EXPERIENCES WITH COOPERATIVE AND COMPETITIVE LEARNING IN ENGINEERING COURSES

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Abstract

In this paper we present some experiences involving cooperative and competitive learning techniques in three courses included in Engineering Degrees at Miguel Hernandez University (Elche, Spain). The main motivation for this initiative is the fact that "traditional" teaching methods present two main problems: first, it is difficult to motivate students and second, they do not allow the development of some of the abilities required nowadays, especially in Engineering courses. In our opinion, the results obtained have been excellent. We have observed that many students have participated in the cooperative activities and that they have obtained better grades and have acquired more knowledge and practical abilities using these methods.

Keywords - Cooperative learning, team work, competitive learning.

1 INTRODUCTION

In the last few years we have found that traditional teaching methods present two main disadvantages: Firstly, they do not motivate students sufficiently enough, and secondly they do not allow students to develop some skills needed nowadays.

Regarding the first disadvantage, lack of motivation, it is a problem which has reached university teaching and every kind of degrees (including technical degrees), so it is necessary to change the methodologies we use in the classroom in some way. We think that if we continue using only "traditional" teaching methods then the percentage of students who do not pay attention during lectures and are not interested in the courses will increase in the future. Concerning the second problem, the need of new skills, one of the most demanding competences by employers is team work abilities. Therefore, the introduction of techniques which boost this competence would be a good idea.

One of the strategies which offers the best results to solve both problems is the so called *cooperative learning*. This method is particularly appropriate for today's university students who belong to the generation known as "Y generation" or "generation of the millennium" and it is based on the belief that students learn better when they learn together. One of the characteristics of these students is their fidelity towards their fellow classmates and, as a consequence, this leads to an increase in their motivation for studying if their classmates' grades depend on their own effort [1]. This makes cooperative learning especially appropriate for this kind of students.

In this paper we describe experiences using cooperative learning in Engineering Degrees. There are a number of examples in the literature describing the use of this learning strategy: For example, in [2] the authors apply a cooperative method based on problem-solving techniques for an Industrial Automation course; in [3] the same methodology is presented, applied to a Chemical Engineering course; and in [4] the method is used as a complement for a Marketing course for Engineers. In this paper we present our personal experiences in the application of these techniques in two core curriculum courses in the Industrial Engineering Degree at Miguel Hernández University of Elche: Electronic and Automatic Systems (fourth year) and Circuits and Systems Theory (second year) and in one elective course in the same degree: Advanced Control Systems (fourth year).

The course "Electronic and Automatic Systems" is a core course and it is divided into two semesters (it is not adapted to the European Higher Education Area, EHEA). It has 6 theory credits and 4.5 laboratory credits. It is divided into three different thematic modules: (1) Instrumentation; (2) State Space Control and (3) Microcontrollers Programming. Modules (1) and (2) are taught in the first semester and module (3) in the second semester [5].

The course “Circuits and Systems Theory” is a core course, divided into two semesters and with 6 theory credits and 4.5 laboratory credits. It is divided into two different thematic modules: Circuits Theory (first semester) and Systems Theory (second semester) [6].

The course “Advanced Control Systems” is an elective course which is usually chosen by students who want to major in Industrial Automation. It has 9 theory credits and 3 laboratory credits. As it is elective, this course has usually a fewer number of enrolled students than the other two courses considered in the paper (from 40 to 60 students) and many of these students are expected to be highly motivated in the subject. However, the course has a high theoretical load and students could find sometimes the course too hard to follow, although the concepts studied have many practical industrial applications. For these reasons, we have applied cooperative techniques in this course to maintain and increase motivation.

As the academic year 2008-2009 was the first time we used this methodology, we decided to include cooperative learning *as a complement* to traditional, only lecture-based, learning. We did so in order to have a progressive transition. As a particularity with respect to other experiences, we have combined cooperative learning with *competitive learning*, in order to improve even more the motivation of our students.

2 COOPERATIVE AND COMPETITIVE LEARNING

Cooperative learning is the instructional use of small groups so that students work together in order to maximize their own and each other’s learning [1]. This process is performed using a strategy which promotes mutual collaboration, obtaining a more harmonious and comfortable atmosphere to achieve the learning objective. Basically, it is based on the interaction between several students (forming groups ranging from 4 to 6 students) who cooperate in the learning process of a specific subject. This learning process is supervised and directed by the teacher.

This methodology deals with a concept of learning which is non-competitive and non-individualist as it is the traditional method. It promotes a collaborative mechanism which aims to develop team work habits or competences, solidarity between classmates and encourage students to take part autonomously in their own learning process.

On the contrary, using *competitive learning* each student works “against” the others in order to achieve specific academic objectives. Within competitive situations, individuals seek outcomes that are beneficial to themselves and detrimental to others. The student effort is on performing faster and better than classmates. Students realize that "they can obtain their goals if and only if the other students in the class fail to obtain their goals." [10]

We have tried to combine both techniques (apparently incompatible or contradictory) in the classroom in order to improve the teaching quality, motivate the students and develop additional competences in addition to, of course, covering the subject contents.

With the use of the cooperative methodology we want to encourage team-work habits and by using competitive methods between the different cooperative work teams we expect to improve the quality of the assignments and tasks the students have to carry out during the course.

3 PREVIOUS EXPERIENCES USING INDIVIDUAL COMPETITIVE LEARNING

Prior to the introduction of cooperative learning techniques, during the academic year 2007-2008 we introduced an individual competitive activity in the course “Electronic and Automatic Systems”. This activity had satisfactory results but, as it was an elective and unknown new activity, it did not attract a high percentage of students.

The competitive methodology consisted, basically, on proposing a programming problem and to asses it positively only for the five better solutions, giving a short deadline (seven days). These problems consisted on programming a piece of code and the best solution was considered to be the one which performed the proposed task in the minimum number of code lines. In this way, the evaluation system was totally impartial and objective. The five students whose programs were the more compacted ones were given 0.25 additional grading points (out of 10). Generally speaking, this method encouraged the interest of a group of students who always took part in doing the assignments (a total of 6 assignments were proposed). This group of students obtained a grade in the range [8,10] in a scale from 0 to 10 in the final exam.

The problem we found using this strategy was that only a small group of students (the most brilliant ones) took part in the activity. We decided to use cooperative learning in the following academic year and this problem disappeared. The rest of the paper describes our experience in subsequent years in the three course mentioned above. The modules in which we applied the methodology are the following:

- Instrumentation module (“Electronic and Automatic Systems” course).
- Microcontrollers module (“Electronic and Automatic Systems” course).
- Systems module (“Circuits and Systems Theory” course).
- Intelligent Control and Adaptive Control modules (“Advanced Control Systems” course).

4 EXPERIENCES WITH COOPERATIVE LEARNING IN THE “INSTRUMENTATION” MODULE

This section describes our experience teaching the Instrumentation module which was given in October and November 2008. The students who took part in this experience were evaluated based on the following assignments or exams:

- *Formal group work*: made up of four tasks which consisted on questions, problems and a compilation of information about sensors.
- *Oral presentations* in the classroom about a section of the formal group work.
- *Final exam (test)*: it was made in November and the final mark was calculated as the mean between the individual mark and the evaluation obtained by the members of the formal group.

For the students who chose the traditional methodology (individual evaluation) the final mark was calculated using only the mark obtained in the final exam.

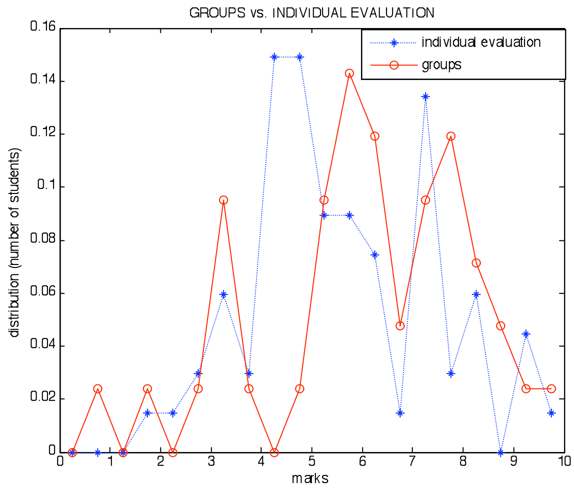

Fig.1: Evaluation results in “Instrumentation” module

The groups were formed by the teacher in the following way: the students chose their own group mates up to a maximum of two or three per group (therefore, in most cases these groups were formed by students who had some affinity) and later the teacher combined two groups to obtain another group of 4 to 5 students, where not necessarily all members had an “affinity”. In this way, these formal groups are called *heterogeneous groups.* Using this method a total of 10 heterogeneous groups were formed and all the involved students performed the programmed tasks and assignments and all of them did the final exam.

The results obtained in our teaching experience have been satisfactory as it is shown comparing the marks obtained in the final exam by the students who worked in a group with those of the students who chose to work individually. The mean marks in the first case was 6.23 and in the second case 5.78. Fig. 1 shows the distribution of marks obtained by the students using both methodologies.

This graphic shows that the distribution of the marks obtained by students who chose the cooperative method is displaced to the right and the percentage of students who passed the exam is higher (79% versus 69%). These data indicate that the experience has been very positive.

5 EXPERIENCES WITH COOPERATIVE LEARNING IN THE "MICROCONTROLLERS" MODULE

5.1 Partial theory and laboratory exams with cooperative evaluation

We used a kind of continuous assessment and, at the same time, we tried to encourage the students to be involved in cooperative work. For this purpose, in this thematic module we planned to do three theory exams and two laboratory exams. The groups were formed by the students (each student chose the group he or she wanted to belong to, up to a maximum of 4 to 6 students), so the groups were *homogeneous* in the sense that the students in each group had an affinity (they chose voluntarily to work together). Using this method we formed a total of 13 formal groups, involving 63 students.

Two of the three theory exams were partial exams. The first partial exam was done after the spring break (on 22th of April) and the second at the end of the course (on 3th of June). The third exam was thought as a final exam involving all the content of the thematic module (on 10th of June)).

Each partial exam covers a small part of the module. In this way we achieved the objective of performing a continuous assessment of the student progress. Furthermore, the exams consisted on multiple choice questions, so that they would not take too long and they could be done in the usual class schedule. In this way, we did not disturb the schedule of other courses and it was easier and quicker for the teachers to correct the exams.

Fig. 2 shows the distribution of marks obtained by the students in the two partial theory exams. Fig 3 shows the distribution of the marks obtained in the laboratory exams.

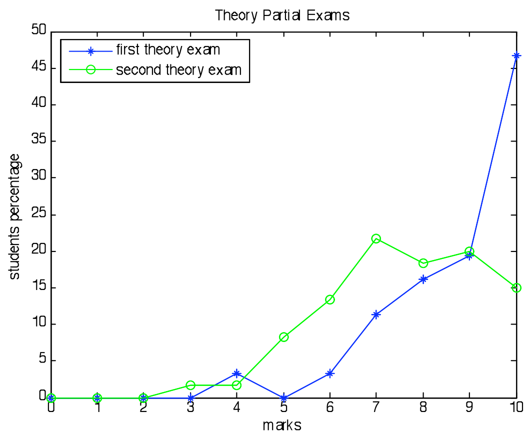

Fig.2: Partial theory exams

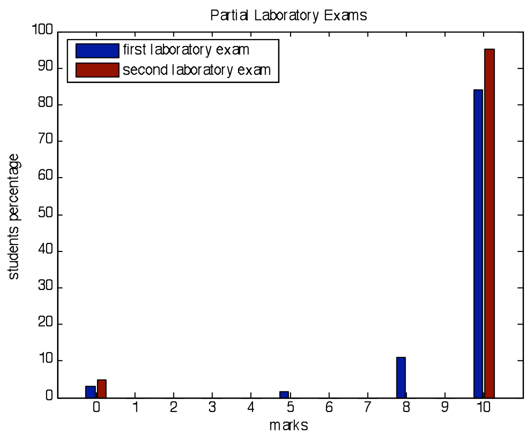

Fig.3: Partial laboratory exams

But the correct way of validating our methodology is comparing the marks of the students working in groups against the individuals. The final exam was performed by all students and so the marks obtained in that exam give us useful information. Fig. 4 shows the distribution of marks obtained by the students using both methodologies. The mean mark in the first case (cooperative groups) was 7.59 and in the second case 6.84, so, again, the results of our teaching experience have been satisfactory.

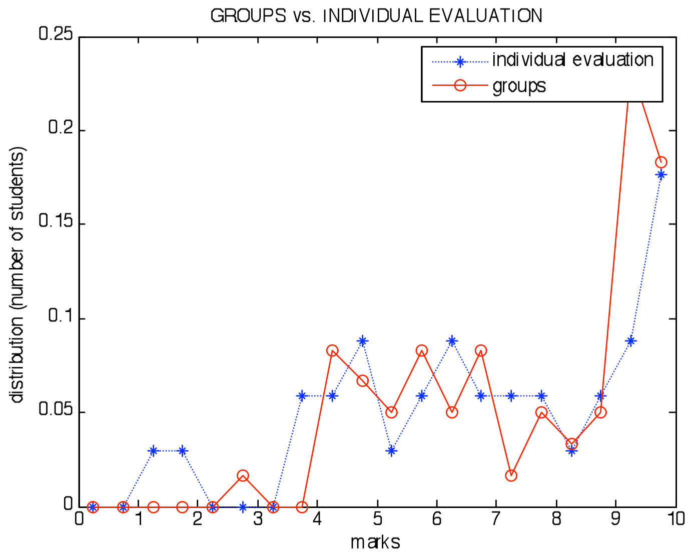

Fig.4: Evaluation results in “Microcontrollers” module

Regarding the cooperative work evaluation, we used a scheme in which the final mark of each student depends not only on the work performed by the student, but also on the results obtained by their group mates. In this way, the groups had to work and prepare their works *in collaboration* because their final marks depended (at least partially) on the work done by each of the other group members. Fig. 5 shows an example of the procedure used to obtain the marks for a hypothetical group of students, as explained below.

	Theory marks					Laboratory marks				FINAL mark		
	22-abr	03-jun	10-jun	average	theory mark	23-abr	04-jun	average	laboratory mark	theory + laboratory	optional exercises	
	e1	e2	e3	0.25e1+0.25e2+0.50e3	t	ep1	ep2	0.50ep1+0.50ep2	p	0.8t+0.2p		FINAL
Pepe	8	10	5	7	6,66	5	10	7,5	7,44	6,81	0,75	7,56
Paco	8	6	7	7	6,66	10	5	7,5	7,44	6,81	0,75	7,56
Juan	3	4	5	4,25	5,28	5	8	6,5	6,94	5,61	0,75	6,36
Lola	8	6	7	7	6,66	8	8	8	7,69	6,86	0,75	7,61

group average 6,3125

group average 7,375

FINAL MARK

80% (theory)

20% (laboratory)

Fig.5: Procedure to obtain the final mark of a cooperative group.

Each student has an individual mark corresponding to the theory exams. This individual mark is obtained as follows:

$$Theory\ \ mark = 0.25 \cdot e_1 + 0.25 \cdot e_2 + 0.50 \cdot e_3$$

where e_1 and e_2 are the marks obtained in the partial exams and e_3 is the mark of the final exam.

Additionally, each student has also a laboratory mark:

$$Laboratory\ \ mark = 0.50 \cdot ep_1 + 0.50 \cdot ep_2$$

Where ep_1 and ep_1 are the marks obtained in the laboratory exams.

These theory and laboratory individual marks are averaged with the mean mark of the group obtained in each part (theory and laboratory) and are then combined to obtain the final mark of the student in the Microcontrollers module (20% laboratory and 80% theory).

It is evident that this methodology favors students with worst marks because when we calculate the average of each student mark with the global mark of the group, students with higher marks obtain a worse mark than their individual one, and the contrary effect occurs with students who have worse marks.

However, this methodology pretends to instill group work competences and increase the motivation of the students for the subject they are studying, because their individual performance can affect the final performance of the whole group. This fact has as a consequence that the students can feel more integrated and they tend, in our experience, not to drop out of the course before it finishes.

In combination with the methodology described above, we proposed some additional assignments (optional) in order to improve students' final marks. The assessments of these optional assignments are shown in the second column from the right in Fig. 5 (*optional exercises*).

Basically, we have proposed additional exercises or works to do within the established formal groups (four assignments in one semester) so that the groups can compete "against" each other. In each case, the task consisted on implementing a program for the microcontroller used in the laboratory sessions.

Each additional assignment had a maximum mark of 0.25. Only the four best programs obtained an additional mark (the programs were evaluated according to their size: the fewer number of code lines, the better). In this way, the formal groups had to make an effort to implement a program which not only did the assigned task but also did it in the most efficient way.

This competence between groups encourage students to make a special effort to improve the quality of their work and tends to avoid plagiarism due to the fact that only the best works obtain an additional mark. So, the students do not succumb to the temptation of copying from another more advanced group because this would not give them any benefit.

In summary, the learning experience in the "Microcontrollers" module has been very satisfactory. The involved teachers have noticed a considerable increase in the motivation and effort made by the students and this, moreover, has been reflected in their final marks.

6 EXPERIENCES WITH COOPERATIVE LEARNING IN THE "SYSTEMS" MODULE

6.1 Cooperative and competitive works

In this module we opted to do an elective cooperative/competitive task. This activity allows the students to increase their mark corresponding to this module up to a maximum of 1 point (out of 10 points).

The activity consisted on the resolution by the cooperative groups of problems proposed in past exams and selected by the teacher. Additionally to the solution of the problem, the students had to confirm the results by simulation using Matlab/Simulink and they had to present in class the resolution of the problems and the simulations. The presentations were made by a member of the group who was chosen randomly from the members of the group (just before the presentation).

This activity achieved different objectives:

- Development of team-work competences.
- Learning of simulation tools (Matlab/Simulink) which were used in the laboratory sessions. In order to simulate some of the problems, the students needed to use some elements not studied in the laboratory sessions, so they had to do a small work of research and documentation about these elements.
- Good preparation for the final exam, because the activity was performed during the last weeks of the semester.

We decided to form big groups which enabled us to do all the presentations in just one theory session. We had a good participation rate (7 groups, with a total of 45 students). Fig. 6 shows the distribution of the marks obtained. It is worth pointing out that the obtained marks were rather high for two reasons: (1) All works presented were brilliant; and (2) it was the first time we used this methodology and we wanted to encourage participation in future academic years.

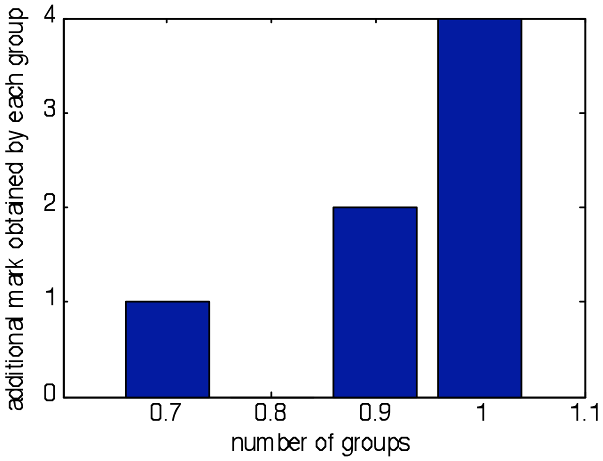

Fig.6: Results obtained in the elective activity ("Systems" module).

6.2 Activities for future years

In future academic years we plan to incorporate another kind of activities, additionally to the activity shown in the previous section. One of these activities consists on doing short exams previously to the laboratory sessions. The objective is to force students to read carefully the laboratory assignment plans *before* the laboratory sessions. In the current situation, most students go to the laboratory not having read the assignment they have to do and, for that reason, the performance of the students during the laboratory sessions is lower than expected.

So, to achieve this objective we considered doing a very short exam before each one of the labs sessions including a list of very simple questions about the laboratory assignment. As a requisite to pass this exam, the students are expected to have read the corresponding laboratory documentation and planning. There are two requirements for this exam:

- We should try to decrease the possibility of copying between the students during the exam (they are usually sitting very closely in the laboratory).
- The duration of the exam should be very short (5 minutes approximately), in order to avoid losing too much time in the laboratory sessions.

The proposed solution consists on performing a multiple choice exam (with 4 possible alternative answers) using the computers available in the laboratory. Each exam has a variable number of questions between 5 and 10 and, in order to answer each question, the students have between ½ min. and 1 minute. The questions reach each computer in a different order which, combined with the fact that the time available is very short, prevent students from copying.

Other activity we plan to implement is to propose additional works in cooperative and competitive groups, with the objective of trying that the students became more motivated in studying the subject. The subject "Systems Theory" is a rather theoretical one and it is difficult to motivate students with this kind of subjects. To overcome this difficulty we propose as an elective activity the development of a web page where the students could explain an application of *Automatic Control* using the concepts studied in the course. To do this we plan to form groups of 4 to 6 students and the topics each web page should include are the following:

- Description of the application.
- Area in which it is going to be applied.
- Theoretical contents studied during the courses which are used in the application.

The web pages will be evaluated by the teacher and, additionally, they will have to be presented to the rest of the students by a member of the group who will be chosen randomly (in order to check the cooperation between the group members). The selected web pages will be made accessible to all students through the official web page of the course and students will be requested to vote for the best web pages (this constitutes the competitive part). The evaluation from the teacher and the result of the voting will be used as a complement to the final mark of the student.

7 EXPERIENCES IN THE “ADVANCED CONTROL SYSTEMS” COURSE

The two courses described in the previous sections are non-elective in the Industrial Engineering Degree. A step forward in the application of cooperative and competitive learning is its extension to elective courses. In particular we are applying it to the course “Advanced Control Systems”, elective course in the fourth year in our University for majoring in “Industrial Control and Automation” [9].

Most students enrolled in this course have followed the previous year a core course about classical methods for the analysis and design of control systems, external representation. There are also a number of students (about 30% in the academic year 2009-2010) who are graduate students from technical university studies (three-years degrees). Some of these students have experience working as engineers, which could provide very useful contributions to the groups in cooperative learning.

In this course some advanced control techniques used in the industry are studied. As said before, the students have previous knowledge about classical controllers (continuous and discrete PIDs, temporal and frequency domain design techniques, direct design of discrete controllers) and they are also studying simultaneously a non-elective course in which they are introduced to state space control.

With these previous concepts in mind, the contents of this advanced course are divided into four modules: (1) Predictive and Minimum Variance Control; (2) Intelligent Control; (3) Adaptive Control; and (4) Optimal Control. During the academic year 2009-2010 we are trying to introduce cooperative learning techniques in modules (2) and (3), because we consider this kind of controllers to be the most appropriate for the methodology.

The number of students enrolled is about 60. With this number of students, 10 groups of 6 students have been formed. In the formation of the groups we have tried to fulfil the following:

- There should be at least one graduate student in each group (from 3-years technical degrees).
- Distribute equally the students who have work experience in Engineering or are combining their studies with a job in Engineering.
- If we know the marks obtained by the students in the previous course on control systems, we tried to distribute them in such a way that the students with good marks are in different groups.

By using these criteria in forming the groups we expect them to be as heterogeneous as possible. We think that in this course heterogeneous groups could lead to a more effective learning process.

For each group, two tasks have been proposed. One task corresponds to the module “Intelligent Control” and the other one to the module “Adaptive Control”. The tasks consist basically on the design of a controller (a fuzzy controller for the first task and an adaptive controller for the second task). By the end of the semester two laboratory sessions will be reserved in which each group will show the performance of their controller.

Each controller is evaluated by the teacher based on their overall performance and the fulfilment of the design requirements. The controllers are ordered according to their evaluation and this ordered list will determine the increment in the final mark for the students in each group. The evaluation of the controllers is made in an automatic way, simulating it with an arbitrary system and measuring their performance in real time. In this way, the cooperative evaluation of the work is public and objective.

7.1 Intelligent Control module

In this module we are applying cooperative and competitive learning to the design of fuzzy controllers. We believe that the characteristics of these controllers are ideal for the application of the methodologies because, in general, there are many possible and very different solutions to the same problem. This makes it a suitable way to encourage discussions of different alternatives between members of the groups.

The proposed task is the design and analysis of a fuzzy controller for an inverted pendulum. In the lab sessions, the teacher explains the model and characteristics of the system to be controlled and some very basic design guidelines are shown. Then, after some time of discussion, the teacher gives the design of a basic fuzzy controller which works well for some basic configurations of the system (for example, when the inverted pendulum is almost at its desired vertical position). Then, the groups analyze this basic controller and find the system configurations in which the controller does not work properly (usually when the pendulum is far away from the vertical position, or when it is moving very quickly).

During the laboratory sessions the groups discuss possible solutions and improvements to the controller and share their findings in turn with the entire class. All this process takes two hours in the laboratory and it ends with some common improvements to the basic controller proposed by the teacher. Then, the groups have to present their final controllers four weeks later.

The initial controller proposed by the teacher has the following characteristics:

- Two inputs and one output.
- Five fuzzy sets for each variable (inputs and outputs).
- 5x5=25 control rules.

The students modify this controller in many different ways:

- They usually include more rules to deal with special situations.
- They try adding more fuzzy sets in order to improve the precision of the controller. Although this has the effect of improving the controllability, it also makes the controller slower, which is penalised in the evaluation.
- Modifying the initial rules to deal with situations in which the controller becomes unstable.

Each group present the controller to the teacher in a specific format. In a laboratory session the teacher simulates each controller using Matlab/Simulink with different initial configurations of the pendulum, and the performance is evaluated according to the following points:

- Settling time.
- Overshoot.
- Robustness (response to perturbations).
- Efficiency.

Using these parameters and considering 10 groups, the controllers are classified and the best controller obtains 1 additional point to the final mark, the second 0.9 additional points and the 10^{th} controller obtains 0.1 additional points.

Fig. 7 shows the final marks obtained in this module after using this method compared with the marks obtained in previous years. Pass marks are A, B and C, with A the best mark. As it can be seen in the figure, better results have been obtained using cooperative/competitive learning. We have found that by using this method the students are more actively involved in their laboratory assignments than in previous years. This is due to the fact that they have to “compete” to obtain a better result and, at the same time, they have the support of their team mates to overcome the difficulties.

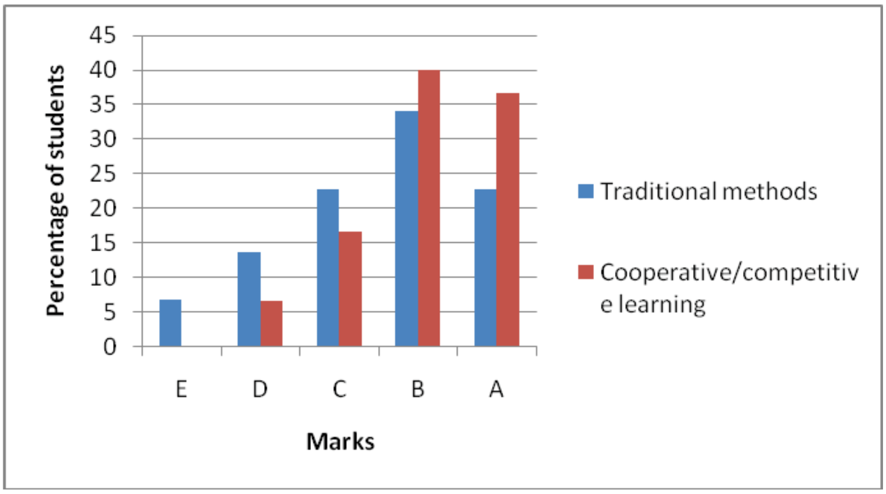

Fig. 7: Comparison of the results obtained using traditional and competitive/cooperative methods

7.2 Adaptive Control module

In this case the design method has also many possibilities. The task proposed to the groups is the design and analysis of an adaptive controller for a first-order model in which some of the parameters are unknown or variable. This first-order model corresponds to a DC motor available in the laboratory.

The students have freedom to choose the design method. The alternatives available are the following:

- Using the MIT rule or gradient method.
- Using the Lyapunov stability theory.
- Self Tuning Regulators (STR) based on on-line identification.

In the first two cases the students have to compute an additional parameter known as the adaptive gain (γ). The performance of the controller depends on the computations performed to obtain it and on the parameter γ. The first method (MIT rule) has the advantage of being very simple, but the disadvantage of leading to systems which could become unstable for certain values of γ, so the students have to deal with this problem. The second method (based on Lyapunov stability theory) has the disadvantage of the complexity of its computations, but it obtains systems which are stable for any γ. The third method is an intermediate solution in which the students have to design an identifier previously to the controller.

So, the students have to choose between a simple, quick and efficient solution taking the risk of instability, a much more complex solution which is more robust, or an intermediate solution which requires more design time. These decisions are the same they would have to make in a real-world scenario. With the cooperative and competitive technique they are expected to discuss these questions within the group and they have to reach an agreement and present a final solution.

The evaluation method is the same as in the previous experiment, but in this case the groups are required to explain to the rest of the class the reasons they had to choose the solution and the problems they have found. The teacher uses the first-order model to test the different controllers by changing slightly the system parameters (the gain and the pole of the system) and introducing four different reference inputs: a unit step, a sequence of steps, a ramp and a randomly-generated input. The performance of the controllers is measured as the time the error of the controller becomes zero, or its absolute value is less than a threshold. The works are then ordered depending on their performance and the marks are changed accordingly (in the same way as in the previous section). We expect that by using this method the marks obtained by the students in the exam of this module will improve with respect to other years.

8 CONCLUSIONS

As the main conclusion of the paper we have shown that it is possible to apply simultaneously cooperative and competitive learning techniques in automatic control courses. The combination of these two techniques allows us to reach two main objectives: (1) To develop competences related with team-work skills and (2) the competition between the groups increases the motivation of the students.

The results we have obtained show that the students have an interest in these activities (considering the level of participation) and that these techniques improve students' performance (considering the comparison between the marks obtained by the students who took part in the activities and those who decided to use the traditional learning method).

Acknowledgements

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