New challenges in the Degree in Mathematics: applications at work

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Abstract

The new “Degree in Mathematics” of the University of Murcia implements in 2011/12 its third year, which includes the compulsory subject “Modeling laboratory”. Its syllabus says “the main aim is that the student be able to afford a problem from other sciences, model it using mathematical techniques, give a solution (even an approximate one) and check and interpret the obtained solution.” For that, “a set of projects will be offered to the students, to work on individually and in groups”. In this paper we show the decisions made by the teachers to put the subject at work, as well as the first results obtained. In particular, we describe the topics considered in the subject (which include discrete models of numerical analysis, differential equations models, (linear, integer and nonlinear) optimization problems, heuristic optimization, multiobjective optimization, routing problems, location problems, game theory problems and project management), the way they are explained, and the activities that the students have to do (both individually and in small groups) to pass.

Keywords: Autonomous learning, real cases study, work in groups;

1. Introduction

During 2011/12 the third course of the new “Degree in Mathematics” has been implemented at the Faculty of Mathematics of the University of Murcia (Spain). “Modeling laboratory” is a compulsory subject, with 6 ECTS. ECTS stands for European Credit Transfer and accumulation System; in the Degree of Mathematics one ECTS is equivalent to 25 hours of work of the student, including not only the attendance to classes, but also work at home, exams, exercises… “Modeling laboratory” is taught in the second semester and unlike the rest of the subjects (all of them with 40% of attendance, i.e., 1 ECTS implies 10 hours in the classroom) it has a 60% of required attendance (15 hours in the classroom per ECTS). According to its syllabus “the main aim is that the student be able to afford a problem from other sciences, model it using mathematical techniques, give a solution (even an approximate one) and check and interpret the obtained solution. Although there will be some theoretical classes, most of the teaching hours will be applied, and may make use of the computer. Using several examples of real applications, developed by the teacher, a set of projects will be offered to the students, to work on individually and in groups”. The models are grouped according to the mathematical techniques required to solve them: discrete time systems, continuous time systems, optimization models, stochastic models, etc. The applied nature of the subject, where the importance is to

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model real problems and not to introduce new topics, makes it advisable to work using “projects” to be carried out by the students either individually or in small groups under the supervision of the teachers. That is why the attendance requirements are higher for this subject as compared to the rest of the subjects of the degree. A special planning has been needed for the implementation of the subject, not only to decide what to explain, but especially how to do it, taking into account the applied nature of the subject. The assessment process has also been a topic of debate. Next we describe the planning and the assessment system, which may, at least in the part related to the development of projects, be used in other subjects of similar characteristics.

2. About the contents

Everybody knows that there is a wide range of problems that can be handled with the very different mathematical tools from analysis, geometry, algebra, statistics or operations research. So as to select the type of problems to be considered in the subject, when the subject was proposed to be included in the new Degree in Mathematics, it was decided that the problems should be as close to reality as possible and very common in daily life. Still, many problems satisfy those requirements. The use of the computer was an additional constraint to select the problems. The last point to be taken into account was the experience and know-how of the teachers that each year will have to teach it.

This course (and probably also during the next two courses) the problems selected are related to numerical analysis, statistics and operations research. In particular, they deal with:

- Discrete systems: population models (exponential, logistic, Fibonacci, …), closed solutions systems (curve fitting, Ptolomeus model).
- Continuous systems: Montecarlo method applied to the computation of areas, random walks, fractal growth, collective movement of animals…; cellular automata (the game of life…), systems based on ODE (population models, the problem of $n$ bodies…).
- Optimization: linear programming, integer linear programming, nonlinear programming, mutiobjective programming, and the use of metaheuristics to cope with difficult problems (genetic algorithms, simulated annealing and tabu search).
- Project management: CPM and PERT.
- Other models: routing problems, location problems, game theory problems…

For the discrete and continuous systems, the software “Easy Java Simulations (EJS)” has been used (see Esquembre, 2004 and http://fcm.um.es/Ejs/), for the optimization topics AMPL (see Fourer, 2003 and http://www.ampl.com) and XPRESS (http://www.fico.com), and for project management, MS Project (see Biafore, 2010 and http://www.microsoft.com/project).

Nevertheless, the particular selected models are not the key part of the subject (they may vary from year to year), but the way in which they are explained. No new mathematical tools are explained during the course: just how a given problem can be modeled, which the mathematical technique required to cope with it is, and which software should be used to solve the problem in a fast and efficient way.

As mentioned above, every topic will be explained by the teacher through a particular problem, which will be solved from the beginning (modeling it) until the end (solving it with the computer). Then, the students will have to solve on their own other problems.

3. About the portfolio of projects

Looking for a balance between the number of projects (both individual and in groups) and the workload required by the students to develop them, and taking also into account the workload of teachers (not to correct them, but to find suitable problems), it was decided that every student would have to prepare 4 individual projects and 3 group projects.
The individual projects require less time to be done, can be written in Spanish and need not to be presented in the classroom.

On the contrary, group projects are a bit more complex, demand more time, must be presented in the classroom and a written report has to be previously presented. Furthermore, in order to obtain the maximum mark (10 points), the report must be written in English. When written in Spanish, the maximum mark can be 9 points. If the project is presented in the classroom in English, then the student doing the presentation may get an extra point. Both initiatives try to foster the use of English, still a matter of concern for some students in Spain.

4. About the groups and the presentations

The groups are composed of 3 or 4 students. Every group is assigned 4 projects, and the students have to select 3 of those 4 projects to do. The day of the presentation of a project in the classroom (announced in advance to the students), the teachers decide who is (are) the student(s) who has (have) to do the presentation. Furthermore, the teachers (and also the students) may ask questions about the project to any of the members of the group (not only to the one who presented the project). In this way, it is guaranteed that all the members of the group have actively participated in the development of the project.

The students have 15 minutes to do their presentations, followed by 5 minutes for questions. If the project is written in English, then some of the questions may be in English, too. It is up to the students to decide how to do their presentations, but they all use a projector and a laptop to show slides and, in some cases, the developed computer programs.

The students are in charge of presenting to the teachers during the third week of the course a proposal with students forming each group. If necessary, the students without a group are assigned to a group by the teachers. Every student says via e-mail to the teachers whether he/she accepts the group to which he/she belongs to. The teachers, after receiving all the e-mails, may redistribute the groups if necessary.

Furthermore, in the middle of the course, before assigning the last two group projects, every student says to the teachers, again via e-mail, whether he/she is willing to continue in the same group. The teachers, after receiving all the e-mails, may redistribute the groups if necessary.

5. About the assessment

Those students unable neither to attend the course in person nor to do the assigned projects, will have to do a final exam, where they will have 3 hours to solve 2 of the 4 real problems proposed.

For those who have attended and done their portfolio of projects, the assessment is as follows: individual projects sum 50% of the final mark, group projects 33% and the presentation of the project 17%.

6. Results and conclusions

At the time of writing this paper, the course is still not finished. So no final results can be offered yet. However, we can already infer some conclusions:

- The students really appreciate this subject. To see what they have been learning in other subjects at work is very interesting for them. Going from the theoretical to the applied maths is a good experience for them.

- The students are not used to this type of subjects, nor to work on real applications. So, even the simplest examples are, at least at the beginning, difficult for them, and they usually need more time than expected to cope with them. This fact should be reconsidered for the following years, i.e., to reduce the number of projects in their portfolio, or to propose more specific problems.

- The students prefer to answer many concrete questions than a single general question. They do not feel confident when they have the freedom to develop a general question, because they are afraid of not explaining what the teachers are supposed to expect from them. With concrete (and usually shorter)
questions they know exactly what they are supposed to answer. This is probably a problem related to the Degree in Mathematics: in all the subjects, be it in the exams or in the exercises they have to give to the teachers, students are always asked to answer very concrete questions. For instance, the first group project assigned to the students was the same for all the groups, and it was just “random walks”, with no further indications about what to do. This provoked so many doubts about what they were (and were not) supposed to do, that an outline had to be given to them with the main points to be considered.

References