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TEACHING AND LEARNING MATHEMATICS AND STATISTICS AT AN AGRICULTURAL ENGINEERING SCHOOL

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This paper focuses on the teaching and learning of mathematical topics at the School of Agricultural Engineering of Barcelona in Spain. The teaching and learning process was hindered by under-achievement, absenteeism and lack of motivation on the student's part. To overcome such obstacles we decided to set to work on a new design for the subjects involved, with the help of computer and other technologies. Therefore, we devised a methodology based on the use of technical tools aiming at solving standard problems and fostering teacher-student communication. This paper outlines the activities performed to this purpose, depending on the specific contents of each subject matter and the context where they are conducted. However, the use (and misuse) of technology entails some drawbacks, which can be overcome by means of other kinds of activities, such as lectures, different types of examination questions or projects. Since the implementation of the sketched methodology absenteeism appears to decrease and students' motivation to improve. In fact students employ statistical tools more frequently than in previous years to complete their final projects. Likewise, this methodology contributes to enhance students' independent work, which fits the framework of the European Higher Education Area.

1. INTRODUCTION

This paper focuses on the teaching and learning of mathematical topics at the School of Agricultural Engineering of Barcelona (ESAB) in Spain. Until 2008 it was an associate school of the Technical University of Catalonia (UPC). The ESAB was managed and maintained by the Barcelona School of Industry Consortium, a public body comprising the Barcelona Provincial Council, the Technical University of Catalonia and the Ministry of Universities, Research and the Information Society of the Catalan government. This aided its integration into the Catalan public university system. The ESAB was created by the Barcelona County Council in 1911 and last year became a fully integrated centre of this university [http://www.esab.upc.edu]. Agricultural engineering studies are divided into six semesters, comprising an industrial training period and a final project. Nowadays, the ESAB offers three programmes leading to the following diplomas: Crop and Livestock Management, Horticulture and Gardening Studies and Agri-Business Management and Food Marketing. Table 1 displays the compulsory subjects in the field of applied mathematics taught at this School, with the corresponding semester, the topics covered and their weight (lecture hours):

Table 1. Mathematics topics taught at the ESAB

	Semester	Topics covered	Weight
Mathematics 1	1	Algebra and Differential Calculus	60 hours
Mathematics 2	2	Integral Calculus and Ordinary Differential Equations	45 hours
Statistics	3 or 4	Analysis of Data and Basic Statistical Inference	60 hours

The efforts invested in the teaching and learning of mathematics and statistics did not produce the desired results. First of all, students obtained rather low marks, which discouraged them. Under-achievement might have been caused by excessive workload and lack of interest in the topics of mathematics and statistics, which in turn might have contributed to absenteeism and even abandonment of the subject in some cases. Besides, the essentially biological profile of the agricultural college with less emphasis on engineering undermined interest in the mathematical and statistical areas.

On the other hand, those students who do not pass all the mandatory first-year subjects (Mathematics 1 and 2 are here included) are not allowed to register for subjects in second and third years. What is more, they may not be able to continue their studies at the School. This proves to be a source of pressure, because students focus their interest on those subjects, which they feel they can manage to pass with a reasonable amount of effort.

To overcome these obstacles we agreed to plan anew and set to work on our subjects by taking avantage of all the resources at hand. Hence, besides improving the teaching and learning process, we were committed to accomplish the following specific aims:

Aim 1. To keep up the attendance and interest through the whole semester and, if possible, to increase the students' level of achievement.

Aim 2. To change the students' opinions and concepts regarding mathematical topics.

Aim 3. To foster interaction between subjects from other areas and to gather their requirements regarding mathematics and statistics. If we were able to show the practical use of the subjects in the mathematical and statistical field, we might render them more appealing to students.

Aim 4. To plan and run activities in order to favour the students' autonomy, as the university policy is heading towards the implementation of the European Credit Transfer System in the context of European Higher Education Area.

2. METHODOLOGY

Since mathematics plays a fundamental role in the education of any engineer, in 2001-2002 a survey was conducted among the teachers of the School to collect data on the needs of the subjects they taught, concerning mathematics and statistics. The survey provided useful information on the wide range of mathematical applications to the agricultural engineering field, such as topography, surveying, irrigation technology, econometrics, environmental science and technology, quality control, food technology, and civil, hydraulic and rural constructions. Such applications proved to be useful as guidelines to define the corresponding competences, taking into account the contents of each subject and may help to decide which attitudes and skills should be stressed the most.

In the mathematics we teach at the School, the teaching and learning process is accomplished through a mixture of lectures, problem solving classes and computer practicals. Students' progress is assessed by a weighted combination of a test during the semester, a final written examination, and several coursework assignments. The latter comprise class-work (involving the solution of problem sheets, along with an oral exposition in some cases), assessed homework, computer practicals, and a project work. The ratio of examination to coursework and computer practicals varies depending on the subject. For instance, as far

as the qualifications Crop and Livestock Management and Horticulture and Gardening Studies are concerned, the assessment in Mathematics 1 and 2 is achieved by using the following weighted formula: one written examination during the semester (25%), one written summative examination (50%) and computer practicals plus coursework (25%). In the case of Statistics the final mark is computed as follows: one written examination during the semester (25%), one written summative examination (50%) and computer practicals, coursework plus a project work (25%). Students must carry out the project work using real data derived from surveys that have been conducted among the students at the beginning of every semester since 2000. The database consists of a collection of attractive data such as: the amount of time students spend surfing the World Wide Web, the amount of time students spend watching TV, students' mobile phone expense, students' job situation or favourite sports. All the available results can also be used to establish comparisons between the three diplomas and different academic years.

Will technology help students to learn? Hubbard states this is one criterion for deciding whether to include technology into a mathematical course (Hubbard, 1995). If so, we teachers have to ensure that technology is actually an efficient learning resource, a means to acquire the technical attitudes and skills required to tackle a problem successfully, and not just an optional software module. Of course the use of technology redefines the teaching and learning process. We now proceed to outline a methodology based on the use of technical tools, which we adopted to fulfil two particular aims: a) solving standard problems and b) fostering the communication teacher-student.

2.1. TECHNOLOGY ALLOWS THE SOLVING OF MANY STANDARD PROBLEMS

Technology is employed here in three different contexts and according to the specific contents of each subject matter: 1) computer practicals, 2) problem solving classes and coursework, and 3) exams.

2.1.1. *Computer practicals*

The computer practicals offer students the possibility to actively engage themselves in the learning process, as well as to apply the concepts learnt to the prospective working practice. In this sense, students should gain competence in the manipulation of a general spreadsheet and of some special purpose packages. Because of its accessibility, both in businesses and at home, we include the use of the electronic spreadsheet program Microsoft Excel in all the three subjects we teach.

- Mathematics 1 and Mathematics 2: Manipulating an Excel worksheet allows the student to graph functions; to solve problems dealing with series and linear algebra; and to introduce numerical methods for approximating definite integrals and solving ordinary differential equations. The Excel Solver tool is a useful technique for solving linear programming problems, which also makes the learning of this specific topic possible and may arouse student motivation.

- Statistics: The student must learn how to use a spreadsheet, and statistical packages in order to carry out elementary statistical analysis. Through the practicals of Statistics students are encouraged to learn how to manipulate an Excel worksheet with statistical purposes. Students also become familiar with two powerful statistical packages: Minitab [http://www.minitab.com/] and Statistical Analysis System (SAS) [http://www.sas.com/]. At the request of those teachers in charge of subjects in the final years, the School purchased SAS program. SAS could be used to run not only some of the practicals of the subject taught at the ESAB, but also experiments involved in the accomplishment of students' final degree project. Though not as powerful as SAS, Minitab is easier-to-use. It renders statistical analysis more intuitive, and its new graphics system contributes to a clearer visualisation of data. Students can easily access Minitab's commands thanks to its uncomplicated structure, with dialog boxes and pull-down menus, whereas to work with SAS the teacher has to introduce students to programming tasks. In addition, students can

download free demo versions of Minitab to work with at home for a specific time period. Consequently students can complement the work developed in the practicals.

2.1.2. *Problem solving classes and coursework*

The Department of Applied Mathematics III of the UPC took part in the production of the following virtual tools to improve the learning process:

i) *EVAM* [http://wiris.upc.es/EVAM/]: *EVAM* is a virtual tool which helps to reinforce the mathematical background of students entering an engineering school, namely, basic linear algebra (matrices, determinants, systems of linear equations), trigonometry, single variable functions (basic concepts, limits and continuity, rules and techniques of differentiation, maxima and minima, Taylor expansions, basic techniques of integration) and plane geometry.

ii) *BasicMatWeb* [http://wiris.upc.es/basicmatweb/]: The creation of *BasicMatWeb* can be envisaged as the continuation of the previous tool. This virtual tool guides the teaching and self-learning of the basic mathematical topics taught during the first year of engineering studies, including linear algebra (algebraic structures, real vector spaces, linear functions), multivariable functions (geometric representations, limits and continuity, partial differentiation, maxima and minima, Taylor series), and ordinary differential equations (general properties, analytical methods for solving some types of first-order ordinary differential equations).

iii) *Derivades i fotons* [http://mie.esab.upc.es/df]: This interactive "sandwich" project was designed by two departments of physics and two of mathematics of the UPC, and with the involvement of our School. In addition to complex numbers and matrices, students of engineering schools can also attempt to acquire some basic knowledge of the principles of physics of fluids.

2.1.3. *Exams*

In Statistics students will be asked about the meaning of some statistical printouts. This will enable then to concentrate more on the interpretation of the statistical output, rather than on the often large amounts of calculation.

2.2. TECHNOLOGY ALLOWS "SOCIAL" EXCHANGE WITH SCHOOLMATES AND TEACHERS

In 2002 the ESAB undertook the use of a virtual teaching tool, the campus *Atenea*. The campus enhances active teacher-student exchange. Since students can e-mail their questions on any subject to the corresponding teacher, the campus becomes a distance tutoring environment. It is a means to submit coursework assignments and to provide students with feedback on their work. From this virtual campus students can download course materials (basic concepts, solved problems, answered or completed exams, lecture slides). Instead of uploading all the course materials right away at the beginning of the semester, we believe it is worth uploading them sequentially, according to the lecturing pace. Materials will be available on the campus for a while. Once the teacher considers students have had enough time to download the materials, they will be removed from the campus. In this way, the teacher can help students manage their own learning pace.

However, the use (and misuse) of technology has some drawbacks. For instance, memorising may fail to be practised. Although there is no sense in memorising a topic without thoroughly understanding it (Hubbard, 1995), memorising should not be completely discarded from the learning process. On the other hand, students must be encouraged to reflect on the activities they are carrying out. Otherwise, learning how to use technical tools may overlook the understanding of the theory behind those tools. Let us have a look at some of the activities we plan to use in order to overcome such drawbacks:

- Lectures, to help students grasp the basic concepts.

- Different types of examination questions, to find out which skills the student has acquired: multiple choice questions, solving exercises, solving problems arising from situations in agricultural engineering, working on computer outputs.

- Exams without the aid of course materials or books, except a one page formula summary prepared by the student, to manage memorising and summarising.

- Oral presentation of resolution of the exercises and problems on blackboard, to develop communication skills.

- Project work, to enable students to work in pairs, as well as to effectively integrate new technologies and the basic concepts learnt in class. This activity is especially suitable for Statistics.

3. RESULTS AND CONCLUSIONS

During the lectures. the learning activities, computer practicals and, to a large extent, the project work for the subject of Statistics, introduce the student to the analysis of real context issues. For instance, the data derived from the above mentioned survey conducted every semester since 2000 offer students a real problem in a relevant context, a challenge for them to create or construct their personal strategies for solutions and understanding of statistics. The real possibility of making true or false conjectures adds to the student's motivation and develops his or her perseverance. The student can decide independently how to distribute and tackle the tasks leading to a successful accomplishment of the project.

Unfortunately, the level of requirements for entry to engineering agricultural studies has recently been lowered. As a consequence teachers have been forced to slow down the working pace (that is, at a conceptual level). Due to the changes in our society, students are better acquainted with technology and accept it naturally as a working tool and in their everyday lives.

Aim 1: However attractive new technologies turn out to be, lectures are still considered as irreplaceable by students. Starting from this premise, students' attitude toward the virtual campus *Atenea* as support for the subjects is highly positive, stressing in particular the course materials available. Student consultations, made through the virtual campus, have remarkably soared. To be honest, though, we have to acknowledge that our students' low achievement persists. However, the percentage of students who pass has at least not decreased, and absenteeism has not increased.

Aim 2: Student ratings on every subject are a means to assess teaching quality from the student's point of view. Table 2 displays the averaged student rating results concerning Mathematics 1 and 2 and Statistics since the academic year 2000-2001.

Table 2. Student ratings concerning Mathematics 1 and 2 (M1, M2) and Statistics (ST)

1 (-) --- 5 (+)	M1	M2	ST
Item 1: I think that this subject helps me acquire new knowledge.	3,5	3,5	3,4
Item 2: I am interested in the topics taught.	2,7	2,5	2,5
Item 3: The resources (rooms, labs, materials, equipment,...) are suitable for the subject.	3	3,1	3,5
Item 4: I have a positive opinion of the subject.	3,2	3,1	3,1

We are very pleased with these results, since they match those obtained by other subjects in which our department is involved. We cannot overlook the fact that most of these subjects are offered by technical schools and faculties where the engineering profile is stressed and where students' interest in mathematical topics is higher than at the ESAB.

Aim 3: Since 2001 there has been strong evidence of an increase in the use of statistical tools to carry out the final degree project.

Aim 4: The implementation of small projects in actual teaching-learning enables the student to obtain positive attitudes towards mathematics and statistics. The project work for the subject Statistics illustrates an activity aimed at students' independent work when it comes to project design and decision-making, a key point in the pedagogical views of the European Higher Education Area.

The methodology we have just sketched will fit perfectly in the framework of the European Higher Education Area. For a professional engineer-to-be, this methodology aids the student to gain competence in working both independently and in a team, managing time effectively and using computer resources appropriately. The course materials generated so far can be easily adapted for distance and blended learning courses. Accordingly, we are running some activities intended to compute student workload, that is, the time required to perform successfully the activities planned in order to achieve the learning outcomes. As a starting point we reconsider the results of the student ratings concerning the subjects Mathematics 1 and 2 and Statistics. From Table 3 it can be inferred that every one-hour lecture means approximately 1-2 hours of student workload. As future work, it would also be interesting to compute the corresponding "teacher workload" in order to plan beforehand the teaching requirements of the School, once it has implemented the European Credit Transfer System in the context of the European Higher Education Area.

Table 3. Averaged student workload

	M1	M2	ST
Item 5: The time that I have to invest to make the most of every one-hour lecture is approximately... *1. More than 2 hours 2. 1-2 hours 3. 1 hour 4. Less than 1hour 5. None*	2	2,2	2,5

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