AC 2010-702: BOLOGNA PROCESS – IT'S TIME FOR A LOOK BACK: A MECHANICAL ENGINEERING CASE

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Bologna Process – it's time for a look back: a mechanical engineering case

Abstract

Three academic years have passed since the formal beginning of the Bologna Process implementation at the Mechanical Engineering and Industrial Management Department at the Polytechnic Institute of Viseu. It is appropriate to begin to take stock of progress (so far).

This paper focuses on the new methodologies of teaching/learning and evaluation that have been introduced since then. It also discusses students' and teachers' strategies, aiming at adapting their behaviour to the way they have perceived those new paradigms. Some significant changes were detected, namely those related to students' work, expected to be autonomous and continuous throughout the semester, benefiting from teachers' tutorial guidance and reflected in a continuous evaluation.

Nonetheless, it has been a road dotted with some difficulties: changing students' attitudes towards work and persuading instructors of the importance and need to look for innovative pedagogical strategies is not an easy task. Still, in a significant number of courses, some new teaching/learning models were introduced, based on skills development models, supposedly more attractive to students, promoting their participation and interaction.

It was considered fundamental that students should understand their role in this new model of higher education. Instructors have been aware of the central importance to the students of building knowledge and acquiring skills in an autonomous meaningful process, a process that ultimately prepares them for an increasingly flexible labour market.

1. Introduction

Higher education in Portugal is going through a process of deep change as in all countries which subscribed to the Bologna Declaration[1]. The idea of creating a European Higher Education Space was formally presented for the first time in the Sorbonne Declaration[2]. 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, making mobility easier for students and teachers in order to share knowledge and experiences, increasing innovation and skill acquisition.

The Bologna Declaration 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 analyses promoted by national and supranational work groups and personalities. From these the need for a paradigm shift arises, not only in educational structures, but also in the creation of thought and knowledge.

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 importance of a lifelong learning policy is related to employability and adaptability, active citizenship and social inclusion. It also includes skills, knowledge, attitudes and behaviors that people acquire in their day-to-day experiences.

The definition of the academic and professional profiles will be related to the identifying and developing students' acquired skills. Actually, the Bologna process is aimed at creating a new higher educational paradigm centered on student work, the importance of skills and preparation for professional life. This goal needs a significant and complex change in mentalities and attitudes, requiring the work and motivation of students and teachers. The pedagogical context is at the core of this process, namely in what concerns the adoption of dynamic new learning-teaching methodologies.

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 graduation that could respond to the new orientations.

Over the last fifteen years, the life span of the Mechanical Engineering and Industrial Management graduation, several measures were taken in order to give students the best education for their future professional lives as well as to contribute towards successful promotion of the graduation.

These measures such as integration, tutorial and socio-pedagogical programs, team 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 degree), 180 ECTS (European Credit Transfer System Units), corresponding to six semesters.

This credit system takes into account all the student's work hours: classes, tutorial, 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 attributing the new subject's credits. Consequently, the new degree has five subjects each semester, one less than the former degree. This new graduation is centred on 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 graduation revealed the need to reinforce practical application of knowledge, to intensify the use of problem based learning, to design new laboratory strategies, to promote team work and to develop the fundamental skills in engineering training.

The new graduation design also resulted from analyzing similar graduations in reference countries in engineering, such as Germany, the United Kingdom, the United States, Switzerland, Denmark, Sweden and Finland. The comparison was mainly in terms of duration, syllabi, credit system units and strategies adopted. The new Mechanical

Engineering degree is comparable in structure to the foreign graduations analyzed: basic sciences (maths and physics), engineering sciences mechanics, materials strength, fluids and energy, electricity and electronics, automation) and industrial management. General skills, critical for a professional future, such as analysis and ability to summarize, communication skills, practical and critical thinking, time management and team work were also considered activities to be coached and developed throughout the graduation.

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 is directed at analyzing mechanical systems based on concepts in kinematics and dynamics. Mechanics II is dedicated to the study of statics. 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 statics syllabus in Mechanics II and introducing the study of structures, namely regarding internal forces and methods of structural analysis.

Important changes were made in class scheduling. Formerly physics was held in three 2-hour classes per week, and mechanics was held in two 2-hour classes. Now both new subjects have 4.5 hours of class time each plus 2 tutorial hours, again for each of the subjects. During those tutorials students are totally free to present topics, questions or problems related to their particular difficulties, namely in those concerning lab work. This strategy encourages 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 in the Department[3]. These are usually difficult subjects and the students have to be motivated and closely coached. 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, in the sense of recognizing patterns more than thinking about situations and applying laws and concepts. Differently from other physics' subjects, mechanics is a matter which normal people come into contact from early age, leading to a set of spontaneous and intuitive theories which are, for the most part, completely divorced from scientific (and "real") reality. This gap is also related to the abstract and non-intuitive nature of mechanical concepts and their complex formality. In a mechanics course, the student faces a conflict between two different ways of observing the world that surrounds him: one, constructed from spontaneous observations and intuitive explanations; the other, which is a scientific and rational construction that, most times, is not perceived as "logical" at all[4]. Each student has his own difficulties and misconceptions, which leads him to a distinguishable learning-teaching path that must be identified.

4. The case of Mechanics I

As mentioned above, kinematics and dynamics are the subjects that present students with considerably more difficulties. For that reason, the work developed along the school term will be presented for the Mechanics I course. Its syllabus is:

1. Physics and Measurement
2. Kinematics of a Particle
3. Dynamics of a Particle
4. Linear Momentum and Impulse
5. Work and Energy
6. Kinematics and Dynamics of a Rigid Body

4.1. Structure of the classes

The classes did not follow the classic, rigid scheme of separation between theory and its applications. This is a measure that was implemented ten years ago in most courses in the department. A particular subject of study may start with a presentation with the aid of power point, based on board work, or both, but always promoting dialogue and discussion. On several occasions, a simple experiment can be the starting point to informal interpellation, as shown in Figure 1.

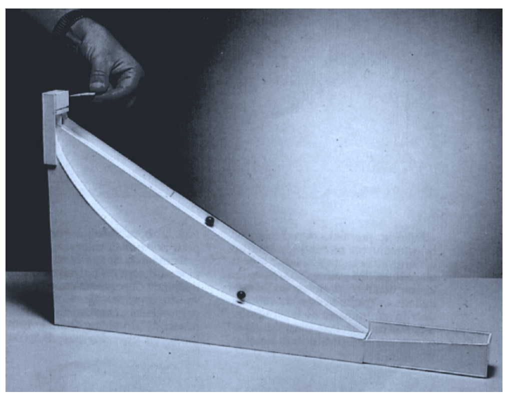


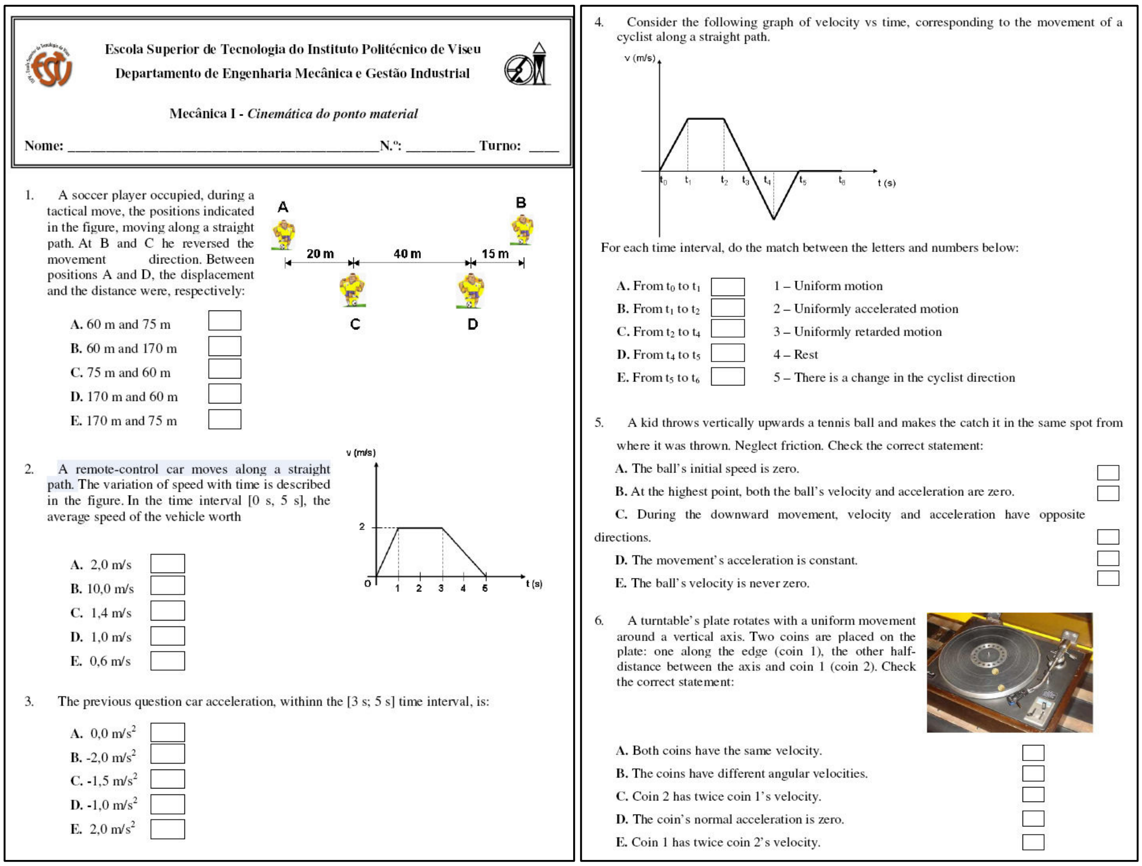
Figure 1. The longest path is the fastest

It also turns out of to be of great importance using simple examples from everyday life to clarify ideas and to start creating a consistent conceptual structure; examples such as those represented in Fig. 2A and Fig. 2B are valuable contributions in that sense.

Figure 2A. Newton's laws

Figure 2B. Friction effects lightning a match

The option for a learning-teaching strategy strongly depends on the students' background in relation to the course syllabus. As a consequence of their different former academic studies, the groups of students, normally with an average of 25 individuals per class, are always very heterogeneous. In order to acquire an initial knowledge about their basic conceptual structure, before beginning the study of each chapter, students must answer quizzes in writing and hand them in. These quizzes were written taking into account the simplest concepts that students should understand. Afterwards, all the questions were discussed and solved in groups under the instructor's supervision and participation.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Departamento de Engenharia Mecânica e Gestão Industrial

Mecânica I - *Cinemática do ponto material*

Nome: ______________________ N.º: ________ Turno: ____

1. A soccer player occupied, during a tactical move, the positions indicated in the figure, moving along a straight path. At B and C he reversed the movement direction. Between positions A and D, the displacement and the distance were, respectively:

A. 60 m and 75 m
B. 60 m and 170 m
C. 75 m and 60 m
D. 170 m and 60 m
E. 170 m and 75 m

2. A remote-control car moves along a straight path. The variation of speed with time is described in the figure. In the time interval [0 s, 5 s], the average speed of the vehicle worth

A. 2,0 m/s
B. 10,0 m/s
C. 1,4 m/s
D. 1,0 m/s
E. 0,6 m/s

3. The previous question car acceleration, withinn the [3 s; 5 s] time interval, is:

A. 0,0 m/s^2
B. -2,0 m/s^2
C. -1,5 m/s^2
D. -1,0 m/s^2
E. 2,0 m/s^2

4. Consider the following graph of velocity vs time, corresponding to the movement of a cyclist along a straight path.

For each time interval, do the match between the letters and numbers below:

A. From t_0 to t_1 — 1 – Uniform motion
B. From t_1 to t_2 — 2 – Uniformly accelerated motion
C. From t_2 to t_4 — 3 – Uniformly retarded motion
D. From t_4 to t_5 — 4 – Rest
E. From t_5 to t_6 — 5 – There is a change in the cyclist direction

5. A kid throws vertically upwards a tennis ball and makes the catch it in the same spot from where it was thrown. Neglect friction. Check the correct statement:

A. The ball's initial speed is zero.
B. At the highest point, both the ball's velocity and acceleration are zero.
C. During the downward movement, velocity and acceleration have opposite directions.
D. The movement's acceleration is constant.
E. The ball's velocity is never zero.

6. A turntable's plate rotates with a uniform movement around a vertical axis. Two coins are placed on the plate: one along the edge (coin 1), the other half-distance between the axis and coin 1 (coin 2). Check the correct statement:

A. Both coins have the same velocity.
B. The coins have different angular velocities.
C. Coin 2 has twice coin 1's velocity.
D. The coin's normal acceleration is zero.
E. Coin 1 has twice coin 2's velocity.

Figure 3. Image example of a quiz

Abandoning the separation between theory and its applications leads to an interesting dynamic in class. Sets of questions, exercises and problems were selected since the beginning of the term, covering the syllabus, which allows various possibilities for choosing the most adequate topics for different pedagogical situations, complementing theoretical approaches. The students were invited to solve some of those questions, exercises and problems during class, individually or in groups, and all the remaining tasks were assigned for homework. They also had the possibility to use tutorial sessions to ask questions in order to obtain or verify solutions and were also invited to share their experiences while trying to solve them. Some interesting discussions revealed common misconceptions. Electronic mail was also available to establish bridges between the instructor and students. Quite often they gave answers and got new questions in return, as clues to help them to make their own way through the problem.

4.2. Homework problems

These homework problems were created at the end of each week and sent to students by electronic mail. They aimed at reflecting some aspects that, in the instructor's own opinion, may not have been sufficiently understood during class and the tutorial. They also meant to establish a more effective connection with real engineering situations, improving knowledge and at the same time increasing motivation. Students were invited to find solutions in writing. They could clear up any doubts using electronic mail or the tutorial. The solutions were handed into the instructor for correction within a week and were discussed with each student (sometimes in groups), when considered relevant.

HOMEWORK - 3

1. Consider the transport system of Fig. 1Each container carries a block and moves with a speed of 4.5 ms-1. The blocks fall on the conveyor belt, when θ = 120º. Determine the distance s. Neglect air resistance and the size of the blocks.

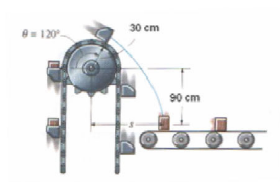
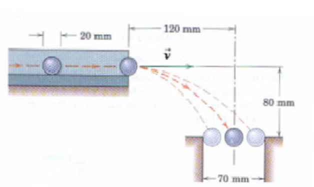


Figura 1



2. Look at Fig. 2. The balls are thrown horizontally with a speed $\vec{v}$ and pass through hole with a diameter of 70 mm. Determine the range of velocity values that allows the balls to pass through the hole. Neglect air resistance.

Figura 2

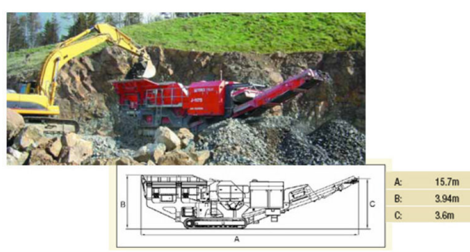


Figura 3

3. Estimate the output velocity of the stone fragments at the upper end of the conveyor belt from the machine shown in Figure 3.

HOMEWORK - 7

1. A very important aspect to consider when driving a car is the braking distance, i.e., the shortest distance needed to bring the car to a stop without slipping or skidding.

1.1. Explain how certain conditions affect significantly the values of this distance.

1.2. Try to calculate and to compare values of stopping distance for two cases of driving under clearly distinct conditions.

Figura 1

2. The seat belt of a vehicle is an accessory that plays an important role. Its use is a major factor in road deaths. Determine the intensity of the resultant force acting on an occupant of a car using a fastened seat belt during a braking process. Consider that the mass of the driver is equal to 80 kg and that the vehicle was moving at 90 km/h, immediately before stopping the car, which took 6 s.

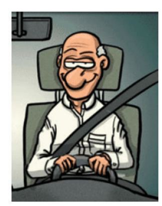


Figura 2

Figure 4. Examples of homework problems

4.3. Lab work structure

One of the components that integrates the Mechanics I course that needed deep reform was the laboratory, mainly concerning lab classes.

Former written protocols were abandoned. These were produced by the instructor who gave a rigid orientation, leaving no room for students' creativity. Quite often students did not prepare their work properly and were passively following protocols. Although being 1st year students with little lab experience, the new learning-teaching paradigm clearly pointed in another direction. A new challenge was being proposed to the students. They would have to create and implement experiments by themselves using the physics lab facilities. If they considered it necessary, they could bring some simple and common materials from home.

Those experiments should cover five main items of the syllabus: projectile motion, force and motion, conservation/dissipation of energy, physics of collisions and rotational dynamics. The goal was to implement, in laboratory classes, learning by project strategy, intensifying cognitive activity, stimulating innovation and creativity as well as promoting team work[5].

4.3.1. Building a project

Following this new strategy, students were informed at the beginning of the term about the subjects that experiments should incorporate; they also came into contact with the existing lab material for the first time. Next, they were invited to split up into teams of 3. Each team had to design five different projects for five different experiments. A month was set as the limit to present plans for the experiments. During that period, students had to imagine what kind of experiments they wanted to perform, they had to clarify objectives and select laboratory material, doing the necessary research. Written plans with the description of the experiments, their objectives and corresponding laboratory material were delivered to the instructor.

After the instructor analyzed the plans, they were discussed with each team in order to clarify or modify some of the proposals. Sometimes they were technically unfeasible, most of the times due to the lack certain lab devices. In other situations it was possible to simplify procedures. In any case, the instructor always tried to ask questions rather than make suggestions. Most of the corrections were proposed by students as a consequence of their own individual and/or in group reflection and discussion.

Two examples of student team's projects are described:

1. Force and motion

The idea was to use a physics lab device that consisted of a path along which a vehicle could be moved by the action of a falling mass suspended by a string and a pulley system, as can be observed in Fig. 5A. The falling mass can be stopped by a braking system. A sensor fixed at the beginning of the path, connected to an acquisition system and a computer, allows the position, velocity and acceleration to be recorded, as shown in Fig. 5B. Data can be worked in distinct ways, highlighting a set of concepts and measurable values. Using different conditions, there are a lot of possibilities to explore.

Figure 5A. Vehicle device

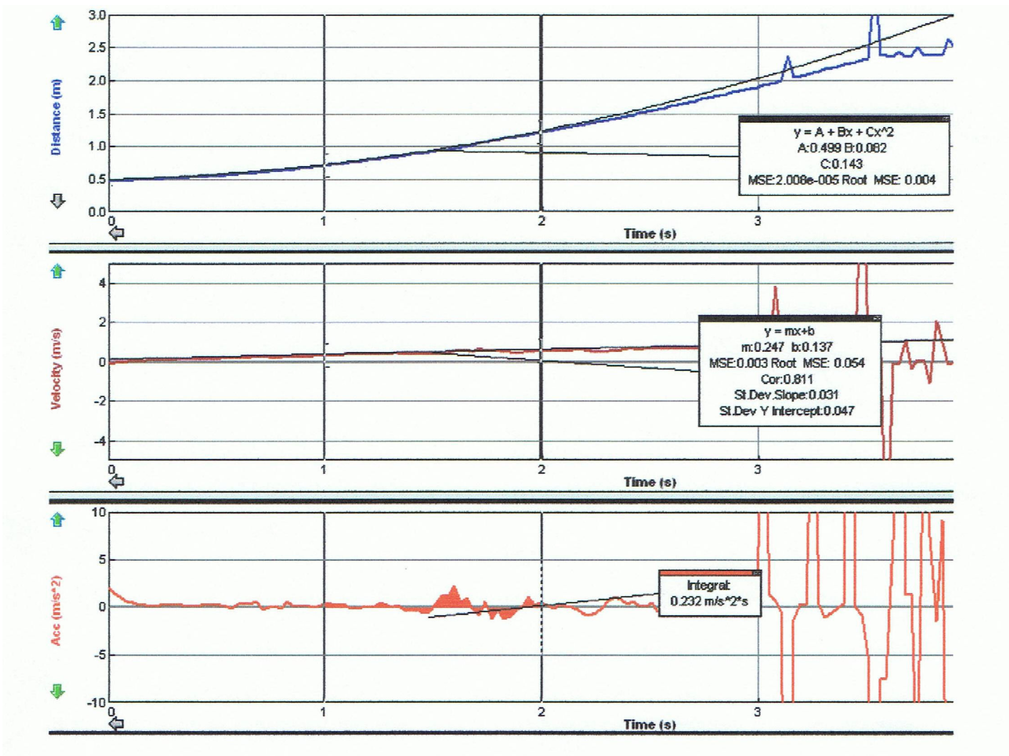


Figure 5B. Motion graphics

Using a chosen suspended mass, this team proposed to:

i) Calculate the resultant force which acted on the vehicle;
ii) Quantify friction during motion;
iii) Measure the final speed;
iv) Measure the stopping time of the vehicle after brake use;
v) Calculate the stopping distance.

As a result of the instructor's analysis followed by a discussion, the team was able to realize that it was technically impossible to measure the force of friction during motion, but only verify its existence. The students could also explain that when they referred to final speed, their intention was to measure the vehicle's speed at the instant before braking. As for all the other points, their experiment plan was feasible and interesting. Student difficulties using position, velocity, and acceleration versus time graphs are quite common. They also include, among others, graphic interpretation, the inability to understand the meaning of the area under different curves or to establish a correct relation between kinematic quantities and applied forces[6].

2. Rotational dynamics

This proposal was based on the use of a rotation apparatus, as can be seen in Fig.6, which consists of a turntable with an inner shaft, where a cord is attached. A mass can be suspended by the cord around the inner shaft. When the mass is released from rest it causes the rotational motion of the system.

Figure 6 – Rotational apparatus

A considerable set of experiments about kinematics and dynamics of rotational motion can be conducted using this device, which is important as this is a subject/topic students usually consider very difficult. The different physical concepts they are related to cause a lot of misconceptions. These experiments always help to clarify some ideas.

This team planned to study the role of moment of inertia in rotational motion. They proposed the use of a tennis ball and a roller hockey ball, brought from home, to perform the experiment. Their first idea was to put each ball at the center of the turntable and for each situation they would measure the time it took that propulsion mass to reach the floor. Using those values they could calculate and compare the moments of inertia of the two balls. After some discussion they added to their plan the calculation of those moments of inertia based on the masses and dimensions of the balls and the comparison with the corresponding experimental values.

It is important to mention the quality of most of the plans, namely in their innovation content as well as in the well defined objectives. It was also very interesting to observe the capacity that students revealed while justifying their options and during the search for technical alternatives. The discussions allowed improving discussion skills, creativity and autonomous learning in a team work interaction.

4.3.2. Working in the lab

Laboratory implementation of different experiments led students to face and solve some technical problems, which was normal in these situations. Most of the students already had some contact with the lab in high school, as a result of directed experiments based on protocols or from observing their teachers' laboratory performance in class. But due to this new strategy they were following their own plans, applying concepts, using selected laboratory materials, interacting in groups, managing time, all in order to achieve the goals that they had set for themselves. The search for explanations for these lab situations is an important contribution to understanding mechanics.

The teacher interacted with all the work teams. He always stimulated the search for solutions, gave clues which allowed students to find answers to their questions inside their own teams, promoted reflection during the experiments and on the results obtained. He could also follow students' evolution with respect to acquiring skills in applied knowledge and experimental work. At the same time he could observe students' behavior as active members of a team, the way they planned, organized and managed the different steps of their work.

4.3.3. The written reports

The teams had to produce written reports concerning all the experiments performed. The reports were also the result of team work because each team handed in a single written report for each experiment. At the beginning of the term some information was distributed about reports, namely concerning their recommended structure. Rigorous time schedules were defined. Each report should be handed in one week after the laboratory work was done.

The reports reflected different aspects of students' progress. The teacher could evaluate effective comprehension of concepts, skills in dealing with analysis of experimental data and to reach grounded conclusions. Good writing could also be evaluated.

4.3.4. Public presentation and discussion of the experiments

At the end of the semester and as a result of drawing lots, each student had to present and discuss in public, i.e., presented and discussed to their fellow students as well as to any other student from school, one of the experiments they had performed. The students had four weeks between the drawing and the presentation. The strategy and structure of the presentations had no specific rules, with the exception of duration: twenty minutes maximum, including questions and discussion. Each was totally free to choose how to conduct it. Students used different supports to present their work: power point slideshow, power point slideshow and board work, board work, oral communication based on lab devices and simple oral communication. 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 and the adequate behavior facing an audience, to name only a few.

After each presentation, the instructors conducted the discussion, asking some questions. The other students could also participate in the discussion but no one did. The discussion allowed both the students and the instructors to observe communication and discussion skills. They also complemented the analysis and evaluation of individual work within the team.

4.4. Assessment

Assessment in Mechanics I covers the different issues of students' work and also intends to motivate class attendance and quality participation, which is considered of major importance (Marques and Paiva, 2000). Assessment is a very complex matter and the actual distribution of values is certainly not perfect. At the beginning of each semester there is always a reflection and a discussion point, opened to changes, as a result of accumulated experience. For the time being, the weights are divided as shown in Tab. 1.

Table 1. Mechanics I course assessment.

Issue	Value (%)
Written exam	58.5
Laboratory work	18.0
Written tests	13.5
Attendance and quality	10.0

The aim in attributing a higher weght to lab components is being analyzed. The first results of this new strategy are very positive and can promote changes. Also, written tests may have a higher value. These tests (usually three or four) are proposed during the semester and allow the students' progress to be monitored, not only by the instructor, but also by the students themselves. On the other hand, the weight of the final written test will probably be reduced.

It is important to mention that a record of attendance is in place. In order to assess the quality of participation, the instructor takes into account performance in class, the tutorial and their homework.

5. Results

A first evaluation was made after the end of the term and before the written exam period. It consisted of an individual semi-structured interview. During these interviews students were asked to give their opinion about the Mechanics I course in general and to answer direct questions related to the new strategies, namely in lab work.

Their opinions were very positive. All of them agreed with the present methodology and considered it much more stimulating; they also considered it allowed an autonomous and deeper learning which was not acquired when the former protocols were in place. Some students' translated comments can transmit a more precise idea of their thoughts:

"It's easier to understand subjects."
"It's much more interesting, because it was our idea."
"The lab work became more simple and understandable."
"We designed something and we were able to do it."

Related to the new lab work and homework problems is the issue of attendance in tutorials. Effectively, as a consequence of adapting Bologna, the goal is to center the learning-teaching process on student work and individual evolution. This requires a great change in the established mentality, which will probably need some motivational pressings.

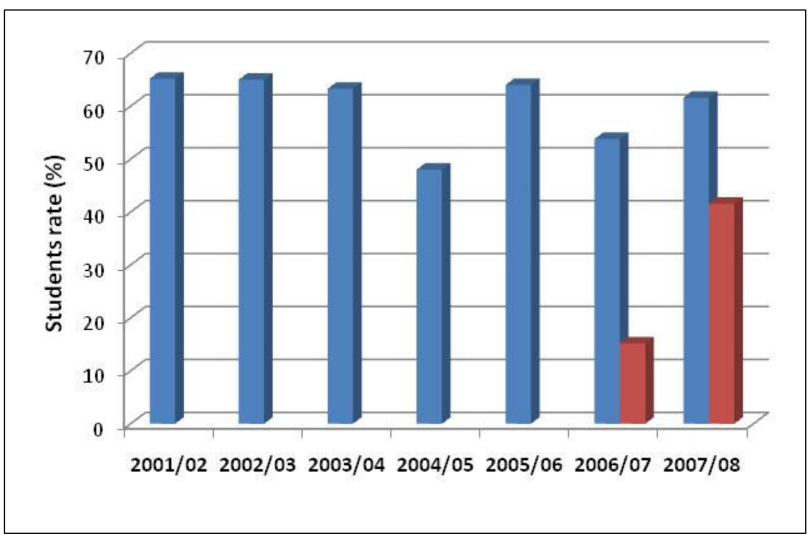


Figure 7. Students' attendance rate: classes (blue) and tutorial (red); Physics (2001-2006), Mechanics I (2006-2008, after adapting Bologna).

During the first year working with the guidelines of Bologna, tutorial attendance rate was very low. The newly implemented strategies considerably increased tutorial attendance.

6. Conclusions

At the moment the results obtained are insufficient to draw significant conclusions. There are, nonetheless, some interesting aspects that can be pointed out:

1. Student's active role in the learning-teaching process clearly contributes to important skill development, as it appears to happen in this new laboratory work strategy.
2. There is an increase in motivation and in students' autonomous work.
3. Change is possible, establishing an end to passive attitudes, helping students to find their own way to success.

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 complete unified set of engineering laws applied to graduated engineers: being able to solve problems independently.

This is a real opportunity 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.

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