TEACHING AND LEARNING MATHEMATICS AND STATISTICS AT AN AGRICULTURAL ENGINEERING SCHOOL

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ABSTRACT: *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 side. To overcome such obstacles we decided to set to work 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 the communication teacher-student. This paper outlines the activities performed to the 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 sorted out by means of other kinds of activities, such as lectures, different types of examination questions or the achievement of a project work. Since the implementation of the sketched methodology absenteeism turns out to decrease, whereas students' motivation seems to improve. In fact students employ statistical tools more frequently than in previous years to fulfil their final degree project. Likewise this methodology contributes to enhance students' independent work, which matches perfectly the framework of the European Credit Transfer System.*

1. INTRODUCTION

This paper focuses on the teaching and learning of mathematical topics at the School of Agricultural Engineering of Barcelona (ESAB) in Spain. It is an associate school of the Technical University of Catalonia. The ESAB is 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 aids its integration into the Catalan public university system. The ESAB was created by the Barcelona County Council in 1911 and is about to become a fully integrated centre of this technical university [http://www.esab.upc.edu]. Agricultural engineering studies are divided into six semesters, comprising an industrial training period and a final degree project. The ESAB offers three programmes leading to the following qualifications: 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 mathematics taught at this School, along with their corresponding semester, the topics they cover and their weight (lectured 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 were not followed by the desired results. First of all, students obtained rather low marks, which by all means 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 School,

with detriment to the engineering scope, turned out to undermine the 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, for students focus their interest and work 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 our subjects by running all the resources at hand. Hence, aside from improving the teaching and learning process, we were committed to accomplish the following specific aims:

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

Aim 2. To change the student's opinion and concept regarding mathematical topics.

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

Aim 4. To plan and run activities enhancing the student's autonomy, since the university policy is heading towards the implementation of the European Credit Transfer System.

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 that each subject covers. Furthermore, they might help in deciding 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, problems 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 (30%), one written summative examination (55%) and computer practicals plus coursework (15%). 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 from real data derived from a survey, conducted among the students at the beginning of every semester since 2000. The data basis gathers 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 information can be also used to establish comparisons among the three qualifications and among 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 SOLVING MANY STANDARD PROBLEMS

Methodology to the purpose

Technology is here employed in three different contexts and according to the specific contents of each subject matter: 1) computer practicals, 2) problem 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 learnt concepts 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 + 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 should learn how to use a worksheet, as well as some statistical packages, 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. Likewise, students also get familiar with two powerful statistical packages: Minitab [http://www.minitab.com/] and SAS (Statistical Analysis System) [http://www.sas.com/]. On 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 they taught, but also experiments involved in the accomplishment of their 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 in this sense to a clearer visualization of data. Students can easily access to 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 period of time. Consequently students can complement the work developed in the practicals.

2.1.2. *Problems classes and coursework*

The Department of Applied Mathematics III of the Technical University of Catalonia took part in the production of the following virtual tools, aiming at the improvement of the learning process:

i) *EVAM* [http://wiris.upc.es/EVAM/]: *EVAM* is a virtual tool which helps reinforcing 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 aims at the teaching and self-learning of the basic mathematical topics taught during the first year of engineering studies, including, among others, 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 the departments of physics and mathematics connected in some way with 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. Hence, they can 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

Methodology to the purpose

In 2002 the School of Agricultural Engineering of Barcelona undertook the use of a virtual teaching tool, the campus *Atenea*. The campus enhances active exchange teacher-student. Since students can e-mail their questions on any issue of a 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, solved 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. Hence, the teacher can help students manage their own learning pace.

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

- Oral exposition of resolution of 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

The learning activities run during the lectures, coupled with the computer practicals and, to a large extent, the project work for the subject 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 entry requirements for the engineering agricultural studies have recently dropped dramatically. As a consequence teachers have been forced to slow down the working pace (that is, at a conceptual level). Nevertheless, changes undergone by our society have strong influence over the university. Thus, students are easier acquainted with technology and accept it quicker as a usual tool at work and in their everyday life.

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 proportion of students who pass has at least not sunk, and absenteeism has noticeably decreased.

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

Table 2. Student opinion poll 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, equipping,...) are fit 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 student's interest in mathematical topics is higher than at the ESAB.

Aim 3: Since 2001 there is strong evidence of an increase in the use of statistical tools to fulfil 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 the student's independent work, when it comes to project

design and decision-making, a key point in the pedagogical views of the European Credit Transfer System.

The methodology we have just sketched will fit perfectly in the framework of the European Credit Transfer System. As a professional engineer-to-be, this methodology aids the student gain competence in working both independently and in 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 to achieve the learning outcomes. As a starting point we consider again the results of the student opinion poll concerning the subjects Mathematics 1 and 2 and Statistics. From Table 3 it can be inferred that every one-hour lecture mean, 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 before hand the teaching needs of the School, once it implements the European Credit Transfer System.

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

ACKNOWLEDGEMENTS

We are very grateful to the Barcelona School of Industry Consortium for its economical support.

REFERENCES

Agència per a la qualitat del Sistema Universitari de Catalunya [http://www.aqucatalunya.org]

Cobo, E., González, J. A. (2006) "Implantación de la semi-presencialidad en una asignatura optativa de la licenciatura en Ciencias y Técnicas Estadística". *Teoría de la Educación*, 7 (1). Salamanca: Ediciones Universidad de Salamanca

Estela, M. R. (2005) *Fonaments de càlcul*. Barcelona: Edicions UPC [2nd edition]

Estela, M. R., Ginovart, M. Jarauta, E., Xambó, S. (2003) EVAM*, Eina Virtual d'Aprenentatge de les Matemàtiques* [http://wiris.upc.es/EVAM/]

Estela, M. R., Ginovart, M. Jarauta, E., Xambó, S. (2004) BASICMATWEB*, Web d'ensenyament i autoaprenentatge en xarxa de les matemàtiques bàsiques* [http://wiris.upc.es/basicmatweb/]

González, J. A., Cobo, E., Recober, M. M., Muñoz, P. (2006) "Desarrollo y aplicación de nuevas tecnologías para la formación universitaria". *Teoría de la Educación*, 7 (1). Salamanca: Ediciones Universidad de Salamanca

Hubbard, R. (1990) *Interesting Ways to Teach Mathematics*. Bristol: Technical and Educational Services

Hubbard, R. (1995) *Ways to Ask Questions in Mathematics and Statistics*. Bristol: Technical and Educational Services

Jarauta, E. (2000) *Análisis matemático de una variable. Fundamentos y aplicaciones*. Barcelona: Edicions UPC

Parcerisa, A. (2004) *Planificar les assignatures en el marc de l'EEES*. Barcelona: ICE UB

Polya, G. (1944) *How to solve it*. Princeton, NJ: Princeton University Press

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