choice questions with only one correct answer. The wrong solutions are based on common student errors or 'false friend' situations where students usually fall down (the so called distracters). Every incorrect answer has a corresponding suggested correction, which identifies the probable error (Vinhas and Paiva, 2006).

For each syllabus the system has problems with different degrees of difficulty, allowing the student to control his own progress as the system corrects the answers in real time. If required, the system can present the complete resolution of the problem and also a report describing the nature of the different errors committed.

In what concerns laboratorial work the goal is to abandon directed experiments, for which there exist plans with the different steps to be executed. So the student will have relative freedom (depending of the existent material) to design the experiment in order to understand and explain the different analyzed phenomena.

4. The Thermodynamics case

Formerly distributed in 3 classes of 2 hours per week, Thermodynamics classes were rearranged in a 2 classes of 3 hours (Paiva, 2005). The reason for this rearrangement was to be able to have three consecutive periods of 45 min each, for each subject. It was possible then to have an initial period of 45 minutes where teachers presented the subject that ensured that the nominal 13 weeks enabled coping 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 transparencies and power point slides, as well as board writing for illustrating applied 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 some doubts. At the end of this phase, 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 phase 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 goes but solving that particular exercise or problem (Mazur, 1997).

In the end, oral answers accounted for 15% of the final mark, thus providing a reward for attending classes regularly since, naturally, only those that 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 were in place for handing in a paper assignment on fuel cells. Marks for both paperwork and exercises and problems were credited globally. As the paper was presented in public, some different evaluations were performed for each of the group members, based on previously exposed criteria (Paiva, 2003).

4.2 Examples (quizzes and tests)

A set of questions was previously prepared for use during classes. In the end, those questions became more as guidelines than a precise road book, 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 feeding data for a future class database. Figure 3 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?

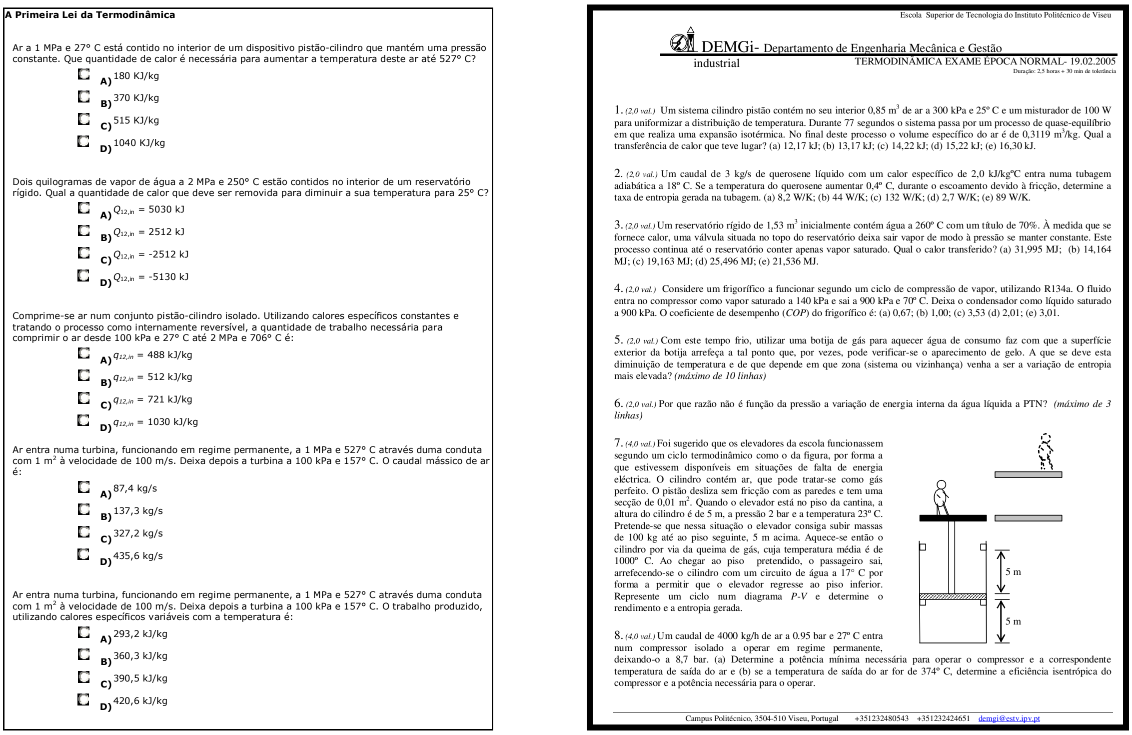
Figure 3. Example of an oral set of questions

The set of oral questions shows a distribution of questions regarding either immediate answer, capable of being addressed correctly by normal conscientious students, as some simple subjects 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 the extra study time at home (or, more generally, outside classes), and will be the prize 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 the teachers; two, they studied regularly and had the same attitude towards doubts; three, left considerable amounts of topics to be covered and had irregular attendance; and four, did not even take a look at the course material.

Were any adviser asked what the most important thing that contributes towards good preparation is, the answer will 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 integrating freshmen). The fact still remains that learning how to prioritize and manage time appropriately makes things a lot easier. Procrastination does not really allow much time for cases one and two and that is why, since the beginning, it is recommended 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 requested to acquire good skills since 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

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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 4. 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 to Thermodynamics. They are alerted from the very beginning of the course to the benefits of avoiding the unfortunately quite common passive attitudes, as since the very beginning there is a record of the efforts to keep up with the subjects. Procrastination is also fought as students are coached by both faculty and peers who are constantly there for answering questions or overcome a difficulty.

Another effort that is consistently made is the one that consists in making clear to students that, within all subjects, there are things that they must know precisely how to deal with, 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, approaches deeper in complexity, for instance, where the evaluation is made on a basis of 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 that 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 that there is an acquired 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 into 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. 4(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 answer them quickly and easily. Questions 4 and 5 address conceptual understanding of daily life phenomena and account for four points, i.e., 20% of the overall mark, thus stressing the importance given to understanding the physics of the processes. Problems 7 and 8 will be the object of a 'constructive' correction, giving a good deal of credit to development of reasoning and not only the final result. They are worth 40% of the final result.

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 and taken advantage of. 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 possible way, 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 solved exercises and problems.

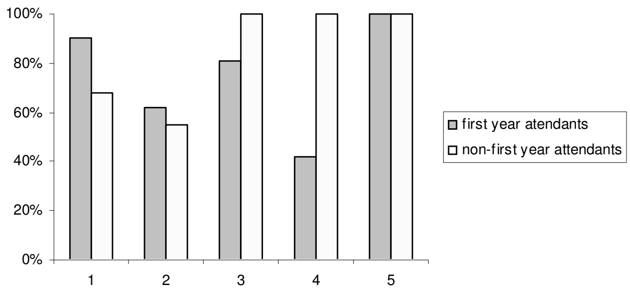

Figure 5. End of Thermodynamics course survey; Key: 1- Difficulties in keeping up; 2- Considered the period of study in class positive; 3- *Idem* oral questions assessment; 4- *Ibidem* multiple choice; 5. Considered using a TIC interface for homework correction favorable

These are some of the questions answered by students shown in Fig. 5. 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 subjected to such a close assistance.

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 having stabilized some information and acquired some knowledge but think that the solution would be a slower pace that 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, in the future, homework corrected through an intranet terminal

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

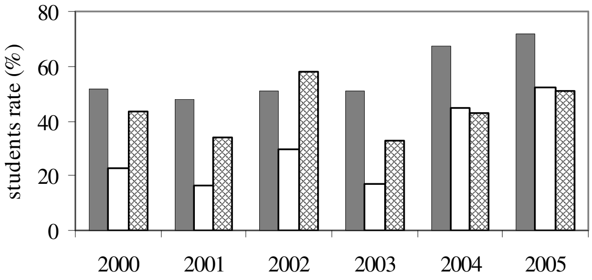

Figure 6. Students' attendance (filled) and evaluation (blank) rates, calculated on a total registered students number; success rates (cross off columns) calculated on the number of attendant students (2000-2005).

The increased rate of students that attended evaluation (tests and exams) shown in Fig. 6 is also the result of experiencing answering quizzes as well as solving exercise during class time. That gave them, beyond some knowledge application, increased self-confidence facing those assessment situations.

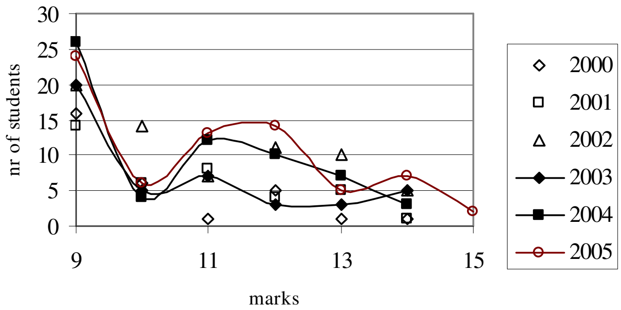

Figure 7. Marks distribution with the number of students.

Many of them, even after failing those assessment moments, told faculty that they knew what 'had failed' 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 7 represents the number of students that 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 no significant changes concerning the higher marks, but they show a slight trend in the 11-13 and 13-15 intervals.

5. The Heat and Mass Transfer case

This course followed the same pattern from Thermodynamics in terms of weekly class's distribution: 2 classes of 3 hours. The syllabus for a semester course is also a classic one:

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 addressed, necessarily, in this sequence.

5.1. Structure of the classes

The main structure was similar to the Thermodynamics' one. The initial 2 chapters, *i.e.*, until finishing the topic of the General Heat Conduction equation, classic exposition, using transparencies and slides was used, along with fostered usage of the book.

At the end of the 45-minute review period oral questions were addressed to individual students. Special attention was given to understanding heat transfer phenomena, simultaneous heat transfer mechanisms and boundary's energy balances, particularly those involving the heat flux notion and its continuity in steady state conditions, using hydraulic analogies.

Once Chapter II was finished things changed. Now we would begin to apply the new paradigm: we were right in the middle of the Bologna's Process implementation.

5.2. The 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 the McDo fries and to deliver a road book 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 deliver it during the next class. In the meanwhile, the problem proposed was, in order to bake a piece of potato with the same dimensions of the French fry, to investigate the possible use of the Lumped System Analysis. Next, some convection fundamentals were exposed 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 kept to work around 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), 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 regular, parallelepiped like fry, has horizontal and vertical panes; to simulate a fin behavior, with the same dimensions, exposed to a high temperature fluid.

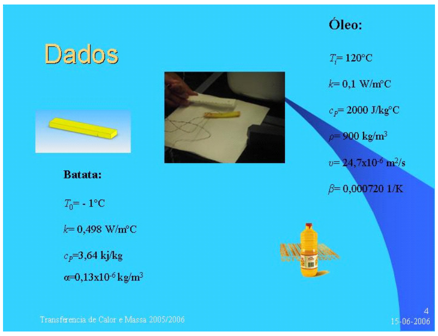

Figure 8. A presentation slide concerning the French fry study.

Every two weeks students, previously (and almost routinely) organized in groups of two or three, had to make a presentation to the whole class. This regular activity proved to be a excellent choice to bring down the anxiety levels. In the end, the last version of the presentation was the assignment work delivered and evaluated, not only on a final work basis 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).

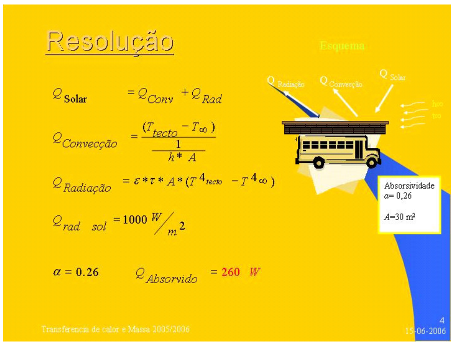

Figure 9. A presentation slide concerning the bus ceiling temperature.

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 economical sector has on several paper related industries, and on the other hand, to the fact that the dimension those fires have been taking make individuals lives and properties 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 that a request was made to evaluate the number of seconds the pine surface would take to reach the ignition temperature.

The third case had to do with a bus that was travelling on a determined 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. 9).

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 some experimental data gathered with a data acquisition system. After realizing that vegetable oil was not an electricity 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.

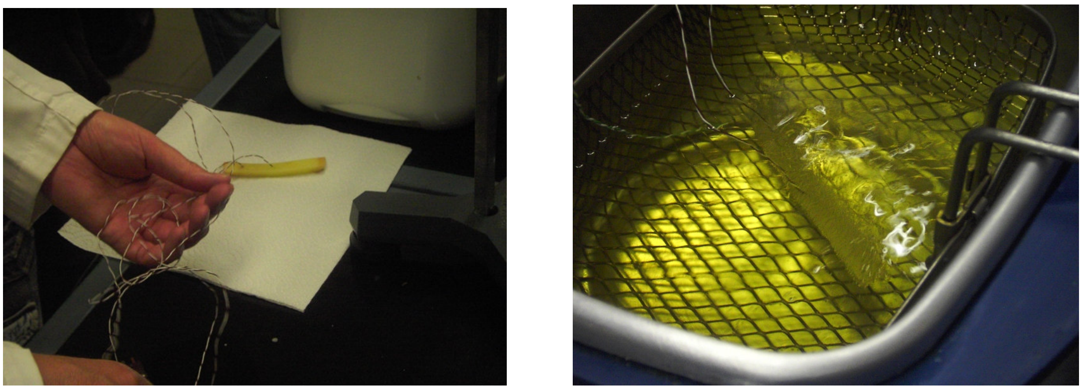

Figure 10. Wiring and frying the French fry.

The natural convection hot horizontal surfaces hexagonal pattern, which description was always a bit "fluid", was identified during the frying experiments (Fig. 11).

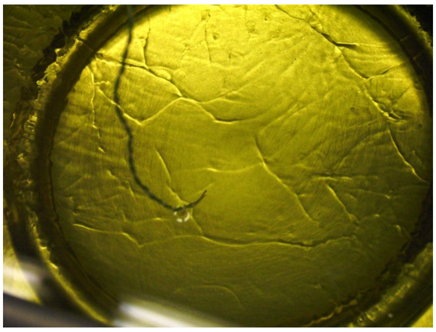

Figure 11. Upper surface of a hot plate, natural convection.

The transient heating process of the electrical frying pan was also used to determine the power electrical 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.

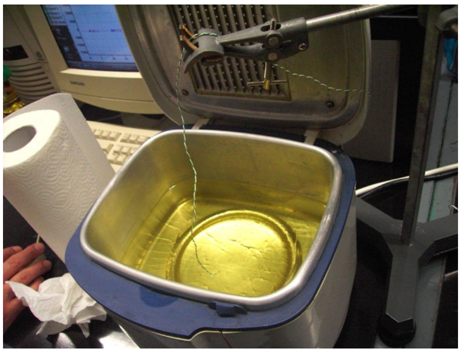

Figure 12. Heating the oil.

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 to be made three days later. The positive issues referred were:

i) improved quality of the language usage
ii) concern with the way presentations look like and with editing quality and adequate use of symbols
iii) communication capacity improvement
iv) improved knowledge
v) improved skills when dealing with esoteric or unusual situations
vi) increased personal feeling of the need to develop regular study habits

As for the negative one's:

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

6. Conclusions

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

Teaching physic related subjects, faculty always complain about the background level and the lack of student commitment. The goal has never been to accept fatalities nor to 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 drag important motivating potentials.

An issue has still to be addressed independently– students own time management, especially when studying subjects that require more dedication, more extended in time. Helping them to find a way out is an issue that shall be dealt on independent activities organized by the whole institution. For the time being, reduced classes' time is an opportunity window 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 that it increases the need for a complete and precise set of professional abilities and skills, must not give any illusions on what is expected from faculty, especially in polytechnics. Definitely, the times 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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