E-materials, E and B learning: a practical approach

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Abstract

After introducing different e-materials (files using CAS, selected web sites, Java applets, on-line calculators, Centres of Mathematics, etc.) we analyse some different possibilities for using these materials in an attempt to match the learning required by engineering students with the time devoted to mathematical issues.

Introduction

Taking into account the new reference framework of the European Area of Higher Education (EAHE) and the greatly increased availability of electronic learning materials, it is necessary, at least in Spain, to make a profound reappraisal of the form and mathematical content to be taught in engineering schools.

During the 1960s and 1970s, mathematics occupied a large part of the curriculum in engineering schools, since it was argued that mathematics developed the students' minds regardless of the specific material covered (which tended to be highly theoretical and in most cases divorced from the mathematical needs demanded by engineering studies). Instructors would give what their "personal inclinations" told them to and there was a trend towards teaching mathematical content that was disconnected from subjects with a more technological focus.

The current mathematics curriculum in engineering studies, which stems from the 1990s, underwent a brutal reduction in the time, in some cases up to 50%, devoted to the study of mathematical concepts. The initial reaction of instructors was either to continue giving the same content, but in less depth, or give a reduced content, in both cases using "traditional methods".

Inertia, a lack of motivation, the sparse recognition by Spanish universities of the teaching activities of its professors (because achieving promotion is based almost exclusively on research performance), together with students' attitudes (such as their unwillingness to give personal sacrifice, the scant interest they place in their studies and very poor studying habits) all work together to create a hostile environment for learning mathematical concepts, which requires tranquillity, understanding, and a mature outlook. This situation will become further exacerbated with the EAHE (Direction General For Education And Culture (2004), Garcia et al.(2006), Parlamento Europeo (2002)). The main milestones here are:

- A competency-based curriculum. It is then possible to plan and select the mathematical content for specific students: engineers, for example.
- A diversified curriculum (theoretical and practical teaching, supervised academic activities, independent individual work, and so on).
- Concern for the student's overall work load; as opposed to the current system in which the only measurement in certain European countries, such as Spain, is the number of lecture hours given in the classroom. This work should have a maximum annual volume estimated at 60 European credits (European Credit Transfer System, ECTS). An initial estimate suggests that one ECTS credit is equal to 25-30 hours of student work, including class attendance, laboratory work, workshops, individual and group tutorials, individual or group work and assessments.
- Prevalence of student learning over the lectures provided by teachers.
- A duration of study more adapted to reality.

The demands on the teaching staff, stemming from the European-wide policy of harmonising higher education studies, are basically as follows:

- Teachers should teach things that add value in the labour market (competencies).
- Teachers should adopt a different approach to teaching (methodological innovation).
- The basic criteria for the planning and development of teaching should be students and their needs (students as a reference point).
- All this involves a greater dedication by teachers to a student's learning process, which should include the teaching hours, planning, material preparation, suggested lines of work, guidance and supervision and, in general, overseeing the student's entire learning process.

This whole situation requires teachers to take special care when planning the following aspects:

- The competencies that students will acquire individually within the context of the full range of competencies that are taught in the subject in question.
- The academic scenarios in which the teacher wants the learning to take place, referring to specialized classrooms (computer rooms, laboratories, audiovisual rooms, etc.), libraries and other documentation centres, provided that the students can proceed independently within them. In addition, the proper use of e-learning can contribute to the actual learning process, taking into account:
    - The working process to be followed by the student for the acquisition of these competencies.
    - The system of tutoring-supervision that the teacher has adopted to control the acquisition of competencies on the part of students.
- The system for assessing the competencies acquired by the student on an independent basis, taking mainly into account: the assessment criteria, the assessment tools and the assessment dates.

The teacher will be required to provide students with material, give lectures, set supervised work or problems, arrange different kinds of tests, use the latest technologies to a greater or lesser extent, in order to generate the number of working hours corresponding to the credits assigned, which are furthermore to be controlled in an effective manner. However, concern over the overall work load of the student and optimisation of the time involves some dedication by the instructor to management and evaluation tasks, and the truth is that many of us fear that this will not be the case because such activity receives little academic recognition; although the tasks are more bureaucratic, they are equally necessary in teaching. In any case, despite the above remarked difficulties, it is necessary to consider the possibility of a profound methodological remodelling of the teaching of mathematics, using the whole technological arsenal now available to us.

The materials

When designing mathematical courses for engineering students it should be borne in mind that our students are users of mathematics and that they use them as underpinning to their specific technological studies. It is crucial that the materials given to them be of high quality so that we can take maximum advantage of the total time devoted by a student to his or her training in mathematics.

The materials provided to students start with text books adapted to their needs and that we have developed in collaboration with instructors from several Spanish Universities. These books contain a compendium of theoretical results that instructors can use appropriately in their theoretical classes. Students can check their level of understanding of the material by doing self-assessment tests with a true/false format. We later choose significant problems, sequenced in chronological order of the contents and level of difficulty, and offer a collection of proposed problems with the same level of difficulty as the worked examples.

The electronic materials (e-learning) are of very different types and can be classified as follows:

1. Files based on CAS (*Derive*, *Mathematica* and *Maple*) for use by students. Depending on the mathematical concepts analysed, these files use different CAS resources (graphic, symbolic or numerical). The authors have participated in the compilation of these materials, either as a complement to more conventional mathematical texts (Garcia et al. (2002), Garcia, Garcia, Lopez, Rodriguez & Villa (2006), Garcia et al. (2007)) or as other types of experiments (Alonso et al. (2001), Garcia et al. (2005), Roa & Villa (2007), Rodriguez & Villa (2005, 2007a)).
2. Materials developed under the umbrella of different European projects in which we are involved. The general philosophy of these projects consists of enhancing cooperative work with a view to optimising efforts in the generation of this type of resource. The projects in which the authors of this communication have been

involved can be found in (Calculus Course (2007), SEFI MWG (2006), EVLM (2008), EVLM-Slovakia (2007), Rodriguez & Villa (2007b)).

3. Materials freely accessible on-line, enhancing their correct use by our students This selection of Internet resources contains Java applets, e- books, exercises and self-evaluation tests, mathematical curiosities, etc.
4. All this material is given to students using B-learning (blended learning) techniques, since it should not be overlooked that we are working with students in a face-to-face teaching situation at the University. In our case, the *Moodle* platform serves as a vehicle to offer our students efficient guidelines that will allow them to take maximum advantage of the resources selected and enhance their participation and involvement in academic tasks.

The use of these materials will be governed by the credits assigned to the corresponding topics, the availability of mathematical laboratories, and the possibility of having tutors able to respond to students' doubts. In any case, it is necessary to mix conventional teaching through lectures with the use of the different materials selected and active supervision by teachers in the student learning process.

Some experiences

Under the auspices of this philosophy we have carried out certain experiments:

1. **A course on calculus at the Engineering School at the Pontificia Comillas University.**
   In this course, the basic material consists of a textbook (Garcia, Garcia, Lopez, Rodriguez & Villa (2007)) in which the authors of this communication have collaborated. The book is accompanied by a CD with the answers to the proposed (and unsolved) problems, most of them made using *Derive*, and tutorials on the concepts analysed in the book. The students are provided with guidelines to the issues addressed in the course, with information about the contents of topics, the problems to be dealt with in practical classes and those forming the personal task of each student. They also receive information about complementary tasks (normally consisting of doing tests and problems selected from the chapters of the textbook), and visiting certain web sites that may reinforce their learning. Students are recommended to use *Derive* and are expected to attempt self-study tutorials, which we anticipate will be easy for them to follow. After the tutorials, it is suggested that they do some exercises with *Derive* and that they use CAS as a check of exercises performed "with pen and pencil". All this information has been organised through the course web site for which an access code is required.

2. **A course using the *Moodle* platform at the Polytechnic University of Madrid.**
   At the School of Industrial Engineering of this University, the *Moodle* content manager is used in the course on calculus in one variable. This has been a pilot experiment since in the design of the course the number of hours for classes and practical work has been reduced to increase those devoted to a CAS (which has also been *Derive*). A textbook has been selected (Garcia, Garcia, Lopez, Rodriguez &

Villa (2007)), and on the basis of this guidelines to the topics addressed in the course (a standard course on calculus in one variable) have been generated. The *Moodle* platform has been used to organise the course and to facilitate the handing-in of work, self-assessment, etc. A detailed overview of the course can be found in Alvarez, Asensio, Garcia-Miguel, Velasco & Villa (2007a,b) and the course's web site is at (Calculus Course (2007)).

3. **A course on ordinary differential equations (ODEs) with a CAS.**
   It is clear that concepts concerning ODEs are the paradigm of "applied mathematics". In all stages of engineering studies phenomena are emerging where it is necessary to study the "variation" of some variable against another variable. For instance, population models, radioactive decay, heat transmission, RLC circuits and mass-spring mechanisms, are examples of technical situations modeled by ODEs. Thus, we must analyze from the theoretical and practical points of view different concepts associated with ODEs. The use of the abilities of a CAS, in our case *Mathematica* and *Maple*, allows a new focus on the teaching of differential equations; mainly by avoiding heavy calculations and paying more attention to the concepts. Taking into account that Computer Algebra Systems (CAS) allow one to obtain the solution of ODEs, in exact form quicker than with "paper and pencil" it is possible to design an ODE course paying especial attention to concepts, structures and some aspects of solutions. CAS can be used to introduce or enhance theoretical aspects related to ODEs and as a calculator for solving ODEs (Rodriguez & Villa (2007a)). We can then focus our attention on analyzing the solutions and the main characteristics: bounds, stability, etc. CASs can also be used to experiment with and simulate different situations involving technical problems, such as RLC circuits and mass-spring mechanisms. The most important numerical methods for solving ODEs (Euler, Runge-Kutta, Adams-Bashforth, etc) can be programmed in the corresponding CAS, or otherwise special libraries can be used. The main goals of the course are: To learn the basic terminology, to use a few exact methods to solve specific ODEs (mainly linear ODEs because the structure of the solutions is very important in the analysis of certain technical phenomena), to interpret as much information as possible directly from the ODE (direction field, qualitative analysis, isocline lines, asymptotic behavior, etc.) and to be able to implement numerical methods and to interpret the results obtained. The use of the different capabilities of CASs allows this alternative. Some examples can be found in the CD in Garcia, Garcia, Lopez, Rodriguez & Villa (2006).

4. **The creation of the Centre of Mathematics at the University of Salamanca.**
   Taking advantage of the experience of other countries such as that reported from the United Kingdom http://www.mathcentre.ac.uk/ with this Centre of Mathematics we offer a face-to-face and on-line tutorial service to which students can turn to resolve all their doubts relating to their training in mathematics. The centre organises what are known as zero-course introduction to university teaching and other activities in the field of basic training.

Conclusions

The strategy for the use of e-materials should be to improve their benefits and to diminish their pernicious effects. According to the European Area of Higher Education (EAHE) our task will be to optimize the time required by our students in learning to use mathematical tools. Regarding CAS, we promote their use only to those students who are able to solve the problem, posed in an academic way, using "paper and pencil". We have produced tutorials for many topics: Linear Algebra, Calculus in one and several variables, and ordinary differential equations. In each topic we begin the tutorial by explaining, if necessary, the commands to be used. Then, the first exercises are solved "step by step" after which, on some occasions, we write a procedure to make the use of the CAS automatic. We have selected interesting web sites where it is possible to find Java applets, theoretical and practical concepts, exercises to be solved by students with immediate checking, etc. We are currently trying to introduce "Centres of Mathematics" where students can find tutorials on-line and immediately consult the instructors as to any doubts arising from the use of such tutorials.

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