AC 2007-2689: INTRODUCING ENGINEERING TO BOLOGNA

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Introducing Engineering to Bologna

Abstract – The European Union efforts to promote the creation of a competitive system on a global scale within its boundaries, induced the adoption of several measures intended to allow the mutual recognition of educational degrees within its boundaries and, mainly, to increase the system's effectiveness and efficiency.
Concerning these last two issues, Portuguese higher education institutions working in technological areas are "doomed" to be confronted with an assessment process driven by the OECD (Organisation for Economics Co-operation and Development). When it carried out former assessment processes in other European countries, it had already established the items that will guide the whole process: ease and ability to find and fulfill a job/profession in a global, modern and ever changing workplace/market.
In the first semester of the first year both the Mechanical and Industrial Engineering graduations board decided to place an Introduction to Engineering course, aimed at giving freshmen a sign of what they are expected to achieve and the attitudes they are likely to develop. This course covers a range of topics that are supposed to, on the one hand, give students the opportunity to acquire a set of important techniques (such as personality recognition and learning styles, effectiveness and effective use of time and problem solving), and on the other hand, to encourage/induce them to adopt cooperative learning and proactive behaviors, both within the classroom and during the time spent studying. To lecture this course a set of professors were chosen: academic/scientific, managers of regionally important enterprises and technicians able to conduct and supervise machine shop activities that are to be used in manufacturing students' own design of small projects.
It is the way this course was organized, how it run and worked out that will be described in this paper.

Introduction

The Bologna process started off as inter-governmental cooperation, the corresponding declaration having been signed in 1999 by 29 ministers of education, and aims at establishing a European Higher Education Area (EHEA). Ministers engaged in coordinating their policies to achieve the desired goal within the first decade of the third millennium. In order to establish this EAHE, this process set itself a first set of objectives, spelled out in the so-called Bologna Declaration that consisted in the adoption of a system of easily readable and comparable degrees, essentially based on two cycles. Additionally, a system of credits was to be established, in order to facilitate and promote mobility as well as European co-operation in quality assurance.

These objectives were further specified in several subsequent ministerial conferences. Among others, the third cycle was added to the two-cycle system and the resulting system was adopted by all the participating countries. In this resulting national framework of qualifications the levels have the function of preparing the students for the labor market as well as for further competence building. There is a common path where each level builds on the preceding one and where it is the qualification acquired that will give access to a subsequent higher level. All the participating countries agreed on establishing national quality assurance agencies that will implement the standards and guidelines for the EHEA and Portugal is set to do this during 2007.

All the rationale behind the Bologna process has been to promote European citizens' lasting employability and the international competitiveness and attractiveness of the European higher education system. There is also a social dimension of the Bologna Process when it establishes that higher education should be equally accessible to all and students should be able to complete their studies without obstacles related to their social and economic background. And this is where a difficult equation has to be solved: the contradiction between a reduction of high student attrition rates and the requirements for a higher quality of graduations.

The ENQA assessment, the OECD framework and the Engineering Graduations

The Portuguese government in office since 2005 established as a main goal to guarantee citizens' qualifications inside the European space and chose the Bologna process as a unique opportunity to encourage higher education attendance, to improve quality and relevance of the competencies offered, to foster students' and graduates' mobility and to expose the higher education system to international assessment.

The European Association for Quality Assurance in Higher Education (ENQA) evaluation of the Portuguese process underlined these issues. A list of relevant criteria to be applied in programme accreditation was released. Concerning the polytechnic sub-sector the criteria are formulated to comply with the Bologna process that specifies the general outcome requirements for bachelor (first cycle of studies) level, including knowledge and experience from the professional practice and the professional orientation of the programme. The competences and professional orientation final qualifications must correspond to the general, internationally accepted description of the qualifications for the first cycle, currently the Dublin descriptors. A graduate from a polytechnic institution must be qualified at the level of starting as a professional in a specific profession or related professional field as well as for a master programme.

The Organization for Economic Co-operation and Development (OECD) Report also addresses these issues and their Review Team was conscious that they were the subject of a separate review by ENQA. Nonetheless, "(…) since the issue of quality underpins all of higher education endeavor, the Review Team believed that it was important that it would focus attention on it in acknowledgement of that significance".[1] The document stresses that higher education institutions should set limits for student failure, repetition and wastage and increase rates of success. The Review Team also reports that several firms complained during the review that while graduates were generally well prepared theoretically, and have good analytical skills, they are afraid to make recommendations for solving practical problems, afraid to make mistakes, and lack "soft skills" of contextual understanding, initiative, project management, teamwork and interpersonal skills. Amongst other items, the preemptive legislation produced by the Higher Education Minister during 2006 already was requesting a transition from an educational system based on the idea of knowledge transmission to a system based on developing abilities, to be performed by the students themselves. This was the main challenge that institutions had to face in preparing the 2006/2007 academic year, particularly with the Mechanical Engineering and Engineering and Industrial Management graduations.

The guidelines released stated that the goal of each graduation should be defined under a 'competencies to acquire' focus, adopting the work performed at the European level embodied in the Dublin descriptors, namely (1) supporting the acquisition of knowledge and understanding on advanced text books with some aspects informed by knowledge at the forefront of their field of study, (2) applying that knowledge and understanding through devising and sustaining arguments, (3) making judgments after gathering and interpreting relevant data, (4) communicating information, problems and solutions and (5) developing learning skills needed to study further with a high level of autonomy.

This aspiration can only be achieved if the teaching/learning paradigm changes from a passive model, based on knowledge acquisition, to a model allowing abilities to develop, including general abilities – instrumental, interpersonal and systemic – and the ones specifically associated to a particular area of training and where the experimentation and design play an important role.

Introduction to Engineering

When preparing for the changes to meet the Bologna criteria, the department soon realized that the shift should begin with freshmen, both in the Mechanical Engineering and Engineering and Industrial Management programmes, where the aim is to solve problems through deep engineering knowledge but also to make use of management techniques focusing on people, processes, production facilities and organizations, and, as recommended by external institutions, to develop and make use of innovative abilities, employing autonomous and cooperative learning, team work and proactive behavior.

As a first contact course, first semester of the first year, Introduction to Engineering was clearly the one where this should be most evident and be carefully handed, besides being more easily addressed. Additionally, but not less important from a retention/effectiveness point of view, knowing how freshmen often abandon graduations during their first semester, where difficulties in different classes, along with the stress of integrating, also became a factor for greater commitment from faculty.

This course was offered at the same time, during the same semester, as the Information and Communication Technologies (ICT) course, under the responsibility of the Computers and Systems department. ICTs courses are broadly perceived by fresh ex-K12 students as a sequel of similar subjects regularly taught in secondary schools and are renouned for being very easy ones, from student assessment point of view. Both courses, Introduction to Engineering and Technologies of Information and Communication Technologies, were offered as an elective to students.

An Industrial Management lab, equipped with 30 PCs cable-connected to the internet, was assigned to the 4.5 hours of the course. Tutorials had to take place in a regular room, due to scheduling problems, both from the department and the availability of several professors. Experienced professors were chosen, along with those who had long lasting ties to the surrounding industries and enterprises; a newly minted assistant professor was in charge of the mechanical workshop.

Table 1. Course Timeline for Introduction to Engineering.

Week#	Module description	Content Summary	Class size	
			Lecture	Lab
1–2	Entering Higher Education	ICTs, Time management, study skills	35	35
3	History	Historical milestones	35	35
4	Engineering and Society	Profiles, Ethics	35	35
5	Science, Technology and Society	Engineering work, research methods science and technology	36	36
6–7	Engineering and Communication	Communication processes, written technical reports, visual communication	37	27
8	Design	The designing process	42	29
9	Modeling	Models and real systems	43	43
10	Simulation	Seminar	45	30
	Creativity	Seminar	45	30
11–13	Mechanical Workshop	Drawing and Manufacturing	45	8

The overall course objectives, from the desired student outcomes, were to know and understand engineering concepts, by means of an integrated historical vision, to organize and plan all the different activities that the graduation requires, applying time management and study techniques, to approach different research methods, to be able to perform bibliographic research, handing in small assignments under the supervision of the Engineering graduations and, finally, to actually manufacture simple parts or assembled devices using the department's mechanical workshop facilities, measurement equipment, machinery and hardware. The experiments and the consolidated experience of the engineering community in the United States and Brazil were inspiring to us and the sources used are referred in the bibliography.

The course was structured in modules. Module #1 discussed higher education as a new stage of a student life, where individuals are supposed to become less like 'pupils' and more like 'students', reflecting on each other studying purposes and the need for an attitude shift in order to achieve greater effectiveness. They were also introduced to different personality types and to the effect these have on cooperative activities, especially group study. The need to memorize and its relationship to reasoning, as well as using different memorizing processes or languages, was the object of some practical games made within this module.

Table 2. Formal description of the Introduction to Engineering course.

INSTITUTO POLITÉCNICO DE VISEU

ESCOLA SUPERIOR DE TECNOLOGIA

Department	*DEMGi*	**Course**	*Introduction to Engineering*		
		Year	*1*	**Semester**	*1*
Graduation	*Mechanical Engineering + Engineering and Industrial Management*	**School year**	*2006/2007*		
Group		**Weekly time (h)**			
		Theoretical	*Theoretic/ Practical*	*Practical/ Lab*	*Tutorial*
Professor	António Almeida Gabriel Lopes João Paiva José Branco Luís Paiva	*1.5*	*1*	*2*	*2*

Other issues such as keeping an open mind when working with others, especially with professors, were shown to improve effectiveness considerably. Setting short, medium and long term goals were applied to the respective cases and identified as important in the motivation process. Attending classes, taking good notes, regularly seeking help from professors, doing several exercises and persistently trying to solve problems, recognizing the need to reread/restudy and trying out lessons in time management gleaned from past tests, were all items discussed and actually performed by each student as means of approaching study activities better, along with time management and implementing strategies based on scheduled tests and an available calendar.

The introduction to ICTs was needed, as students that would choose Introduction to Engineering would not be able to attend Information and Communication Technology (they were options and coincided in the timetable). A decision was taken to approach this area of study as a consequence of the normal requirements for research topics, studying and handing in assignments, instead of reserving a certain amount of time to address it specifically.

<table>
<tr><th></th><th colspan="7">Typical week</th></tr>
<tr><th></th><th>Monday</th><th>Tuesday</th><th>Wednesday</th><th>Thursday</th><th>Friday</th><th>Saturday</th><th>Sunday</th></tr>
<tr><td>9:00</td><td rowspan="4">Work</td><td rowspan="4">Work</td><td rowspan="4">Work</td><td rowspan="4">Work</td><td rowspan="4">Work</td><td rowspan="5">Work</td><td rowspan="2">Physical Exercise</td></tr>
<tr><td>10:00</td></tr>
<tr><td>11:00</td><td rowspan="2">Intelectual Activity</td></tr>
<tr><td>12:00</td></tr>
<tr><td>13:00</td><td rowspan="2">Lunch</td><td rowspan="2">Lunch</td><td rowspan="2">Lunch</td><td rowspan="2">Lunch</td><td rowspan="2">Lunch</td><td>Lunch</td></tr>
<tr><td>14:00</td><td>Lunch</td><td>Rest</td></tr>
<tr><td>15:00</td><td rowspan="4">Work</td><td rowspan="4">Work</td><td rowspan="4">Work</td><td rowspan="4">Work</td><td rowspan="4">Work</td><td>Intelectual Act</td><td rowspan="6">Study</td></tr>
<tr><td>16:00</td><td rowspan="5">Study</td></tr>
<tr><td>17:00</td></tr>
<tr><td>18:00</td></tr>
<tr><td>19:00</td><td rowspan="2">Classes</td><td rowspan="3">Classes</td><td rowspan="3">Classes</td><td rowspan="3">Classes</td><td rowspan="4">Classes</td></tr>
<tr><td>20:00</td></tr>
<tr><td>21:00</td><td>Dinner</td><td>Dinner</td><td>Dinner</td></tr>
<tr><td>22:00</td><td rowspan="4">Study</td><td>Dinner</td><td>Dinner</td><td>Dinner</td><td rowspan="3">Study</td><td>Fun</td></tr>
<tr><td>23:00</td><td rowspan="3">Study</td><td rowspan="2">Classes</td><td rowspan="3">Study</td><td>Dinner</td><td rowspan="3">Study</td></tr>
<tr><td>0:00</td><td rowspan="2">Fun</td></tr>
<tr><td>1:00</td><td>Study</td><td>Fun</td></tr>
<tr><td>[1:00; 9:00]</td><td>Rest</td><td>Rest</td><td>Rest</td><td>Rest</td><td>Rest</td><td>Rest</td><td>Rest</td></tr>
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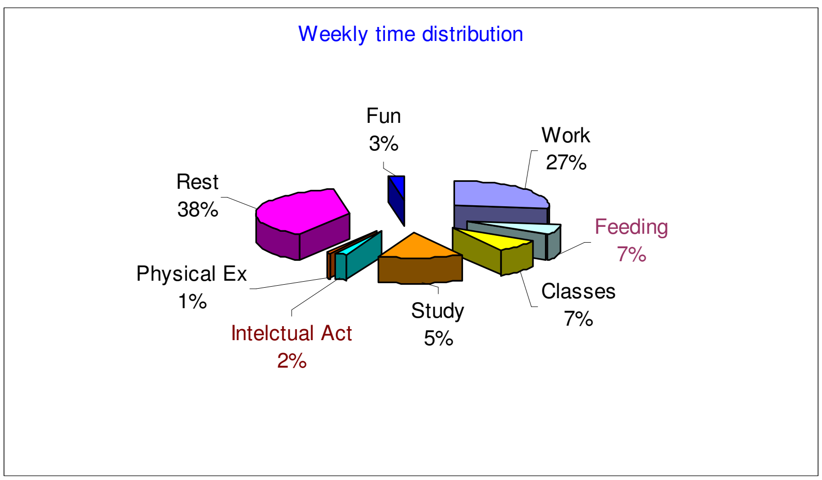

Figure 1. Example of a student own weekly schedule.

Module #2 addressed the beginnings of engineering and some historical milestones. Using timeliners (like those on Fig. 2), with an emphasis on realizing the exponential achievements of modern times.

The development of the Portuguese University, from the 11^{th} century to present-day engineering schools was also addressed, particularly those where Mechanical and Industrial Engineering are better known.

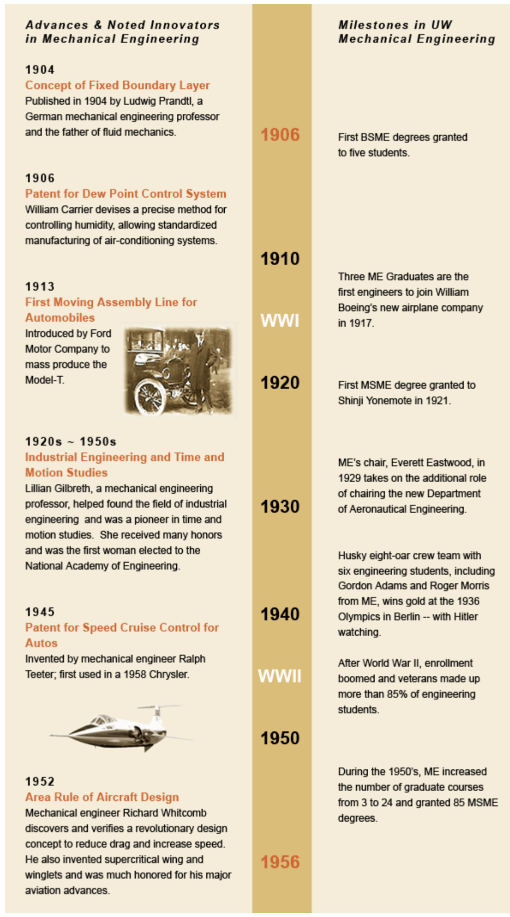

Figure 2. Example of vertical timeliners used to locate engineering important dates.

Module #3 dealt with the topic of Engineering and Society, especially the profiles of Engineers, the difference between an engineer and a technician, ethics, lifelong learning, the relation between engineering profiles and engineering functions, and engineering societies in Portugal and abroad. The goal was to provide cases and situations where students could know and understand the importance of engineering in society, to recognize the field of engineering and the applications that can be performed, as well as the social and ethical responsibility that an engineer must keep in mind when designing and taking decisions.

Also under this item, through the professor's own life experience, students' awareness was raised to the importance of life-long learning; he also raised their awareness of cases of engineers who experienced several changes in their lives which forced them to redirect their professional careers, thus stressing the need for an open-minded approach when planning one's life.

The fourth module was broad in scope: Science, Technology and Society. The items covered were Research Methods, examples of engineering and research work and how to organize a research. It started by covering the distinction between Science and scientific applications, technology and engineering, and between Research and (Technological) Development, focusing not only the differences but also the complementarities. The following subjects dealt with research methods and the steps they involve, describing each one of them and their concatenation. Everything was achieved by means of slide presentations, which were provided to the students by email immediately after the show, so they could be used during that class.

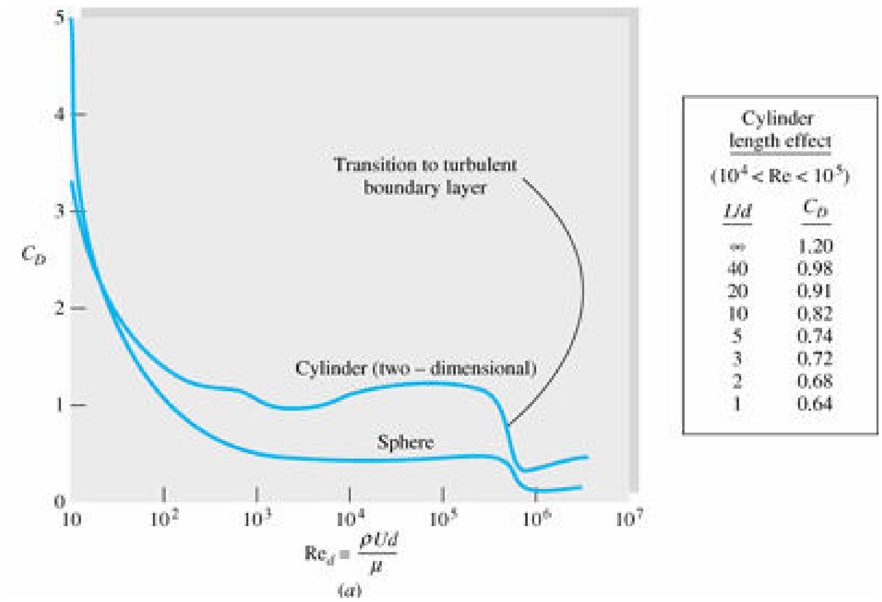

Figure 3. Example given of a research work

At the end of the class, each group had to choose a subject related to Engineering or Technological Development and hand in a small report (one page) on the subject. So that the students wouldn't come up with overly complicated ideas that would make them go over the time remaining, some 'restraining' examples were given, such as 'clip', 'compass', 'insulated bottle', 'zipper', ...

The fifth module had to do with the relationship between the engineer and communication: communication processes, how to structure and write a report, how a technical report was made, the importance of the graphics elements in communication and communication skills, both oral and written. The importance of visual communication for engineers was emphasized using drawings, sketches, and graphs. Some specific games were played to show the importance of good questioning, both in explaining something among classmates and obtaining the benefits of receiving answers from professors.

Module #6 covered design, the essence of Engineering and Industry. It dealt with the designing process, both scientific and technological, the steps to be followed in designing and the way problems are approached in engineering. It also intended to demonstrate the influence of engineering design in enterprises, both by positive and negative (or missing) effects, by evaluating several divisions of a particular enterprise. A professional engineer in charge of the industrial division of the region's most important corporation was chosen to conduct this part. He prepared and guided a visiting tour to a kitchen furniture manufacturer, belonging to the group.

The seventh module focused on Modeling and Model Classification, the relationship between the model and the real physical system, the validity of simplifying assumptions and the purpose of the model. The aim was to demonstrate the crucial importance of models in Scientific Research or Technological Development. Different types of models along their strengths and their limitations were presented, as well as some very successful mathematical models.

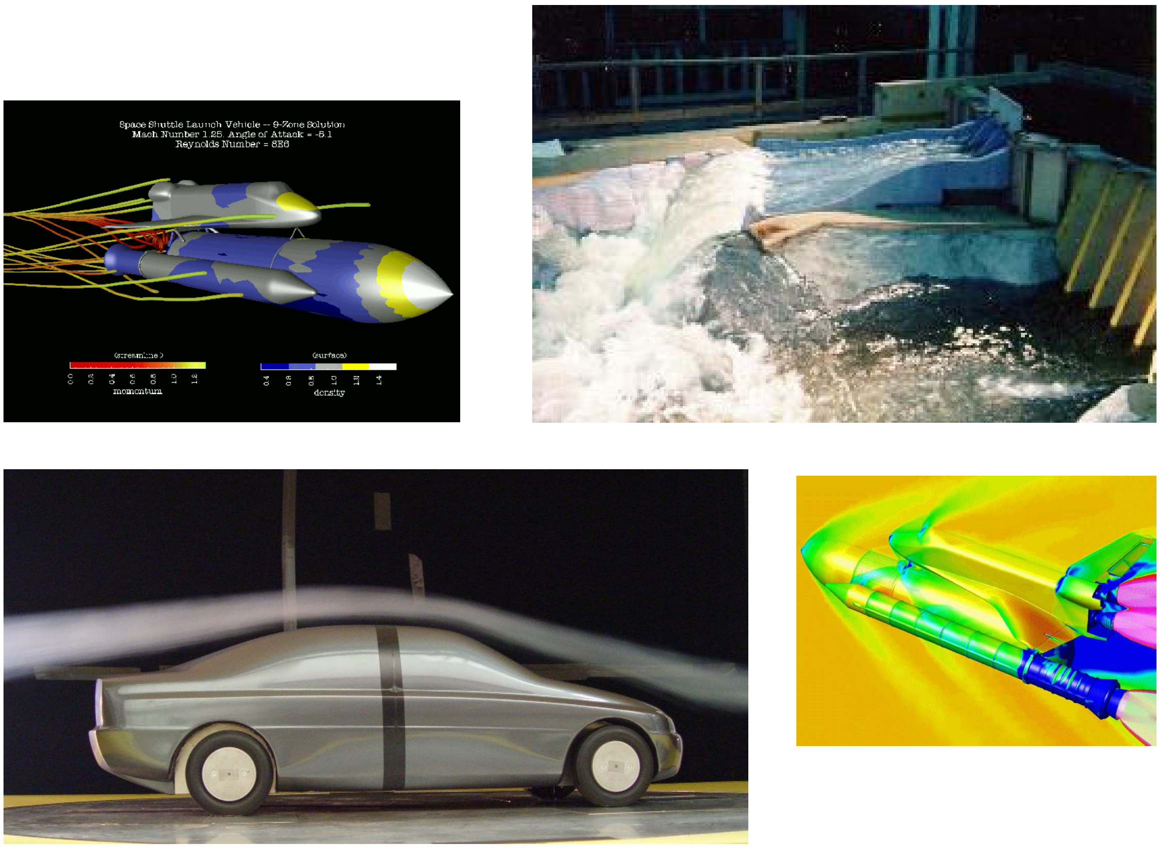

Figure 4. Examples of different type of models presented.

Students made some comments about aerodynamical models. At the end of the session they were requested to present a simple mathematical model to fit to a simple physical model. As the Calculus tools required were not yet mastered, a numerical model was developed and implemented in Excel®. The analytical solution was later disclosed so that they could see that, with the numerical process, they were not that far from the exact solution.

The last two conventional modules were Simulation and Creativity, both providing outputs to be materialized in the department mechanical workshop. Students were challenged to create, simulate and manufacture a device to be used in the Physics Lab of their department. The device had the purpose of demonstrating the Conservation of the Angular Momentum Principle. The suggestion was using a rotating platform capable of supporting a person that would induce the rotational movement using a spinning bicycle wheel on his hands.

Results

Module 1 and 2: At the end of these two modules, all students were able to use basic software, word processors and spreadsheets, as they sent in their assignments as attached files through a web mail address created especially for that purpose (with a suggestive password: "holidays"). Only 8 out of 44 initially had and knew how to use an email account; at the end of these modules, roughly three weeks later, all students, without exception, were using it regularly. 15 students had fulltime jobs; they were very interested in time management techniques, either because they had already had the opportunity to recognize its importance, or because they were feeling that they would need it more than ever. Their interaction with regular freshmen was very helpful in demonstrating the usefulness of those techniques. On the other hand, they felt the sessions on memory use, study techniques and problem solving were very interesting, and probably very reassuring. Recognizing and using different learning styles was a major step for all of them, who had not been studying, in some cases, for over a decade.

During the Ethics component, third module, the students were asked to analyze and compare different codes of ethics, first presented for discussion on slides in the classroom. Team work assignments were done comparing national with European (FEANI) and American (north– ASME– and south– CONFEA) ethic codes issued by professional associations. Among the requirements was stating an outline of the values espoused (humanism, reciprocity, tolerance, competence, public service, welfare, health, honesty, loyalty, unbiasedness, …). The assignments were discussed in class.

The results of the module concerning Science, Technology and Society and their relation with Research and Development were not as successful as former ones. The assignments handed were almost only a simple 'copy, paste' of material from Internet sites.

Communication processes was quite interesting, from the students' point of view. The fact of having to communicate an idea, at the end of the session, using a minimum of two forms of media and with a time limit of 3 minutes for each group to get the rest of the class to identify it was very popular and successful. Some of the issues discussed were later put into practice, with a high degree of success, namely when the public session was organized and performed for the whole school community.

At the end of the sixth module, students handed in an assignment where they had identified the sectors where the enterprise was strong (where, supposedly, engineering was present) and those that needed improving (where engineering was still absent or weak). The results were satisfactory.

Simulation and Creativity were approached as part of an answer to a problem: how to equip the department's Physics lab with a specific device, meant to demonstrate a Physics principle, which subsequently would also be exposed during itinerant exhibitions the department carries out in secondary schools. Once the Conservation of the Angular Momentum challenge was placed to the students, several ideas arose: a simple wooden board over wheels, an indefinite air cushion, a plastic board on ice, a one point suspended pendulum and even an (also) undetermined magnetic field. The simplest, though less radical, option was chosen.

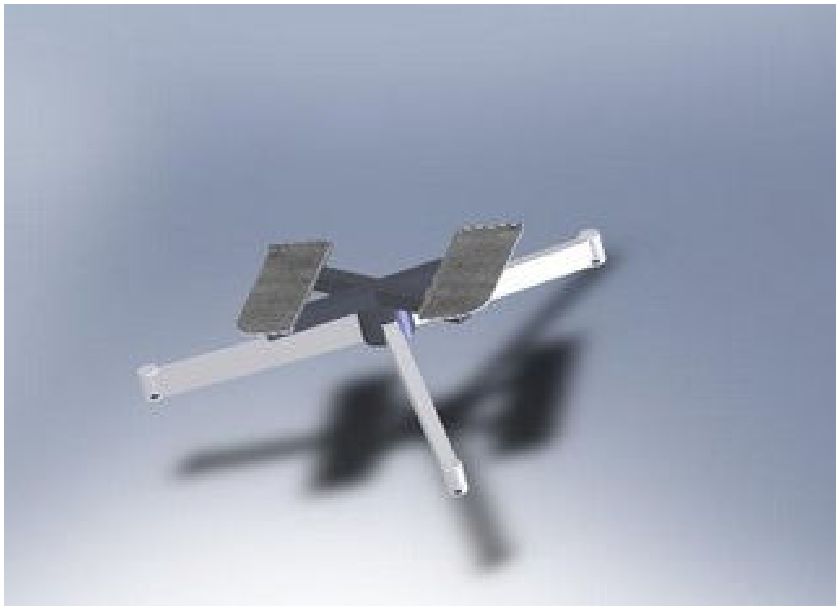

Figure 5. The chosen device.

One of the purposes was to introduce SolidWorks® software. Each group had to hand in one of the components of the final device. Making a corresponding drawing was an intermediate step which enabled students to use that particular software with some familiarity (keeping in mind this was only an introduction).

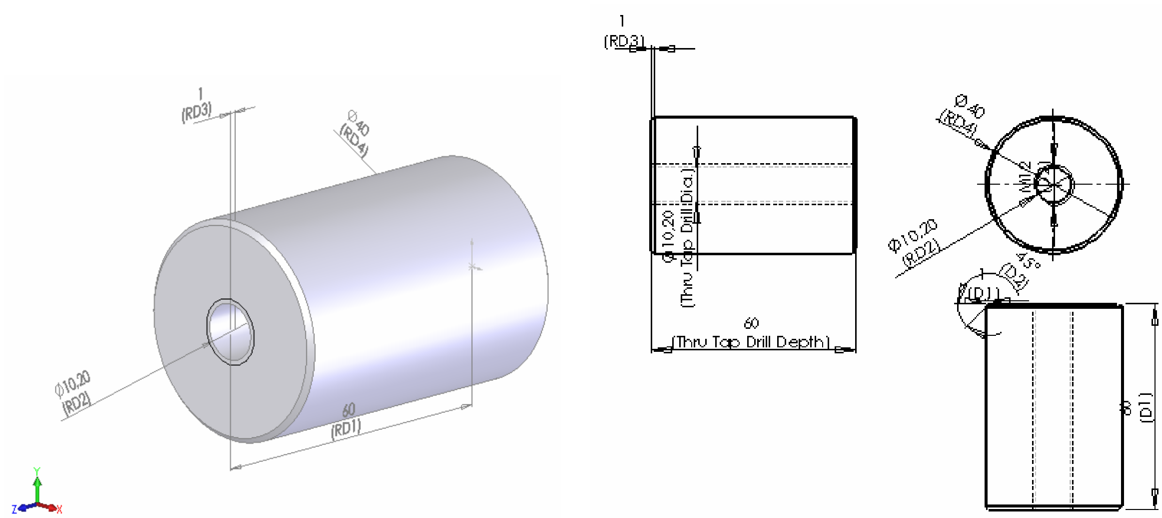

Figure 6. Drawing of one of the parts of the device.

After all the parts were ready, following a previously determined calendar, the class advertised the event.

Figure 7. Flyer (front and back) distributed by the students to promote their presentation.

They have also created a blog (http://www.conservacaodomomentoangular.blogspot.com), beyond composing and creating a poster and a flyer. It received a considerable number of hits, not only by school faculty and students but also by community members who are currently living outside the region. This allowed the way the work was being developed to be observed and also promoted discussion among participants.

Figure 8. Poster placed by the students all over the school to promote their presentation.

The public presentation was entirely prepared and carried out by the students; they used PowerPoint® and, among the traditional sequence of slides, a video was exhibited that included a "making of" the project, showing the different stages of manufacturing as well as some funny situations and good camaraderie.

Figure 9. At the end of the presentation, a student performed a demonstration like the one represented in this central photo.

In the end, students were very proud and considered the activity the "First Design" of their engineering career. An individual portfolio of all of the assignments was due at the end of the course and graded towards their final marks, along with all the other graded work.

Table 3. Modules Assessment Methods.

Module description	Assessment Method
Entering Higher Education	Report, quiz
History	Report
Engineering and Society	Report, presentation
Science, Technology and Society	Report, quiz
Engineering and Communication	Report, survey, presentation
Design	Report, survey, quiz
Modeling	Report, quiz
Simulation	Report, lab behavior
Creativity	Report, lab behavior
Mechanical Workshop	Report, lab behavior, public presentation

There were 52 students registered. Of those, 45 regularly attended classes, with an average attendance level of 69% (76% missed less than 2 classes out of a total of 26) and 43 succeeded the course. A survey conducted near the end of the semester showed that all students want to continue their studies.

Table 4. Student scores.

Module #	Number of students Score Range (percentage)			
	< 50	51-70	71-90	91-100
1- Entering Higher Education	0	27	8	0
2- History	0	23	12	0
3- Engineering and Society	0	23	12	0
4- Science, Technology and Society	0	29	7	0
5- Engineering and Communication	0	26	11	0
6- Design	0	22	20	0
7- Modeling	6	33	4	0
8- Simulation	2	37	6	0
9- Creativity	2	33	10	0
(10)- Mechanical Workshop	2	11	29	3

The Dublin descriptors were not tested because the authors still have no work done on how to implement such a measurement; it will be the object of further work to be carried out next year. Still, there seem to be encouraging results on some of the issues, such as "(…) applying knowledge and understanding through devising and sustaining arguments, making judgments after gathering and interpreting relevant data and communicating information, problems and solutions (…)".

Conclusions

Although they had different interests, between "regular" students and full time job/working students, future mechanical engineers and aspiring industrial engineers, most of the modules were well accepted. Two of the objectives proposed, both retention, on the one hand, and acquiring basic useful tools for the students' academic and professional careers, on the other, were completely achieved regarding the former, and we think that good results were reached with latter. There are many aspects to correct, namely those which aim to achieve a greater involvement in topics that are not immediately embraced and present some entry barriers (anything involving math and physics, more or less explicitly). However, on balance and considering that it was a first attempt with this course/subject, we can consider this to be a positive experience. One can stress that, regarding students' active behavior, for the most part and most occasions, when they got involved they produced good results and, in some cases, very good results (blog and public presentation). Therefore we can conclude that, overall, the objectives of this first edition were met.

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Acknowledgments

We would like to thank A. Almeida (our shepherd), L. Paiva, and G. Lopes. We would also like to thank Fernando Almeida from Florida, our reviewer and (anonymous) referee for his helpful comments.