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Two-Tier Assessment Based on Collaboration and Competition to Enhance Engineering Students' Motivation*

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This paper reports the results of a two-year experiment in which competitiveness and collaboration were employed to support university students in their learning process, with the intention of simultaneously improving their motivation, teamwork, initiative and resolution. The main novelty of the designed framework is that it is composed of two tiers: Global competition in all subject activities is complemented by short-term competition associated with the lab sessions. The short-term competition favors students' ongoing work and engagement, whereas the global competition can help them balance their workload. A total of 167 students of engineering participated in this study. The results show that the approach was beneficial to the students.

Keywords: student motivation; higher education; competitive learning; collaborative learning

1. Introduction

Higher education at European universities, specifically at Spanish ones, suffers from a common problem: a lack of student motivation [1], which in turn leads to worse academic performances [2, 3]. Although this phenomenon is not new [4, 5], the economic crisis has made it even more evident. It is known that the economic crisis has seriously decreased job prospects for most people in Spain (the unemployment rate is over 20% in Spain and over 30% in the area surrounding the province of Jaén). This fact has dramatically affected young students, who face very few possibilities of finding a job in their area of study despite holding a higher education degree. Moreover, the public university qualification system forces a significant percentage of students to study for a degree or at a center that was not their first choice. Our surveys have verified that even in the third course of the telematics engineering degree at the Universidad de Jaén (Spain), there are students who feel that they made the wrong decision about their studies. That is a small percentage, below 10%, but those students are strong candidates to abandon their studies. We have conducted several surveys among 50 students of four different subjects during the last two courses, and only 57% were completely satisfied with their studies, whereas the rest showed different levels of discontent about the degree that they were studying for. Only 2% were completely unsatisfied.

We have detected other serious learning problems during our experience of more than a decade of working with students in practical and laboratory sessions and in different telecommunication degrees. These problems include a lack of attention, initiative, resolution and participation. As a consequence, teamwork experiences are usually useless. These problems become important drawbacks in the students' future professional activities, as collaboration and coordination (which are developed in teamwork tasks) are career requirements. This creates a vicious circle that is difficult to break.

An analysis of the causes behind the above-mentioned problems indicates that motivation is the main factor that contributes to all of them. Concerning the social aspects, one of the most important drawbacks in the Spanish context is the lack of an effort culture in the academic background of most students. This is a very alarming concern that we have detected among our alumni: they do not aspire to obtain the best marks in a subject through the learning process; instead, they just study to pass the course and do not care if they have acquired the right competencies and abilities. Although the European Bolonia Process [6] was implemented to encourage better techniques for evaluating the real efforts of a student, the marks obtained in final exams are even worse than before this deep change occurred. In our department, this

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effect can be explained because the impact of these new tests on the final marks is only 30%. Therefore, although students must pass the exam, they are satisfied with just passing and are not interested in working on the alternative activities proposed by the professors to achieve better results.

Another important characteristic among the students is their lack of initiative and resolution to solve common tasks and exercises in a subject, even the simplest ones [7]. This serious problem is related to the lack of effort, but it is not the sole cause. Another cause is poor practices in the tasks prepared for laboratory sessions, such as activities that only require students to "fill in the blanks" to complete the work. Another problem is that our alumni do not feel that their learning is focused on real-world problems. This concern reduces their motivation and their initiative because they find classwork useless. Regarding those last problems, we have observed that in the present environment in which most students have their own laptop or smartphone connected to the Internet 24 hours a day, most of them ask the teacher for help, or even for the solution, before analyzing the course material or performing an Internet search.

It is also important to consider that the EHEA (European Higher Education Area) strongly recommends reinforcing motivation as a key factor in the lifelong learning needed by the future professionals [6]. The new education environment also promotes active learning, in which students should actively make decisions about their study routines and show some willingness to address additional material. To be an active learner, motivation is a requirement. Working with motivated students will also decrease plagiarism, an undesirable behavior that has been detected in recent years.

Another important deficiency in the learning process at Spanish universities is students' tendency not to study until just days before the exam. Continuous work, which will help them to acquire a comprehensive knowledge of the subject, is not common among the students. We believe that motivation could also overcome this serious problem.

Consequently, it is necessary to employ special techniques to guide the learning process of the students, foster their motivation and effort and keep them away from becoming frustrated [8] or worse, abandoning their study. These techniques should motivate students throughout the semester by promoting active learning and discouraging plagiarism.

As stated in [9], competition is a good way to enhance student motivation because students like to interact with other classmates and compare their progress. However, competition-based activities should be carefully designed to avoid negative emotional consequences. Moreover, competition and collaborative learning are two high-demand abilities in professional engineering careers. Taking into account these premises, we designed and applied a collaborative competition assessment method that focuses on collaboration, teamwork and effort. As a novelty, we designed this experiment with two tiers of complexity: the first is a competition for each practical exercise separately, and the second is a competition that assesses all of the course material. Both methods will be explained in detail in Section 3.

The proposed competition framework has the following main features:

- It is based on collaborative learning, which promotes interaction with other classmates. In this way, social relationships skills, which are necessary among engineering professionals, are reinforced.
- It is tailored for subjects that combine practical and theoretical lessons, particularly those that are part of the engineering degree program.
- It combines two types of competition: one type covers the entire semester, and the other shorter type requires two or three sessions to be completed. The short competitions encourage continuous studying.
- It is similar to the Olympic Games in that the activities of the competition are rewarded with medals (gold, silver or bronze). This procedure allows the competition to be easily understood and more quickly engages the students.

The remainder of the paper is organized as follows. The next section presents a review of the state of the art in motivation techniques for higher education. Section 3 describes the employed method as previously mentioned, and Section 4 shows the results obtained with the experiments conducted. The paper concludes with a discussion of the results and future work in Section 5.

2. Related work

Student motivation is not a new problem, and it has been approached in very different ways [8, 10]. Furthermore, in the university context, the authors of [1, 12] show the benefits of new performance goals that are based not only on traditional academic goals (marks) but on self-efficacy or self-esteem. They state that traditional learning goals sometimes lead to the undesirable alienation of the students, who are only worried about their marks. As a consequence, they lose motivation when they have to face bad results or difficult tasks.

To cope with the problem of motivation, some authors [11] propose that if the students are more involved in the academic process, they will achieve better results. Alternatively, the authors in [12] show the importance of achieving goals as a way for students to demonstrate their success to others and boost their egos. However, as identified in [12], an academic environment based on competitiveness can stress the students and have the opposite of the desired effect, namely, it could demotivate the students. Thus, they propose that competition-based activities needs to be combined with teamwork. A similar recommendation is noted in [9].

Cooperative learning and competition have been an important focus in educational techniques in recent years, and previous work [13–15] shows that such experiments are beneficial because the students usually exert greater efforts and give their best during competition. It is also important to note the evolution of the method over different years [16], even among different students. The mixture of results for different years and subjects is not common in the literature. Therefore, in our paper, we present a method based on two stages that has been applied to two different subjects over two different courses.

The main reason for implementing this method with two stages, or tiers, is to motivate students in two learning scenarios. First, we apply the method in laboratory sessions, where we have detected that students lack a minimum level of initiative and resolution, and second, we use the method for the rest of tasks that are required for the assessment of each subject. This approach differs from [16] or [17], among others, because of the two-tier method of competition. The experiments were conducted during the academic years 2013/2014 and 2014/2015 for the first subject and during the years 2014/2015 and 2015/2016 for the second subject.

3. Collaborative competition motivation method

The Collaborative Competition Motivation Method (C2M2) is based on two tiers of actuation. In the first phase, we try to promote students' initiative and participation in laboratory sessions, whereas the second phase encourages their involvement in the remaining activities of the subject: exercises, the redaction of reports and documents, presentations, self-evaluation tests, etc. The final exam is not included in these activities.

In contrast to previous works, our experiment was created with two different levels, as we have previously mentioned. This number of levels is the consequence of our design, which takes into account the learning goals and our teaching experience. During the first stage, we hoped to encourage greater participation and involvement in practical and laboratory sessions. We aimed to preserve this competition and avoid interference or distraction from other tasks. This type of session constitutes a strong motivating learning method, as we have found from our experience. In particular, this motivation arises mainly from the professional background of most students in the engineering program. We then established the second level, in which all of the students compete for their marks in all the items that are evaluated in the subject.

3.1 Assessment method

To understand the importance of the rewards that students can obtain if they participate in the C2M2, it is necessary to briefly explain the assessment method used in our telecommunication degree programs.

Our students are evaluated in four different main aspects: attendance and participation (S1), theory (S2), exercises and problem solving (S3) and practice (S4). In the final evaluation of the class, each aspect accounts for a certain percentage: 10% for S1, 15% for S2 and S3, and 30% for S4. The remaining 30% is based on the final exam. Therefore, although we have an important variety of elements with which to assess a student, this variety can sometimes discourage students from participating in some parts of the course because they feel overburdened. For that reason, it is very important to keep students motivated; however, rewards that come only in the form of extra points at the end of the term are insufficient. Sometimes students need a more immediate challenge, a way to demonstrate that they are doing something better than others are in the middle of the term. This type of activity also helps students to self-evaluate. For this reason, our C2M2 includes two phases or tiers. Tier 1 relies on short activities in the laboratory, each of which is rewarded with a medal (gold, silver, bronze) and has a corresponding impact on the S4 grade. Tier 2 includes the remaining exercises, practical and laboratory work, partial exams and tests.

Furthering the analogy with the Olympic Games, Tier 1 is like a speed race, whereas Tier 2 is like a long-distance race.

The reason for offering two types of competition is to encourage students to maintain a consistent effort throughout the semester and to place a special emphasis on practical learning, where we have detected a particular lack of motivation and initiative.

Thus, we designed and implemented the C2M2 framework, whose team creation method and phases are explained in the following sections.

3.2 Team creation

A key issue in a competition-based framework concerns how the teams are generated [17]. First, if we let students determine their own groups, the most knowledgeable students would all end up in the same group. This would discourage the rest of the groups from participating because they would not perceive themselves as having any chance of beating the group comprised of highly knowledgeable students. However, if groups are established randomly, some groups may include members who do not have any affinity. Consequently, they may be uncomfortable working together, and their interest in the activities could decrease. This situation is not especially relevant when all of the activities in the competition rely on an information system because the interaction is supported by a machine [9].

Taking into account the previous statements, we use a mixed approach to create teams. First, we divide the students into work groups, usually into pairs. Students pair up without any restriction. As opposed to [9] [Muñoz-Merino], the knowledge levels of each member of the pair are not considered during this step because we prefer students to work with those with whom they share an affinity to promote a friendly situation that does not lead to negative emotions.

Then, we create teams composed of several couples. They are free to form teams as they prefer, but all must have the same number of members. In this way, they are forced to consider pairs outside their affinity circle, but the situation is not volatile because they have the support of the other members of their pair. Moreover, when people socialize in larger groups, they usually try to collaborate more than when they work in pairs.

The number of students per team varies depending on the total number of students in the course. The objective is to form at least four or five teams. In addition, we recommend that the students name their team, but in our experiment, we did not take this factor into account. Because team names could increase students' interest in the competition, we will require them to name their teams in future experiments [17].

All the teams manage a personalized area within our Learning Management System (LMS) where they record all their achievements in the form of virtual medals: gold, silver and bronze, as in the Olympic Games. The procedure for earning medals is very simple: when a group finishes an activity correctly (in a lab session or theoretical exercise) in the first, second or third place, they receive the corresponding medal. A medal is rewarded in different ways. Receiving a virtual medal for Tier 1 activities (lab sessions) only affects a group's marks in the S4 section, whereas a virtual medal for Tier 2 directly impacts the team's final marks for the subject. For Tier 1 activities, the gold medal earns the team one point, the silver medal earns 0.5 points for the team, and the bronze medal earns 0.3 points. For Tier 2, the rewards depend on the difficulty of the tasks. More details about the procedure used to quantify the medals' impact is provided in the following section.

3.3 C2M2 Tier 1: Practical session enforcement

Once the teams are formed, the first stage of the collaborative-competitive method starts during practical sessions in laboratories, where each group has to finish its work in a limited number of sessions. This stage usually requires two or three two-hour sessions per activity. At the beginning of each practice or exercise, the teacher explains the objectives of the work and uploads all the material that can be used in the LMS. After the explanation, the competition begins, and the teacher does not respond to questions or concerns about the task until all the medals are won. In this way, we guarantee equality because the professor's interaction does not benefit any particular team. The first group that finishes its task correctly wins the gold medal, the second group wins the silver medal, and the third wins the bronze medal. For the rest of the groups, normal questions and concerns are then resolved as usual.

One restriction is that although students can collaborate with members of their own team (and in fact, team members need to collaborate to finish their tasks on time), interaction with other groups is forbidden, and each group has to finish its work on its own.

With this competition, we encourage a higher level of participation, initiative and motivation during practical lessons and reinforce teamwork under the guidance of the teacher.

Because this type of competition can stress the students, it is important to adequately describe the duration of the work and the number of sessions needed to accomplish it. In our case, this is possible because of our experience of more than 10 years engaging in similar types of exercises and practical work. Therefore, sessions are usually planned with a least 20% or 30% extra time beyond that required by the groups that finish first.

3.4 C2M2 Tier 2: Global competition

This phase encompasses all of the exercises (performed in the classroom or in the lab) and partial exams or tests. The results for Tier 1 also impact this phase.

The idea is that if a team works hard and maintains high marks throughout the semester, it will earn an important prize: additional points on the final evaluation for the class. Thus, we take into account the results for the S1, S2, S3 and S4 activities, and we rate the teams. To do so, we compute the total number of points (TNP) as follows:

$$TNP = S1 \times 0.1 + S2 \times 0.15 + S3 \times 0.15 + S4 \times 0.3 \quad (1)$$

where:

- S1, S2, S3 and S4 are the marks obtained for all the tasks in those categories.

The reward for the best team (the one with the highest TNP) is one point; the second-best team earns 0.5 points, and the third-best team earns 0.3 points. All team members receive this bonus because they all contributed their efforts to achieving good marks throughout the course. This contribution is guaranteed by the design of the activities.

As shown, obtaining a virtual medal in the global competition is much more beneficial than earning one in Tier 1. Nevertheless, both tiers are connected because S4 counts for 30% of the final evaluation. Therefore, a high number of achievements in S4 will significantly raise a team's TNP and practically ensure that it will win 3 points out of 10 in the global evaluation.

The type and number of assessments varies from one subject to another, but C2M2 is applied in the same way for all subjects. When all of the tests and exercises are completed, and just before the final exam, all of the students receive their continuous evaluation mark (or CEM), which represents 70% of the final mark for the class plus the award from any virtual medal they have received. To obtain the CEM, the marks for every task are adjusted by their weight in the final evaluation, accordingly to Equation (2).

$$CEM = \min(TNP + reward, 7.0) \quad (2)$$

where:

- *reward*, if any, is 1.0 for the first team, 0.5 for the second team and 0.3 for the third.

Therefore, taking into account that in Spain, the higher education evaluation system requires marks from 0 (the lowest) to 10, the maximum CEM value must be 7 to guarantee that with the final exam (whose percentage is 30%), the maximum mark that a student will obtain would be 10.0. Students who received excellent marks for S1, S2, S3 and S4 and received any C2M2 rewards for Tier 2 would have a CEM higher than 7.0. The application of the minimum function is thus necessary.

4. Results

There are several mechanisms for measuring student motivation, including the MSLQ (Motivational Strategies for Learning Questionnaire), the Zoller Test, the MAPE-3 (Motivation to Learning and Execution), the MAE (Motivational and Attitudes in Engineering) and the EMQ-B (Environment Motivational Quality Questionnaire) [2]. However, all of these methods are supported by questionnaires, which may not be completed by the students. In fact, during the experiment in [17], we noticed that making the questionnaires available online did not increase the number of responses. Thus, rather than using a questionnaire, we opted to measure how motivation was enhanced by analyzing the learning outcomes and the professor's observations regarding the students' interest.

To proceed, we have divided the results of our study into two categories: (i) objective results based on the evolution of student marks and (ii) subjective items based on the teacher's observations throughout his/her classes.

The competition framework was applied by two teachers in two different subjects, both in the 4-year Telematics Engineering Degree of the Universidad de Jaén. These subjects are Access and Transport Networks (SB1) in the second year and Transport Protocols (SB2) in the third year. The number of students per subject is provided below.

4.1 Teacher perceptions

We documented several different reactions to C2M2:

- During the first stage, when the method is presented, most **students showed interest** and were willing to participate. Moreover, they accepted that they could not ask the teacher for help with no complaints.
- **Classwork improved significantly**, without inconvenient or minor questions about the work. In this sense, we noticed that the students worked harder and the number of updates in the GitHub platform [18] (where they share developed code with their teammates) has increased.
- Some students (approximately 20%) reviewed **material from other sources**, such as the *Request For Comments* of the protocols used in the lab sessions. Thus, they did not rely only on the class slides. This may be viewed as a minor achievement, but in previous years, no students reviewed supplementary materials despite the teacher's insistence. This behavior can be considered an improvement in the initiative of the students, who sought not just to finish first, but to do their work properly.

- Students made an effort to provide **imaginative solutions**. Consequently, the number of different solutions or approaches increased noticeably, and plagiarism was almost null. Plagiarism has been a serious problem for years. Despite the fact that practical work rotates from one course to another, at least 30% of students based their work on material they collected from previous years instead of their own effort. Moreover, they did not understand what they were copying, even when they did not hesitate to present that work as their own.

4.2 Objective analysis

We must remark on the difficulty of evaluating different groups of people throughout the courses. To do so, the type of assessment must be kept relatively similar along the different courses (indeed, some of the assessments were the same). The results obtained were divided into two categories. The first one shows the evolution in the marks obtained by the students for two different years, considering several items. The second category consists of the analysis of the participation in C2M2 and the number of students who earned a reward.

4.2.1 Mark comparison

As we have previously mentioned, we have applied C2M2 in two different subjects: Access and Transport Networks (SB1) in the second year and Transport Protocols (SB2) in the third year. For SB1, the periods under study are the first semester of the courses 2013/2014 (Y1) and 2014/2015 (Y2); for SB2, the considered intervals are the first semester of 2014/2015 and 2015/2016 (Y3). The number of students who participated in the experiment is detailed in Table 1.

We must note that the results were obtained with different students. Although it could be difficult to compare them, the statistics that we used focus on specific elements that show the level of acceptance of the method and the improvement in student marks.

Table 1. Total number of students in subjects SB1 and SB2 for the analyzed courses

Subject	Y1	Y2	Y3
SB1	48	57	
SB2		37	25

Regarding the student work, we measured the following parameters:

- Attendance of practical lessons (AP) measures the percentage of students who regularly attended practical sessions in the laboratory.
- Attendance of master classes (AM) represents the percentage of students who regularly attended master classes for a course.
- Finished work (FW) stands for the percentage of students who finished their work on time and had it validated by the course teacher.
- Marks for the same exercises (ME) reflects the mean (*m*) and standard deviation (*sd*) of the marks obtained by the students for exercises that are the same in different courses. These marks range from 0 to 10.

All the students came from the same socioeconomic environment and were almost the same age. The results for the parameters described above are shown in Table 2 and Table 3 for SB1 and SB2, respectively.

As Tables 2 and 3 show, the collected data indicate that the students who participated in courses where C2M2 was implemented generally received better marks. For finished work, the increase was significantly greater for both subjects in almost all the exercises.

Regarding the acceptance of C2M2, we evaluated how the experiment was performed using the following parameters:

- Mean of the incentives awarded in practical lessons (IWm). The maximum possible value was three for each subject.
- Standard deviation of the incentives awarded (IWsd).

Table 2. The results obtained for SB1 after the application of the C2M2 method

Parameter	Y1		Y2	
AP	0.86		0.86	
AM	–		–	
FW	Exercise 1	87.27%	Exercise 1	96.61%
	Exercise 2	89.09%	Exercise 2	93.22%
	Exercise 3	76.36%	Exercise 3	84.75%
	Exercise 4	76.36%	Exercise 4	77.97%
ME	Exercise 1. m = 5.95 sd = 1.79		Exercise 1. m = 5.33 sd = 1.50	
	Exercise 2. m = 4.82 sd = 1.56		Exercise 2. m = 6.24 sd = 1.85	
	Exercise 3. m = 5.76 sd = 2.08		Exercise 3. m = 5.28 sd = 1.89	
	Exercise 4. m = 5.63 sd = 2.72		Exercise 4. m = 6.42 sd = 2.25	

Table 3. The results obtained for SB2 after the application of the C2M2 method

Parameter	Y2		Y3	
AP	92.60%		95.00%	
AM	80.40%		76.68%	
FW	Exercise 1	92.85%	Exercise 1	100.00%
	Exercise 2	100.00%	Exercise 2	100.00%
	Exercise 3	82.14%	Exercise 3	90.00%
ME	Exercise 1. m = 7.44 sd = 1.21		Exercise 1. m = 7.87 sd = 0.60	
	Exercise 2. m = 7.23 sd = 1.08		Exercise 2. m = 8.37 sd = 0.90	
	Exercise 3. m = 7.02 sd = 1.15		Exercise 3. m = 7.85 sd = 0.76	

Table 4. Summary of the C2M2 method performance for SB1 and SB2

Subject	IWm	IWsd	IWv	P	WT1
SB1	1.186	0.655	0.81	100%	68.42%
SB2	0.62	0.82	0.67	60%	50.00%

- Variance of the incentives awarded (IWv).
- Participation (P), which represents the percentage of students involved in the experiment. High values of participation demonstrate that students are receptive to new assessment methods outside the traditional academic ones.
- Winners T1 (WT1), which consists of the percentage of students who participated in the experiment and received a virtual medal in Tier 1. A high value in this parameter shows that most students competed seriously and that the same group did not earn all of the virtual medals for all the exercises. It also validates the way the teams are generated. The percentage for Tier 2 is not shown because three teams always won.

The values obtained for both subjects are summarized in Table 4.

As shown, the impact of the experiment favors the participation of an important percentage of the students (shown by parameter P). Thus, we can state that the designed framework engages students easily and that teachers can use it to promote student motivation. In addition, we observe that only a few students did not obtain the rewards (represented by WT1). However, students need to work to earn the incentives as IWm is far from the maximum value (set at 3). We can conclude that a competitive and collaborative framework does not need to rely on easy tasks to be successful.

5. Conclusions and future work

Motivation is necessary to improve the learning process in university degree programs. To foster students' motivation and their initiative, we have designed a two-tier framework that favors continuous work, initiative and the collaboration among students. As a novelty, the framework is based on two levels of competition: one related to lab sessions and one concerning the whole course. The framework was applied over two-year periods in engineering degree programs.

The results obtained showed significant improvement for most of the parameters tested. However, for some parameters, there was no significant improvement over previous courses, although the results were still better. Thus, one could conclude that the experiment was successful. Nevertheless, measured parameters are not absolute units because the population of participants varies from course to course. It is difficult, even when the same types of exercises are used, to assume that the experiments are fully comparable.

As we have explained, the two most relevant patterns in the student profile are age (20–21 years old), and origin (province of Jaén). Only a minimum percentage of students repeat the experiment in the same subject, and when they do, it is because they failed the final exam or dropped the course. Therefore, the subjective perceptions of the teacher appear to be of paramount importance under these conditions.

Thus, the main conclusion of this experiment is that the students maintained a constant level of effort throughout the semester, with very few drop-outs for SB1 and almost none for SB2. This improved motivation and initiative was demonstrated by the originality of the students' work, their attendance of classes and tutorial sessions and their dedication. These changes led to almost the 100% of the students finishing their tasks on time and completing all the objectives.

It has been observed that students do not track their scores for Tier 2. Therefore, for future experiments, it is important that the teacher publish partial scores at least once every two or four weeks. The other important issue is enforcing team collaboration for some exercises during practical lessons; we have noticed that some teams do not share their feedback in class, while in other teams, the members continuously receive feedback from one another.

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