2006-1893: GLOBAL EDUCATION: PHYSICS ON LINE

Joao Paiva, Politecnico de Viseu

Joao Monney Paiva, PhD Professor of Thermodynamics, Heat and Mass Transfer, Pneumatic Transport, Energy Audits and Operations Management; Coordinator Professor since 1995; Head of the Mechanical Engineering and Industrial Management Department of the Escola Superior de Tecnologia of the Polytechnic of Viseu from 1990 to 2002; Chairman of the Scientific Council of the Escola Superior de Tecnologia of the Polytechnic of Viseu from 1996 to 2004; Coordinator of Engineering Education seminars since 1998; CEO of Provela, SA, since 1996; CEO of Transcome, SA, since 1995; Director of Transagri, Lda (www.transagri-lda.com), Mangualde, Portugal, since 1986; Engineer at Brown Boveri Corp., Baden, Switzerland, 1981-83; Assistant engineer at MAGUE, Construcoes Metalomecanicas, Alverca, Portugal, 1980-81.

Joao Vinhas, Politecnico de Viseu

João Vinhas, MSc Professor of Physics and Mechanics; Assistant Professor since 1998; Director of the graduation in Mechanical Engineering and Industrial Management of the Escola Superior de Tecnologia of the Polytechnic of Viseu from 2002 to 2005; Researcher at the Joint Research Centre of the European Union at Ispra - Italy from 1994 to 1996.

Global Education: Physics on line

1. Introduction

Over the last few years the need for engineering professionals in Portugal has become an issue of key importance in order to achieve higher levels of productivity, competitiveness and innovation in different fields. Higher learning institutions, responsible for engineering degrees, have had to adjust their strategies in accordance with their incoming students' profiles.

The engineer's role in his or her professional life has changed over these last decades. Also, important vocational differences can be detected for engineering students. Newcomers that begin their studies in this area can come from very different backgrounds. Consequently, they bring numerous gaps in their knowledge, particularly in physics and mathematics. The initial contact with this new reality in their lives is crucial to future success, revealing a great importance for personal and professional development and creating tight bonds with positive influence on dropout rates. These challenges led to the decision to implement a new socio-pedagogical project called GOIS (from Damião de Góis, a prominent Portuguese and European renaissance man). It introduced important innovations and new strategies involving computer-student interaction during teaching-learning processes. Problem-solving skills are fundamental tools for the future engineer; so, the goal is to improve those tools and coach the student in a rational way.

A generation ago freshmen would have had very little chance of finding a door to knock on with the hope of getting some understanding and encouragement. The rigorous freshman and sophomore courses in engineering schools were viewed as a way to weed out weak students. Those who could not deal with it were of no one's concern. Engineering schools only wanted the best students. Back then, the local saying "Whoever wants acorns must climb the tree," was a sentiment often expressed in university corridors.

It was only after the *student crisis* in our school in 1996, which acted as a wake up call, a strong ring/alarm at our unused faculty ears, that the real extent of the engineering shortage became apparent. We realized that we could not afford to be complacent. It was only a matter of time for many other higher education institutions to realize that they could not afford to discourage engineering students anymore either. As Chris Kroeger, an associate dean of engineering and applied science at Washington University in St. Louis, said "We want to be a pump, not a filter." (Loftus, 2005)[1] Similar attitudes were also adopted by well-known institutions. These include Washington University in St. Louis, Virginia Tech College of Engineering, Rose-Hulman Institute of Technology, Syracuse University, Clemson University, University of Missouri, Texas A&M, and a very long list of many others.

Almost a decade has passed since then and the intermittences of political guidelines have meant that Portuguese engineering schools continue to have their work cut out in order to meet our urgent demand for engineers. We face particular social challenges, like those arising from the integration of some students who are the first generation in their families to go to college. We can reason that all students can use some encouragement now and then, especially when they are freshmen. However, these personal backgrounds in conjunction with a region which has no tradition in technical areas whatsoever, marked very strongly by rural environments, is a major drawback to efforts to win this battle. If we add to this an almost total lack of comprehension or perception regarding these issues from the superstructure of the institution itself we have a clear picture of current trends and the difficulties in changing them. This concern with freshmen is the result of all those years monitoring students' evolution/progress. We are quite certain that the majority of drop-outs among engineering undergraduates occur at this stage. Our ten-year surveys clearly show that all of the students who make a successful transition to the sophomore year graduate and that those who manage to keep going after a less performed first year, even in the face of some difficulties, graduate as well, though naturally taking longer.

What is it about engineering programs that turns off nearly half of the first-year students in Portugal? (The Mechanical Engineering and Industrial Management Department has succeeded in bringing this number down to less than a quarter, which is still too high). Portuguese society lacks role models for present and prospective students to follow thereby knowing what an engineer actually does. Some television shows have started to work on this but they have not been on long enough to see if it is working.

Since there is a recognition of the importance of knowing what to set our sights on– helping engineering students to persist and not to give up too soon – some initiatives were implemented, such as the Mechanics Oscars. They are supposed to raise the bar as they have gone from building experiments only developed in curricular courses in former years to a hands-on experience conducted by GOIS assistant faculty members. They try to give students a taste of real-life engineering. Again, with the upshot that the further they go along, the less likely it is they will leave engineering.

Creating opportunities for students to work together and to achieve goals, such as creating and building small projects at the end of the year like those included in the GOIS program, seems to be a way of maintaining the kind of enthusiasm that fosters retention.

2. The Mechanical Engineering Course

Several threats have been acting on technological areas of Portuguese higher education: a decreasing population (though this has inverted since 2003), a lack of a comprehensive policy to attract young people, successive budget reductions that exert considerable constraints on the number of professors and assistant professors existing in each course, pressure to reduce the extended period to obtain that period to graduate. Added to these are the pressures of external evaluation processes conducted by the Foundation of Universities and Polytechnics to assess the degree of adequacy that alumni experience when entering the workplace environment. The Mechanical Engineering and Industrial Management Department has been dealing with all of these issues for almost 15 years now, trying to act as a support structure for its students, helping them to cope with the new trends.

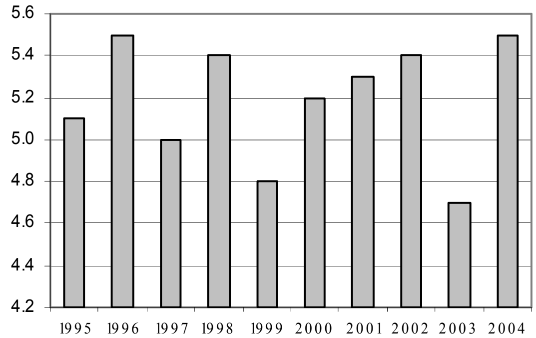

Figure 1. Years of study per pass degree.

As shown in Fig. 2, the ten-year average reveals that it takes five years to obtain a three-year curricular diploma.

The bottom line is that all graduated students found a job within 3 months. They find jobs all over the country and are requested from the beginning of the 3rd year by companies that include former Mechanical Engineering and Industrial Management students among their staff. Still, challenging areas such as Materials Resistance, Thermodynamics, Fluid Mechanics and Electricity, structurally underpinning the course, force individuals to experience difficulties in problem-solving that go beyond knowledge acquisition and application (Neto, 1998)[2].

Though the figures are below the national average for technological areas in higher education systems, and within values for the whole of the European Union, the situation has been addressed through a number of initiatives, such as the analysis of state high schools to prepare revision tutorials and lab classes, as well as seminars/workshops on study methods, and a reduction in class size.

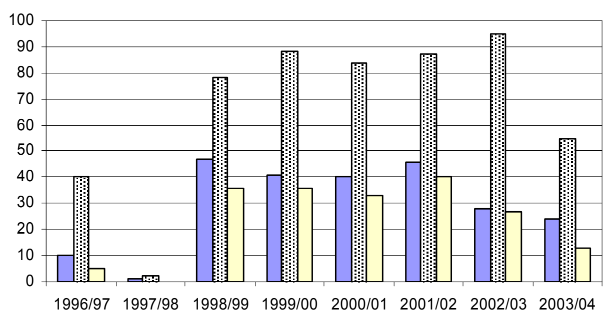

Figure 2. Freshmen dropout rates (%), filled columns, total number of incoming students, dotted columns, overall dropout number of freshmen, blank columns.

A second major constraint is the measure that states that graduations with less than 20 freshmen must close within three years. This and the fact that the K-12 average marks on math and physics show no sign of reversing the trend whereby only 25% of students succeed in overcoming those hurdles. This should provide some idea of the grip this problem has over the department/students/institution.

Several efforts have been made to adapt our educational practice to incoming students, following some guidelines from well-known authors (Vygostky, 1986; Resnick, 1989, Postic, 1995)[3, 4, 5], as well as incorporating knowledge obtained from our own experience. Among these, the unified approach to theoretical and tutorial classes and the mandatory record of attendance were the hardest to implement. Several initiatives have been carried out to ensure transparency within the academic context, such as printing question values on test sheets and displaying discrete marks obtained for each quiz.

High dropout rates led to the decision to implement a new socio-pedagogical two-semester project called GOISII, a first edition of which was launched in 2002. All freshmen were interviewed according to a set of items that constituted the selection criteria (Fachada, 2001)[6]: gender, profession and residence; incoming options in choosing the graduation; level of commitment: motivation, interest and availability to attend the initiative. It was developed through one-hour weekly sessions dealing with issues such as study techniques, relationship management and reading comprehension.

3. GOIS II: New Improvements

After the first experimental year, it was decided to develop a second edition with some improvements. This new edition, which is currently in practice, covers the whole group of freshmen and some non-freshmen. One of the major improvements is related to the introduction of ICTs in contact with the most problematic first year curricular courses, i.e. physics and calculus. This paper presents the work that has been done in the physics area, which includes the traditional general physics course as well as some introductory thermodynamics topics will be developed and followed up in the second year by this group of students.

An important gap in the students' background is related to an imperfect understanding of concepts and consequently their incorrect application. In order to resolve this situation the students need to practice a great deal, working on a considerable number of conceptual exercises. This is not a very attractive study routine and the student needs to be encouraged, accompanied from the beginning and helped step by step.

Over the fourteen years of teaching physics in the Mechanical Engineering and Industrial Management course it has been possible to identify our students' major difficulties and misconceptions. They are related to different subjects but it is simple to verify that Newtonian mechanics represents one of the most important gaps. This might be related to the abstract and non-intuitive nature of mechanical concepts and also to the complex formality often associated with them. In order to construct a solid conceptual structure it is very important to interact with the students' acquired view of the world. Although some of their perceptions and understandings of phenomena are based on incorrect ideas and models, it is fundamental to begin by understanding that existing conceptual structure to try to reconstruct or to replace it with a new one. 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'.

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

Some examples of these difficulties/misconceptions are:

1. Situations which involve the concepts of position, velocity, and acceleration usually present some difficulties. Sometimes students cannot distinguish the motion graphs from the path of the movement. The concept of acceleration is often associated with increasing speed and not speed variation. Displacement and distance are also usually misunderstood.

2. Another common situation is related to the comprehension of the forces involved in the interaction of bodies. The concept of force, as an associated entity with an interaction, is more evident in Newton’s third law, and students only begin to understand this concept when they are able to apply it correctly, properly drawing the force diagrams of interacting bodies. A great number of students correctly represent some external forces, but they do not deal with friction forces easily, namely when they are developed between two bodies and there are different possibilities for their dynamic behavior.

3. It is also clear that each student has his own difficulties and misconceptions leading to a distinct learning-teaching path which must be identified. This is only possible if teachers begin by understanding these difficulties.

At the Department of Software and Applied Mathematics at the University of Girona, Spain (Boada *et al.*, 2004)[7] a web-based tool was developed with the purpose of reinforcing teaching and learning of introductory programming courses in order to tackle these problems.

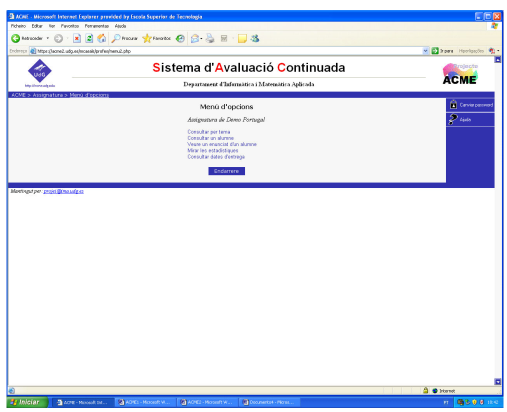

Figure 3. The ACME webpage.

As a result of the collaboration between professors from both institutions, a new project is being developed in order to apply this tool to physics.

The goal of introducing a computer supported experimental learning-teaching program is to have a more interesting and efficient model, so as to improve students’ motivation through the use of an ICT and allow immediate assessment of their own results.

The structure of the GOISII program allowed regular assessment of the activities as the accompanying professors and assistant professors regularly reported the hindrances/obstacles the exercises were presenting as well as proposing some significant improvements regarding the approaches chosen. The use of this ICT facilitated students' involvement and, as far as its application in the Girona University is concerned, it presented a significant rise in final marks, which rose from an average of 10 to 14 points (out of 20/on a scale of 20).

A decision to launch this new project was made during some meetings of the GOISII initiative. The idea was to have a considerable number of exercises in a repository available on the web, with easy student access in the very near future. For the moment and in order to test the students' reactions to this new tool, the computer provides a set of physics problems related to the different topics studied. The students try to solve each problem and write/find a solution. The system corrects and returns its answer to the student in real time. In case of error it is possible for the student to find a new solution. This procedure can be repeated as often as necessary until the correct answer is found, even though the actual system in place only allows three attempts. After that, the solution is disclosed but/and a new problem is presented to be solved by the student.

A significant feature of the system is the possibility of identifying errors committed while the problem is being solved incorrectly and to provide a report on request. This report is a vital 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 (so-called distracters) are based on common student errors or 'false friend' situations where students usually go wrong. Every incorrect answer has a corresponding suggested correction, which identifies the probable error.

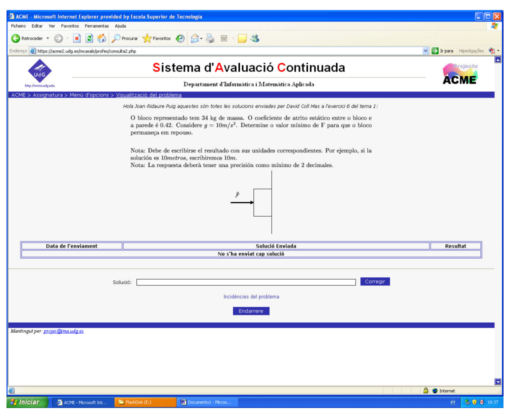

Figure 4. Example of a physics question.

In order to explain the kind of strategies related to the proposed problems we can analyze the following examples:

Example 1. A particle moves and its positions are shown in the following table as a function of time.

Table 1. Particle experimental values of position *versus* time for Example 1.

Time t (s)	Position s (m)
0	2
1	5
2	9
3	5
4	-1

Students are supposed to calculate the scalar displacement between the instants t = 1 s and t = 4 s.

Students who try to solve this very simple problem might arrive at some wrong answers based on their misconceptions. The most common wrong answers can be identified and the system will give/provide suggestions for correction. In this particular type of problem it is quite common to detect students' misconceptions related to the concepts of displacement/position, displacement/distance and even with the calculation of the displacement itself.

Then, the correct solution will be:

$$\Delta s = s_{(t = 4\,s)} - s_{(t = 1\,s)} \quad (1)$$

or

$$\Delta s = -1 - 5 = -6 \text{ m} \quad (2)$$

Some of the possible errors delivered in message format to the user are:

$$\Delta s = -1 - 5 = -6 \quad (3)$$

(*units are missing*)

$$\Delta s = 5 - (-1) = 6 \text{ m} \quad (4)$$

(*the scalar displacement is given by* $\Delta s = s_f - s_i$)

$$|\Delta s| = |-1 - 5| = 6 \text{ m} \quad (5)$$

(*the scalar displacement is incorrectly given in absolute numbers*)

$$\Delta s = -1\text{m} \quad (6)$$

(*the scalar displacement is misinterpreted as position*).

Example 2. A box has a mass of 10 kg. The static friction coefficient between the box and the wall is 0.25. Calculate the minimum value for F which makes the box remain at rest. Consider $g = 10 \text{ m/s}^2$.

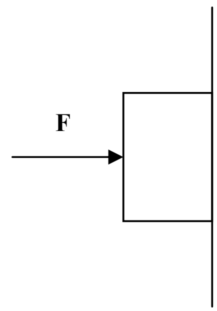

Figure 5. Schematic for Example 2.

In the solving these kinds of problems it is very common to observe students' difficulties related to the depiction of free body diagrams, namely concerning normal reactions and friction forces. There is also a common misconception between mass and weight; establishing/determining equilibrium equations is also accountable for some wrong answers. The correct solution is:

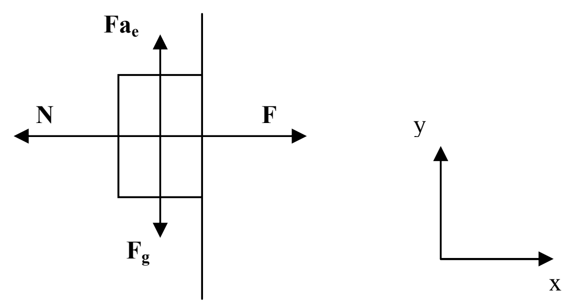

Figure 6. Free body diagram of the box in Example 2.

Establishing the equilibrium vector equation:

$$\mathbf{F_g} + \mathbf{Fa_e} + \mathbf{N} + \mathbf{F} = 0 \tag{7}$$

and writing the corresponding scalar expressions, along the x axis

$$F - N = 0 \tag{8}$$

and y

$$Fa_e - F_g = 0 \tag{9}$$

From Eq. (8)

$$N = F \tag{10}$$

and remembering the concept of static friction force

$$\mu_e N - F_g = 0 \quad (11)$$

From Eq. (10) and (11), we have

$$\mu_e F - F_g = 0 \quad (12)$$

so, with these sample values, is

$$0.25F = 10\times 10 \quad (13)$$

and finally

$$\mathrm{F} = 400\,\mathrm{N} \quad (14)$$

Again, some of the possible errors delivered by the system are:

$$F = 400 \quad (15)$$

(*units are missing*)

$$\mathrm{F} = 40\,\mathrm{N} \quad (16)$$

(*mass was used instead of the weight of the box*)

$$\mathrm{F} = -400\,\mathrm{N} \quad (17)$$

(*incorrect formulation of equilibrium scalar equations*)

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 provide the complete solution of the problem as well as a report describing the nature of the different mistakes made. And this report is available for both the professor and the student. During this initial part of the experimental program, the presence of GOISII assistant professors was of major importance, reporting and assessing students' behavior as well as discussing suggestions to improve this new tool.

4. Results

This experimental phase in introducing Information/Communication Technologies in physics was quite peaceable, considering the amount of friction that existed in other schools where it was first implemented in programming areas. A survey was conducted at the end of the semester to make an initial assessment, the results of which are shown in Fig. 7.

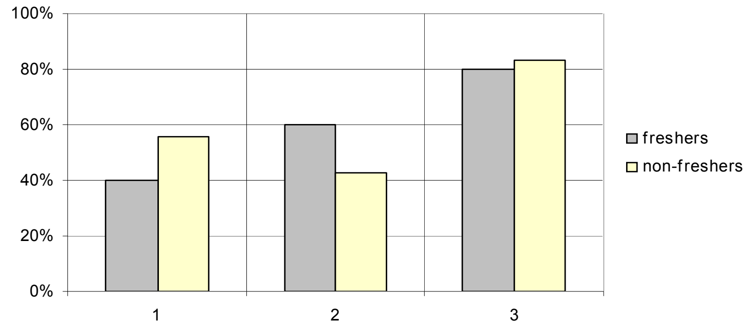

Figure 7. Freshman and non-freshman satisfaction index: 1- Considered a reduction of the number of classroom hours positive; 2- would change class hours for intranet exercises; 3- would like to be assessed on intranet data.

Freshmen that tried this interface considered, with moderate enthusiasm, that it could reduce the time spent in the classroom with an assistant professor. Non-freshmen did not seem very keen on those eventual changes. The reaction improved a little when the question was to exchange hours from classical to asynchronous. A definite increase was registered when asked how they would feel if part of the mark would come from credits obtained by using the interface, regularly, to deliver a certain number of assigned exercises and problems. Due to the limited time that it was put to use, there are still no results regarding the influence of this method on final physics grades.

5. Conclusions

The feedback obtained in solving basic physics problems was good, and it seems that the 'intensive' use of this new tool helps to provide qualified knowledge. It is also supposed to stabilize the triad of knowledge, comprehension and application through the regular use by having to solve a certain number of exercises each week. This will also have a positive effect in terms of regular study and, indirectly, on time management. Students will also realize their progress in the assignments handed in more 'just in-time'.

Using a computer supported learning-teaching program seems to be a good approach to develop an attractive and hopefully efficient model to improve students' motivation through both the use of Information Communication Technologies and self-assessment. Future work will consist in attaining a higher number of subjects progressively, as well as assessing grade impact and, indirectly, drop out rates.

References

1. Loftus, M. "Lending a Hand", Prism American Society for Engineering Education,Vol. 14, No. 5, January 2005, pp. 25-29. 2005.
2. Neto, A. *Resolução de problemas em Física*, Instituto de Inovação Educacional do Ministério da Educação, Lisboa, Portugal. 1998.
3. Vygotsky, L. *Thought and language*. Cambridge, Massachusetts, The MIT Press, USA. 1986.
4. Resnick, L. *Education and learning to think.* National Academy Press, Washington DC, USA. 1989.
5. Postic, M. *Towards a Pedagogical Strategy of School Success.* Porto Editora, Lda, Porto, Portugal. 1995.
6. Fachada, M. O. *Psicologia das Relações Interpessoais.* Edições Rumo, Lisboa, Portugal. 2001.

7. Boada, I., Soler, J., Prados, F., Poch, J. "A teaching/learning support tool for introductory programming courses". Proceedings of the 5th International Conference on Information Technology Based Higher Education and Training, Istanbul, Turkey. 2004.