Healthy Competitions in Education through Cooperative Learning

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ABSTRACT

Competitions in education have been widely discussed in the literature, and it is still controversial whether they are positive or not. Aiming to clarify this controversy, and attempting to develop a healthy, valuable, stimulant, and enjoyable activity in the classroom, we designed a team competition based on Cooperative Learning. We evaluated the competition in a case study with engineering students. To identify and analyze the benefits and drawbacks of the competition, we proposed a number of evaluation components and methodologies, which could be used to design and assess other types of collaborative learning activities. The obtained results show that we effectively conducted an activity that was not harmful for the students, independently of their position in the contest ranking.

KEYWORDS

education, student motivation, competition, cooperative learning, learning evaluation

1. INTRODUCTION

Human competition is a contest where two or more people strive for a goal that cannot be shared, usually resulting in a victor and a loser. Competition exists when there is a scarcity of a desired outcome. Individuals and/or groups are then in a position where they must vie for the achievement of that outcome. For instance, in most team sport competitions, teams engage for the purpose of winning matches to take first place in a tournament.

It is partially true that the world is competitive, and it is difficult to avoid competition entirely in life. Nonetheless, it is also true that for the most part, competition is a self-imposed or at least self-selected condition. We can easily live an existence based more on a cooperative and self-referential behavior than on competing against others. In this context, if we as educators prepare students for the real world by putting them in artificially built competitive situations, we may be imposing our view of the world on them (Shindler, 2007). Thus, one could argue that in a broad sense, if we encourage a more competitive learning environment, we create a more competitive future world, whereas, if we encourage a more cooperative learning environment, we create a more cooperative future world.

Competitions in education have been widely discussed in the literature. Johnson and Johnson (1999), and Kim and Sonnenwald (2002), identify three learning styles: individualized, cooperative and competitive. The individualized learning style indicates a student's preference for working by one-self to ensure that the own learning achieves established working goals independently of other students' effort. The cooperative learning style indicates a preference for achieving individual working goals in group. Finally, the competitive learning style indicates a preference for learning in an environment where students work against each other to achieve a good grade, and only some of them succeed.

It is controversial whether competitions in education are positive or not. Hence, for example, Verhoeff (1999) is a strong supporter of their benefits, claiming that a well-organized competition challenges its participants to give their best, and it thus enhances the students' motivation and learning. Lawrence (2004) agrees on that idea saying that competitions encourage active learning and increases motivation. Fulu (2007) also identifies several odds in competitions, such as recognition gain, and higher motivation and self-esteem. Moreover, Fasli and Michalakopoulos (2005) show that a competitive element acts as an incentive for all students to put in more effort, and even weaker students persist with participating in the activity. In this line, Siddiqui et al. (2007) present a study that demonstrates there is a high sense of competition among students. Lam et al. (Lam et al., 2001), however, state that competition damages the learning process by forcing students to focus on goals instead of on the process itself. Vockell (Vockell, 2004) also argues that the stress to which a student involved in a competition is exposed has a negative effect that is greater than the benefits extracted from it.

Despite this controversy, there is a more general agreement that team competition is less harmful for students, and can effectively improve their learning skills. Thousand et al. (1994) state that cooperative goals make students take better care of their responsibilities and tasks for the sake of their groups. Yu et al. (2002) examine students' preferences towards different kinds of competition, and their satisfaction with regard to the learning experience. Their results show that students prefer anonymous rather than face-to-face competition, since the former is more likely to reduce stress and other similar negative emotions. Moreover, Shindler (2007) defines a "healthy" competition as a short activity where outcomes have to be trivial, and which has to be focused on the process rather than on the outcomes.

Aiming to clarify the above controversy, and attempting to develop a healthy competition in the classroom, during the academic year 2009-2010, for a particular subject, we organized a team competition designed following the principles claimed by Yu et al. (2002), and Shindler (2007). Close to 80 engineering students grouped in teams of between 4 and 6 members participated in a 6 week competition, split into 4 rounds. In each round, the students had to collaboratively elaborate, resolve and evaluate questions and exercises about specific topics of the subject.

The results of the experience were encouraging (Hidden for review). Regarding the students' satisfaction, 71% of them confirmed that the activity was useful or very useful to achieve individual learning goals. Moreover, 71% of the students evaluated as very positive the collaborative nature of the activity. Interestingly, and in accordance with Siddiqui et al.' statements about the existence of a high competitive sentiment among students (Siddiqui at al., 2007), 47% of the participants affirmed that winning the contest was their main motivation in the activity, whilst only 18% of them showed interest in the (symbolic) surprise prize for the winners. The complexity and the needed time to complete the proposed tasks were evaluated as adequate by 69% and 81% of the students, respectively. At the end of the activity, 82% of the participants recommended continuing organizing the competition in the subject, and 100% confirmed that the social atmosphere was good or very good during the contest.

The study, nonetheless, revealed certain limitations and weaknesses of the activity. First, we detected a significant number of cases in which some students barely contributed to their teams' work. For such cases, we had not established specific prevention and action plans. On the one hand, we identified that students were not assigned specific roles and tasks. On the other hand, we observed that having teams created by the students themselves lets some participants to avoid working, while being concealed by their mates, with whom they had consolidated friendship relations. Next, we detected that we had not fomented and evaluated transversal competences, which is a major formative requirement in the frame of the European High Education Area (EHEA). Finally, we observed that 41% of the students did not enjoy the competition, especially during the last rounds. Analyzing open responses in evaluation questionnaires, we identified that the type of problems and exercises proposed in the activity were repetitive for the students, who progressively did lose their interest in the activity.

To address the above issues, in the academic year 2010-2011, we redesigned and better evaluated the competition. Specifically, to avoid situations of unbalanced workload, the teams were created by the teacher in a well-adjusted way according to previous marks of the students in the subject; and each student was assigned different roles during the competition. To foment and evaluate particular transversal competences –effective work in group and oral communication skills– specific tasks were defined. Finally, to avoid a loss of the students' motivation and enjoyment due to monotony in the developed work, several types of problems and exercises were presented during the competition rounds.

In this context, new design aspects incorporated into the activity were inspired in the well known Cooperative Learning methodology (Johnson & Johnson, 1975; Johnson et al., 1988). As a summary, we intended to develop an activity in the classroom where pairs or small groups of students (inter) exchange information not only for the purpose of improving their own learning and results, but also to improve the learning process and results of their classmates, since the success of a team depended on the individual success of each of its members.

The main contributions of this work are twofold. First, we present a team based competition by following principles derived from previous studies, and by incorporating characteristics and elements of Cooperative Learning. According to our evaluation results, the proposed competition schema really represents a valuable, stimulant, and enjoyable type of activity to be used in the classroom. We thus claim to have identified features a competition in education should have to be healthy for students. Second, to assess the benefits and drawbacks of the competition, we conduct an exhaustive analysis of a number of components, which, in our opinion, should be taken into consideration when assessing a competitive learning activity. We believe the proposed evaluation components and methodologies could be applied to assess other types of collaborative activities in education.

The remaining of the paper is structured as follows. In Section 2, we introduce the Cooperative Learning methodology, and describe its main characteristics and elements. In Section 3, we discuss several features a competition based learning activity should have in order to be non harmful for students. In Section 4, we present our approach to design a healthy competition in the classroom through cooperative learning, and describe the particular study case in which we conducted and evaluated our proposal. In Sections 5 and 6, we report and discuss results obtained from the competition, comparing them with those results we obtained in the preceding experience. Finally, in Section 7, we provide some conclusions and potential lines of future improvement and innovation on our approach.

2. COOPERATIVE LEARNING

Cooperative Learning (Johnson & Johnson, 1975; Johnson et al., 1988; Brown & Ciuffetelli, 2009) is a teaching methodology that consists of organizing a classroom activity where students work in groups in a coordinated way to resolve a given problem, which cannot be resolved by students alone in the time assigned to the activity. Differently to individualized or autonomous learning, in cooperative learning, the learning process of a particular student is enhanced –or even provided– by the skills and work of her group mates, and by the effective communication they maintain during the activity, e.g. by asking and sharing information, evaluating ideas, and managing and supervising the different tasks and outcomes (Chiu, 2000; Chiu, 2008). Thus, a student has success on her learning goals if and only if the rest of members of the group have success as well. In this context, the role of the teacher changes from presenting the students with information to easing the acquisition and processing of such information by the students themselves (Cohen, 1994; Chiu, 2004).

In order to being effective, a cooperative learning activity should satisfy two main requirements: a) students have to work for the achievement of the group's goals, and b) this achievement depends on the learning process of each student (Brown & Ciuffetelli, 2009). Thus, when designing a cooperative learning activity, the tasks and responsibilities of the members of a group have to be well defined and delimited. A student has to know what she is in charge of and respond for on behalf of the group. Moreover, those tasks of which a student is responsible of cannot be completed by any of her group mates. Hence, all the members of a group, taking care of the success of the group, have to participate in the activity doing their best.

More specifically, Brown and Ciuffetelli (2009) establish five fundamental elements that a (formal) cooperative learning activity should have:

- *Positive interdependence*. A student has to feel her membership and contribution to the group are so important that she cannot achieve any success if the others do not achieve it as well (and vice versa). In other words, students should perceive the feeling that "all are in the same boat." In a problem resolution session, the positive interdependence may be articulated by the agreement of consensus on the solving strategies and responses to each problem (goal interdependence), and the agreement of acceptance on the responsibilities and tasks assigned to each member (role interdependence). Other ways to assuring positive interdependence may be based on the existence of collective rewards, and dependencies among resources and tasks.
- *Face to face promotive interaction*. Within a group, students have to explain each other how to resolve a problem, analyze together learned concepts and strategies, and teach to the others what they know. This interaction promotes collaboration, help, encouragement, and support among students during the learning process.
- *Individual accountability*. The teacher has to provide evaluations of individual results of each student, and communicate these evaluations to the individual and to the group. The group members have to know who needs help to complete assigned tasks, and have to be aware they cannot success only with the work of the others. Some strategies to articulate self-enforcement include making individual exams, making a particular student to present the results of her group, and making individual questions to students when supervising or evaluating the work of a group.
- *Social skills*. Students have to develop and exploit skills like leadership, decision making, trust building, effective communication, and conflict management.
- *Group processing*. During the activity, the members of each group have to analyze and assess how well goals are being achieved, and whether cooperation is being really effective. At the end of a work

session, a group has to assess its performance addressing the following questions: a) what has been done by each member that was useful for the group? and b) what could be done by each member to improve the group's results? These reflections let students to focus on preserving the group together, and ease the acquisition of cooperative skills.

Cooperative learning thus requires students to get involved in the tasks of a group, which not only allows enhancing their own learning processes, but also provides additional benefits such as improving their social relations and skills. Recent research works show overwhelming positive results of cooperative learning. For instance, the study conducted by Tsay and Brandy (2010) reports that students who participated in cooperative activities, showing a collaborative behavior and providing constructive feedback, had better marks in final exams. Slavin (2010) reinforces the results obtained by Tsay and Brandy demonstrating that cooperative learning increases the students' self-esteem, enhance their perception about classmates, and break ethnic and ideological barriers, encouraging positive interactions and friendship relations.

In this paper, we present a cooperative learning activity which, aiming to provide additional student motivation and enjoyment, is based on a team competition. The competitive contest is carefully designed in order to be "healthy", non harmful for the students. In the next section, we describe the main features such a healthy competition should have in education.

3. HEALTHY COMPETITIONS IN EDUCATION

Although it is under discussion if competition in education can be healthy at all, what it is clear is that there are features that a competitive classroom activity should have in order to be more beneficial, or at least non harmful for students (Thousand, 1997; Yu et al., 2002; Shindler, 2007). In the following, we discuss some of these features, which are related to the definition of "healthy" competition given by Shindler in (2007): a short activity in which the winning outcomes have to be trivial, and which has to be focused on the (learning) process rather than on the outcomes.

First of all, competition prizes for winners should be either symbolic or of very little importance (e.g. sweets and polite applauses for the winners), in order to assure that the students' efforts are intrinsic and not driven by the expected outcomes. When we give students a meaningful reward for winning, we make the winning what is important, and students care at least as much about getting the reward as they do about the quality of their effort. In particular, recorded grades of high relevance, material things of value, and privileges of any kind must be avoided at all cost. In any case, it is convenient to maintain the concept of winning prize, which would be seen by students as a goal to achieve collaboratively, and would motivate them to put an extra effort not only for their own interest, but also for the interest of their team mates. This does not entail that we cannot allow students to obtain an evaluation mark for the subject from their work in the activity. Of course, in addition to achieving learning goals, evaluation marks represent an important incentive for students to do their best in the activity. However, achieving learning goals should prevail over obtaining high marks. This may be obtained if the students really get involved in the contest, enjoying participating and collaborating with their team mates, with whom they could also win a (symbolic) prize. In this context, the competition design should allow obtaining the highest marks independently of the ranking positions of participants. Moreover, different marks could be assigned to each student in a team based on individual evaluations, or a single mark could be assigned equally to all members of a team.

Next, a competition should be short. A too long duration of the contest will increase its sense of prominence, and will decrease its sense of intensity and fun, both undesirable effects. The competition, on the other hand, has to be long enough to avoid the students' demotivation because of bad initial results, and has to assure that all participants have a good chance of winning until the end of the activity. In a previous experience (Hidden for review), we obtained that a four round competition conducted in six weeks is a good choice. Nonetheless, we noticed that in such period of time some of students got bored. We found out that this was due to the fact that we set the same type of problems and exercises in all the competitions rounds. Diversity of topics and unexpected changes in the tasks to do are thus important issues to be taken into consideration when designing a classroom competition.

Finally, the goal of the competition must be clearly set into the process instead of into the results, making it clear that finally winning or losing has very low importance in comparison to learning and improving while competing. In order to achieve this, the first discussed feature –symbolic prizes– can be considered as a prerequisite, because setting a valuable prize for the contest will easily lead students to focus on it. Self-evaluation tasks may also help students to think about and focus on the achievement of the learning goals. A competition design thus has to include time slots in which students have to individually and collectively take care of the correct progress of the learning process.

Summarizing and putting all the above features together, we could conclude that healthy and beneficial competitions in education are those that:

- are undertaken for a symbolic value,
- are conducted in a relative short period of time,
- provide diversity on topics and tasks to do,
- are characterized by all participants feeling like they have a chance to win, and
- assign a conspicuous value to the learning process, quality and evaluation.

In the study described herein, we attempted to ensure a competition as healthy as possible, by following the above principles strictly in the process, and by adopting elements and characteristics of Cooperative Learning. In the next section, we present our competition design, and describe the case study in which it was tested.

4. COMPETITION DESIGN AND CASE STUDY

In the academic year 2009-2010, we organized a classroom competition satisfying some of the features presented in Section 3. A total of 77 students grouped in teams of between 4 and 6 members participated in the activity, consisting of 4 rounds during 6 consecutive weeks. In each round, the teams had to propose, resolve and evaluate questions about particular topics of the subject. The surprise prizes for the winners were small board games, puzzles and bags of sweets.

The evaluation of the activity (Hidden for review) through online questionnaires filled by the students showed very positive results regarding the students' satisfaction with the work done and the knowledge learnt, and regarding the good social atmosphere within and between the teams. The adequacy of the tasks according to their difficulty level and execution time was also assessed favorably. The evaluation, however, also revealed several limitations and weaknesses of the activity. We identified cases of too unbalanced workload between participants, noticed a lack of promoting and evaluating transversal competences, and were aware of a significant number of students who barely enjoyed the activity due to repetition and monotony of the tasks.

Aiming at addressing the above problems, in the academic year 2010-2011, we redesigned the activity to satisfy all the features of a healthy competition presented in Section 3, and the fundamental beneficial elements of cooperative learning, explained in Section 2. To avoid situations of unbalanced workload between participants, and to assure *positive interdependence*, the teacher chose the members of each team in a well-adjusted way according to previous marks of the students in the subject, and assigned to the students different roles during the competition rounds. To encourage and evaluate certain transversal competences, corresponding to *face to face promotive interactions* and *social skills*, we defined specific tasks for group work, and effective oral communication within and between teams. To avoid decreasing motivation and enjoyment of students, we developed two types of problems and exercises, each of them followed in two different competition rounds. Finally, to control the *individual accountability* and *group processing*, the students had to complete questionnaires of individual and group assessment. At the beginning and the ending of the competition, the students also completed questionnaires regarding their achieved learning expectations and goals. In the next subsections, we describe in detail the above issues in the frame of a particular implementation and evaluation of our approach.

4.1. Competition Context

The conducted experiment took place in a "hostile" learning environment. It was performed in a subject called *Applied Informatics*, which is taught to first year Chemical Engineering grade students at <University name hidden for review>. The subject's contents are organized in two parts. The first part addresses introductory topics to Computer Science: definition, general concepts, and history of Computer Science, hardware and software, digital representation of information, and issues related to telecommunications (computer networks, Internet, the Web). The second part is about computer programming, and more specifically, about the general-purpose programming language of the Matlab[1] tool. In general, most of the students, who do have little knowledge and expertise on computers, consider this particular subject as non-relevant and very difficult in comparison to others. Because of that, the students' motivation and expectations on the subject are generally very low.

Table 1 shows statistics about the students' knowledge, expertise and expectations at the beginning of the courses in academic years 2009-2010 and 2010-2011. For both courses, in the first class day, the students were asked to optionally and anonymously fill online introductory questionnaires. These questionnaires were intended to measure several features that would allow us to understand two important issues: how "hostile" the learning environment where the competitions were going to take place was, and the students' actual background and knowledge on Computer Science. There were 54 and 48 responses out of 77 and 60 students involved in the activity during 2009-2010 and 2010-2011 academic years respectively. The students were asked questions about their initial interest in the subject, the difficulty they expected the subject would have, and the use and utility they thought the covered topics would have for their academic training. The results showed that almost all the students felt Computer Science as being very important for Chemical Engineers, but expected that the subject would be difficult. Although 60% and

[1] Math Works, http://www.mathworks.com

69% of the students expressed they were expecting to like the subject, only 4% and 16%[2] admitted they had some knowledge and expertise in computer programming. The students' knowledge and background were tested by asking about their experience and skills with concrete computer applications including office suites, operative systems, and programming languages. Most of the students used computers regularly, but only knew how to use common programs, such as word processors, Web browsers, and media players. As already mentioned, nearly none of them had any programming experience at all.

Table 1. Statistics about the students' knowledge, expertise and expectations on the subject at the beginning of the courses in academic years 2009-2010 and 2010-2011.

		Responses	
Question	**Answers**	**2009-2010**	**2010-2011**
When was the first time you used a computer?	Less than 1 year ago	6%	2%
	Between 1 and 5 years ago	6%	10%
	Between 5 and 10 years ago	**48%**	**48%**
	More than 10 years ago	40%	40%
How often do you use a computer?	2 or 3 days a week	7%	0%
	4 or 5 days a week	6%	8%
	Almost every day	**87%**	**92%**
What do you usually use the computer for?	Work	26%	33%
	Entertainment	**74%**	**67%**
How do you identify your skills in using operative systems (e.g. Microsoft Windows)?	Null/Low	31%	35%
	Medium	**52%**	**46%**
	High/Advanced	17%	19%
How do you identify your skills in using word processors (e.g. Microsoft Word)?	Null/Low	11%	4%
	Medium	**52%**	**50%**
	High/Advanced	37%	46%
How do you identify your skills in using spreadsheets (e.g. Microsoft Excel)?	Null/Low	**48%**	29%
	Medium	39%	**40%**
	High/Advanced	13%	31%
How do you identify your skills in using presentation programs (e.g. Microsoft Power Point)?	Null/Low	35%	31%
	Medium	**46%**	31%
	High/Advanced	19%	**37%**
How do you identify your skills in using graphics editing programs (e.g. Adobe Photoshop)?	Null/Low	**72%**	**57%**
	Medium	13%	25%
	High/Advanced	15%	19%
How do you identify your skills in using Multimedia applications (e.g. audio and video players)?	Null/Low	22%	21%
	Medium	**50%**	27%
	High/Advanced	28%	**52%**
How do you identify your skills in using Web browsers (e.g. Microsoft Internet Explorer, Mozilla Firefox)?	Null/Low	17%	4%
	Medium	**48%**	44%
	High/Advanced	35%	**52%**

2 In the academic year 2010-2011, some of the students who filled the introductory questionnaire already attended the subject lectures of the previous year, so they already had some knowledge and expertise in computer programming at the beginning of the course.

How do you identify your skills in using e-mail clients (e.g. Microsoft Outlook, Mozilla Thunderbird)?	Null/Low	33%	37%
	Medium	**57%**	**38%**
	High/Advanced	9%	25%
How do you identify your skills in using scientific and computational tools?	Null/Low	**68%**	**67%**
	Medium	28%	25%
	High/Advanced	4%	8%
How do you identify your skills in using programming languages and tools (e.g. C, Java, Matlab)?	Null/Low	**96%**	**84%**
	Medium	2%	8%
	High/Advanced	2%	8%
How much do you like or are interested in computers?	Nothing/Little	11%	6%
	Neither little nor much	**65%**	15%
	Much/Very much	24%	**79%**
How important is computing for a Chemical Engineer?	Not useful at all/Not useful	2%	2%
	Useful	41%	19%
	Very useful/Indispensable	**57%**	**79%**
How difficult do you think the subject “Applied Informatics” will be for you?	Very difficult/Difficult	**56%**	**56%**
	Neither difficult nor easy	37%	42%
	Easy/Very easy	7%	2%
How do you think your opinion about the subject will be after the course?	I will hate it/I will dislike it	2%	4%
	I will neither dislike nor like it	37%	27%
	I will like it/I will love it	**60%**	**69%**

The hostile learning environment was also characterized by the number of students in the classroom. The creation of the European Higher Education Area (EHEA) following Bologna Accords, and its implementation in <Nationality hidden for review> universities, make it necessary to organize specific activities to provide a continuous assessment procedure. In order to fulfill the EHEA objectives, the students’ motivation is seen as a key feature (Regueras et al., 2008). Unfortunately, for our subject, the current number of students in the classroom is very high (close to 80), and organizing such activities consumes most of teacher’s time, and does not benefit students as much as it could with smaller groups of students. In addition of investigating the effects of competitions in education, the proposed approach intends to face the above two problems.

Despite the previous difficulties, as we shall show in Section 5, the competition organized in the subject was a success not only because of the students’ academic achievements and transversal competence acquisition, but also because of increasing their motivation, enjoyment, and social skills. Before reporting and discussing these results, in the next subsections, we describe the stages, tasks and scoring mechanism of the competition.

4.2. Competition Description

A total of 60 students participated in the second edition of the competition. The participation was not mandatory, representing an extra maximum mark of 1 point in the subject, which was evaluated in a scale of 0 to 10 points. The registration process was done individually by each student via an online form, easily created by the teacher with the Google Docs[3] tool. Once the registration stage was completed, before starting the competition, the teacher assigned each student to a team composed of 6 members. The team assignment was conducted in a balanced way according to the students' previous marks in the subject. In the classroom, the teacher announced the teams and their members. Then, the students had to sign a (non formal) agreement for working on the team tasks to be done in the classroom and at home during the contest. Once the collaboration agreements were signed, and having no disclaimer with the intention to participate in the competition, the students had to agree a name for their teams. Also, each member of a team received an identification number from 1 to 6. These personal identifiers were maintained fixed and had to be remembered by the students during the entire activity.

As done in its previous edition, the competition took 6 weeks, and was composed of 4 rounds of 1.5 weeks each. In each round, the students had to solve a given problem by implementing a computer program. The topics of the posed problems were manifold: controlling the turbines of a hydroelectric plant, managing the stock of a pharmaceutical company, developing simple graph algorithms on a social network, and accessing and exploiting information about the road network in a GPS device. In addition to the thematic diversity, the nature of the problems changed between the first and the last pairs of rounds. In the first and second rounds, the teacher only provided the problem statements at hand, and the students had to design and implement the corresponding computer programs. In the third and fourth rounds, the teacher also provided a number of *functions* (i.e., autonomous fragments of code that offer particular functionalities)

[3] Google Docs, https://docs.google.com

that should be used by the programs to implement. In the second half of the competition, the students thus had to make a double effort, understanding and utilizing the teacher's code, and designing and implementing their programs accordingly.

Each round had 4 stages:

1. **Problem statement**. In the classroom, the teacher explains the problem to address in the round, and provides the students with the first (main) part of the problem statement. The teacher also announces the day when a second (extended) part of the problem is going to be addressed.
2. **Problem solving**. Out of the class time, during 1.5 weeks, each team has to solve the stated problem. The outcome of this stage is a computer program composed of a few functions.
3. **Problem extension**. In the classroom, on the day established in the first stage, the teacher provides the student with the second (extended) part of the problem statement, which consists of 2 small extensions of the original problem. Each team is then split into 2 sub-teams of 3 members that have to solve separately one of the two problem extensions, from now referred as questions A and B. Based on the personal identifiers (numbers from 1 to 6), the 6 students of each team T are assigned to one of the corresponding sub-teams, T_A and T_B. Moreover, in each sub-team, a student receives one of the following roles: *evaluator*, *speaker*, and *writer*. These roles are explained below.
4. **Round assessment**. Out of the class time, individually and in group, the students fill small online questionnaires to analyze and assess personal and team work, results, and conflicts during the round.

The stage 3 of a round is conducted in the classroom during a lecture time of 50 minutes, and is the most dynamic among the different round stages. Each team arrives to the classroom with several printed copies of its solution, i.e., its computer program that solves the current round's problem. Then, each team has to address 2 new questions, A and B, which are built upon the addressed problem. For such purpose, the students have to accomplish the following tasks:

3.1. **Sub-team, role and question assignment**. At the beginning of the stage, the teacher splits each team into 2 sub-teams, T_A and T_B, of 3 members, using the students' identifiers. Each sub-team receives a) the statement of a question (A or B) to solve, b) the assignment of a location in the classroom where the round *meetings* have to be done, and c) report sheets in which question solutions and evaluations have to be reported. In each sub-team, a student is assigned a role – evaluator, speaker or writer–, according again to her personal identifier.

It is important to note that during the competition, a rotation schema is followed for the sub-team and role assignments, so any student has to collaborate (at least once) with most of his 5 team mates, and has to play (at least once) each of the 3 considered roles. Table 2 shows the sub-team and role assignments for a student in the different competition rounds.

Table 2. Sub-team and role assignments for each member (1-6) of a team in the competition rounds. The students collaborate with different team mates, and play all the competition roles, according to a rotation schema.

	Sub-team T_A			**Sub-team T_B**		
	Evaluator	**Speaker**	**Writer**	**Evaluator**	**Speaker**	**Writer**
Round 1	1	2	3	4	5	6
Round 2	6	1	2	3	4	5
Round 3	5	6	1	2	3	4
Round 4	1	2	4	3	5	6

All the above information –question statements, team meeting locations, sub-team and role assignments, solution and evaluation sheets– is provided in printed documents gathered in a plastic folder, to each team just when (some of) its members arrive to the classroom. We do provide examples of these documents in the appendices of this paper.

3.2. **Question solving**. [20 minutes]. All the members of each sub-team meet to cooperatively solve the corresponding question, A or B.

3.3. **Question evaluation I**. [10 minutes] Several tasks are done in parallel:

- Meetings of *evaluators* belonging to sub-teams A of 3-4 different teams.

  Each evaluator briefly presents the solution obtained by her sub-team A. After all evaluators conclude their presentations, they discuss the different solutions. Then, each evaluator assesses the solutions of the other sub-teams, assigning them numeric marks between 0 and 10, and writing a short paragraph arguing these marks.

- Meetings of *evaluators* belonging to sub-teams B of 3-4 different teams.

  These meetings are equivalent to those done by evaluators of sub-teams A.

- Meetings of non-evaluators.

  The rest of members (speakers and writers) of each team have meetings in which they discuss the solutions obtained by the team. The *writers* start to make reports with the solutions obtained by their sub-teams.

3.4. **Question explanation**. [5 minutes]. The 2 sub-teams of each team have a single meeting. The *speakers* (A and B) explain the solutions of their questions to the evaluators of the other sub-teams (B and A), in a cross way fashion.

3.5. **Question evaluation II**. [15 minutes]. Several tasks are done again in parallel.

- Meetings of *evaluators* belonging to sub-teams A of 3-4 different teams.

  The *evaluators* of several sub-teams A do meet again, but now they present their team's solutions to question B, to which they did not contribute at stage 3.2. Similarly to that stage, each evaluator assesses the solutions of the other sub-teams, assigning 0-10 marks and writing a short paragraph arguing these marks

- Meetings of *evaluators* belonging to sub-teams B of 3-4 different teams.

  These meetings are equivalent to those done by evaluators of sub-teams A.

- Meetings of non-evaluators.

  The rest of members (speakers and writers) of each team have meetings in which they finish discussing the solutions obtained by the team. The *writers* conclude the reports with the solutions obtained by their sub-teams.

Table 3 shows the assignments of teams to meetings in the stage 3 of the different rounds of the competition. As done in the sub-team and role assignment processes, the assignment of teams to meetings is done following a rotation schema, which lets each team to be evaluated by most of the other participants.

Table 3. Meeting assignment of the teams (1-10) in the different competition rounds, according to a rotation schema.

	Evaluation meeting #1			**Evaluation meeting #2**			**Evaluation meeting #3**			
Round 1	1	2	3	4	5	6	7	8	9	10
Round 2	1	6	2	7	3	8	4	9	5	10
Round 3	1	8	5	2	9	6	3	10	7	4
Round 4	1	6	4	9	2	7	5	10	3	8

In order to assure an effective completion of all the tasks in stage 3, the teacher has to maintain an exhaustive supervision and management of the whole process, especially when announcing time progress, task changes, and meeting locations. Nonetheless, of a particular interest is the fact that in the fourth round of the conducted competition, unexpectedly, the teacher did not need to take care of the activity at all. The students were aware of the different tasks in the stage, and perfectly knew how, when, where, and with whom they had to do these tasks. The teacher was just a spectator of what was happening in the classroom.

At the end of stage 3, the teacher asks each team for a printed copy of the solution obtained for the main problem (stage 2), the report sheets made by the *writers* with the solutions achieved for extended questions A and B, and the assessment sheets made by the *evaluators*. Afterwards, the teacher evaluates assigning numeric marks to all the main problem and extended question solutions. With the marks provided by the teacher and students, a score value is computed for each team. We provide details about the used scoring formula in Subsection 4.3.

Once finished the 4 rounds of the competition, at a short ceremony celebrated in the classroom, the teacher announced the winners of the contest. The winners received from the teacher the surprise prizes, consisting of small board games and bags of sweets, and kind congratulations and applauses from the rest of the students. As happened in the first edition of the activity, the winners gave sweets to all other participants, evidencing the good social atmosphere and friendship relationships originated during the competition.

To conclude this subsection, we list and briefly describe the principles followed for the design of the structure and tasks of the competition. As explained in previous sections, these principles are based on a) the definition of “healthy competition” given by Yu et al. (2002) and Shindler (2007), b) the beneficial competition features derived from the first edition of our contest (Hidden for review), and c) principal elements of Cooperative Learning (Johnson & Johnson, 1975; Johnson et al., 1988; Brown and Ciuffetelli, 2009). A healthy competition should:

- be undertaken for a symbolic value, letting students to focus on the learning process instead of on the content outcome;
- be conducted in a relative short period of time, in order to avoid losing the interest of some students, especially those in the last positions of the contest ranking;
- provide diverse topics and tasks to do, in order to challenge the students, and reinforce their motivation to continue participating;
- be characterized by all participants feeling like they have a chance to win, which could be provided e.g. with a scoring strategy that allows significant changes in the ranking positions during the competition rounds;
- assign a conspicuous value to the learning process, quality and evaluation, by e.g. performing specific self-assessment tasks;

- avoid unbalanced workload among students, and assure positive interdependence, in order to avoid situations where participants leave the activity;
- promote face to face interactions and social skills, by e.g. performing specific tasks for effective group work and oral communication;
- control the individual accountability and group processing, by e.g. asking the students to complete questionnaires of individual and group assessment.

4.3. Competition Scoring

The performance (scoring, ranking) of participants in a competition round is evaluated as follows. Let G be the groups of students who participate in the competition. The total number of groups is $|\mathrm{G}|$ (10 in the experiment). Let t be the teacher of the subject who evaluates the responses/solutions submitted by the different groups. We define $\mathrm{S} = \mathrm{G} \cup \mathrm{t}$ as the set of subjects involved in the competition, i.e., the groups of students and the teacher.

Let P, A and B be respectively the principal, 'A' and 'B' exercises/problems proposed in the round, and let R be the set of responses to such questions, with $\mathrm{r}_{g,i}$ the response to i-th question ($\mathrm{i} = \mathrm{P}, \mathrm{A}, \mathrm{B}$) given by group g. We define $\mathrm{eval}(\mathrm{s}, \mathrm{r}) \colon \mathrm{S} \times \mathrm{R} \rightarrow [0,10]$ as a function that corresponds to the numeric evaluation value given by subject s to response r. Finally, let $\mathrm{g_a}$ be the active group, i.e., the group whose score value we want to compute. The score value obtained by $\mathrm{g_a}$ is a function $\mathrm{score}(\mathrm{g_a}) \colon \mathrm{G} \rightarrow [0,10]$ defined as:

$$\mathrm{score}(\mathrm{g_a}) = \theta_{\mathrm{eval\_t}}\left(\lambda_P \cdot \mathrm{eval}\left(\mathrm{t}, \mathrm{r}_{\mathrm{g_a},\mathrm{P}}\right) + \lambda_A \cdot \mathrm{eval}\left(\mathrm{t}, \mathrm{r}_{\mathrm{g_a},\mathrm{A}}\right) + \lambda_B \cdot \mathrm{eval}\left(t, \mathrm{r}_{\mathrm{g_a},\mathrm{B}}\right)\right) +$$
$$\theta_{\mathrm{eval\_g}}\left(\frac{\sum_{\mathrm{g}\neq\mathrm{g_a}} \sum_{\mathrm{i=A,B}} \mathrm{eval}\left(\mathrm{g}, \mathrm{r}_{\mathrm{g_a},\mathrm{i}}\right)}{2 \cdot (|\mathrm{G}| - 1)}\right) +$$
$$\theta_{\mathrm{dif}}\left(10 - \frac{\sum_{\mathrm{g}\neq\mathrm{g_a}} \sum_{\mathrm{i=A,B}} \left|\mathrm{eval}\left(\mathrm{g_a}, \mathrm{r}_{\mathrm{g,i}}\right) - \mathrm{eval}\left(\mathrm{t}, \mathrm{r}_{\mathrm{g,i}}\right)\right|}{2 \cdot (|\mathrm{G}| - 1)}\right)$$

where $\theta_{\mathrm{eval\_t}}, \theta_{\mathrm{eval\_g}}, \theta_{\mathrm{dif}} \in [0,1], \sum_{\mathrm{i}} \theta_{\mathrm{i}} = 1$, are fixed parameters that weight the influence of three factors considered in the computation of the score value: the teacher's evaluation on the active group's responses, $\theta_{\text{eval\_t}}$, the other groups g's evaluations on the active group's responses, $\theta_{\text{eval\_g}}$, and the differences between the evaluations of the teacher and the active group on the responses of the rest of the groups, θ_{dif}. In the formula, the evaluations provided by the teacher on the active group's responses are also weighted for the different questions by parameters $\lambda_P, \lambda_A, \lambda_B \in [0,1], \sum_i \lambda_i = 1$. In the conducted experiment, the values of the fixed parameters were $\theta_{\text{eval\_t}} = 0.5$, $\theta_{\text{eval\_g}} = 0.3$, $\theta_{\text{dif}} = 0.2$, and $\lambda_P = 0.5$, $\lambda_A = 0.25$, $\lambda_B = 0.25$.

The final score value of a group in the competition is computed as the sum of its score values in the different rounds. The above choice of parameter values assures that there are not unfair evaluations among students. Since student evaluations are compared with the teacher's evaluations, actual better student responses obtain higher score values. The parameter setting also assures that there is a significant probability that changes may occur in the rankings of the groups until the last round of the competition. In fact, during the experiment contest, there were changes in the ranking through the rounds. Thus, almost all students felt they had the chance to win. This is shown, among many other findings and conclusions, in the analysis and discussion of the evaluation results reported in subsequent sections.

5. EVALUATION RESULTS

As explained in Section 4.2, a total of 60 students participated in the second edition of the proposed competition. The students were grouped into 10 teams of 6 members. In the remaining of the paper, the teams are identified with integer numbers from 1 to 10. Before starting the contest, the teacher assigned each student to a team in a balanced way according to the students' previous marks in the subject. In the first edition of the competition, students were allowed to create the teams by themselves. We observed that in some cases the knowledge and expertise between and within teams was too unbalanced, and that some students did not collaborate at all with their team members, who accepted that situation because of their friendship relations with the former. For the second edition of the competition, Table 4 shows the degrees in which the students knew and had worked with their team mates before starting the activity. It can be seen that although 54% of them already knew 3 or more members of their teams, only 23% of the students had worked together with 3 or more members of their teams.

Table 4. Degrees in which the students knew and had worked with their team mates before the competition.

Question	**Allowed answers**	**Responses**
How many members of your team did you know before starting the competition?	0 1 or 2 3 or 4 5	15% 31% **39%** 15%
How many members of your team had worked with you before starting the competition?	0 1 or 2 3 or 4 5	33% **44%** 23% 0%

Each round was composed of 2 main stages:

- *Problem solving stage* (stage 2 in Subsection 4.2). In this stage, for a period of 1.5 weeks, and out of the class time, the teams were asked to develop a computer program to solve a given problem. To address the problem, and implement and test their programs, the students met where and when they decided. All of them did it in the faculty labs after the daily lectures.
- *Extension questions solving stage* (stage 3 in Subsection 4.2). In this stage, during a class time of 50 minutes, the teams were asked to modify the program implemented in the previous stage in order to address a couple of new questions, which were small extensions of the original problem. As explained in Subsection 4.2, this stage was composed of several tasks to be done in the classroom, being thus much more dynamic (and complex with respect to team organizational requirements) than the problem solving stage.

The topics of the problems to solve were manifold:

- Controlling the turbines of a hydroelectric plant

- Managing the stock of a pharmaceutical company
- Developing simple graph algorithms on a social network
- Accessing and exploiting information about the road network in a GPS device

Moreover, the form of problem statements changed during the competition. In rounds 1 and 2, the teacher only provided the students with a description[4] of the problem to solve. In rounds 3 and 4, in addition to the problem description, the teacher provided the code of a number of functions to be integrated into the requested programs. We understand that the students' effort needed to deal with this last form of problem statement was higher than that needed when only having problem descriptions. We believe, however, that this change was appropriate to challenge the students, and increase their motivation in the competition. We support this opinion with conclusions derived from the previous edition of the competition (Hidden for review), where students complained about the monotony of the tasks they had to do.

As we shall present below, all the above issues –competition topics, round stages, and problem statement forms–, together with others, such as the teams' ranking positions and the members' roles, are taken into consideration in the evaluations and analysis we performed.

These evaluation and analysis were done on personal assessment data provided by the students through various online questionnaires. Specifically, the students were asked to voluntarily fill an *intermediate questionnaire* after each round, and a *final questionnaire* once the competition was ended. Respectively, 48, 38, 33 and 32 students participated in the intermediate questionnaires of stages 1, 2, 3 and 4, and 44 students expressed their opinions in the final questionnaire.

The questionnaires were created by the teacher with the Google Docs tool, and were filled by the students online at most two days after each round (for the intermediate questionnaires) or at the end of the competition itself (for the final questionnaire). They were composed of around 20 multiple choice questions to assess specific aspects of the activity, plus 1 opinion open-text question to give personal comments and

[4] The reader can find an example of problem statement as an appendix of this paper.

suggestions. The choice questions were designed in order to evaluate whether the proposed competition was really a healthy valuable, stimulant and enjoyable activity in the classroom. For such purpose, we established the following generic *evaluation components:*

- *Duration*. Was the time spent by the students on the different rounds, stages and tasks adequate?
- *Difficulty*. How difficult were the problems and extension questions to address in the different rounds? How complex was the proposed competition structure?
- *Utility*. Were the requested tasks really useful for the students' learning process and goals?
- *Motivation*. Was the competition interesting and challenging for the students?
- *Enjoyment*. Was the competition funny for the students?
- *Social atmosphere*. How was the social atmosphere within and between the teams?
- *Cooperative environment*. How was the competition appreciated by the students in terms of being a cooperative activity?
- *Competitive environment*. How was the competition appreciated by the students in terms of being a competitive activity?

We believe these evaluation components, and the methodologies we followed to assess them are generic, and may be used to evaluate other types of collaborative activities in education. As mentioned before, the evaluation of the above components is performed based on several aspects that allowed us to better discern whether the competition was beneficial or harmful for the students. Specifically, in the following, we report an analysis and discussion of the proposed components for the different competition topics, round stages, and problem statement forms, according to the teams' ranking positions and the members' roles.

5.1. Duration

The first evaluation component we analyze is the adequacy of the competition duration. Following the <Nationality hidden for review> implementation of the EHEA Bologna Accords, a student should spend at most 8 hours a week working on a particular subject, from a total of 5 subjects per semester. Taking into account that our subject has assigned a total of 5 lecture hours a week (3 and 2 hours for theory and labs lectures, respectively), and that a round is conducted in 1.5 weeks, a student should not spend more than 4.5 hours working on a competition round.

In the intermediate questionnaires, we asked the students how much time they spent on each round. The responses are summarized in Table 5. It can be seen that around 75% of the students admitted they had spent less than 4 hours in each round, and almost the rest of the students said they had spent between 4 and 6 hours. As expected, they had to dedicate more time for rounds 3 and 4, where the problem statements included both the problem description and pieces of code to use.

Table 5. Time spent by the students on each round of the competition.

		Responses			
Question	**Allowed answers**	**Round 1**	**Round 2**	**Round 3**	**Round 4**
How much time did you spend for the problem solving stage?	Between 1 and 2 hours	23%	34%	24%	**34%**
	Between 2 and 4 hours	**56%**	**50%**	**52%**	**34%**
	Between 4 and 6 hours	19%	16%	24%	29%
	More than 6 hours	2%	0%	0%	3%

In addition to the above objective data, we also asked the students for their personal opinion about the time they spent on each round of the competition. Table 6 shows the obtained responses. Around 75% of the students were satisfied with the time they spent. The rest of them admitted the time they spent was insufficient, but recognized they would not have needed much more time to complete the tasks properly.

Based on the results reported in Tables 5 and 6, we can claim that in general we achieved our goal of designing a not long activity.

Table 6. The students' opinion about the time the time they spent on each round of the competition.

Question	Allowed answers	Responses Round 1	Round 2	Round 3	Round 4
How adequate was the time you spent for the problem solving stage?	Insufficient	0%	0%	6%	3%
	Insufficient, but we would have needed only a bit of more time	8%	29%	24%	19%
	Adequate	**92%**	**72%**	**70%**	**75%**
	Excessive, but we could do the tasks quite well spending that time	0%	0%	0%	3%
	Excessive	0%	0%	0%	0%

5.2. Difficulty

Related to the adequacy of the competition duration, we now analyze the degree of difficulty of the activity, according to several aspects: the difficulty of the problems to solve, the difficulty of working in group, and the difficulty of understanding and managing organization issues in the classroom.

After each round, in the intermediate questionnaires, we directly asked the students for their opinion about the difficulty of the competition problems and extension questions. Table 7 summarizes the obtained responses. Regarding the main problems, in rounds 1 and 2, around 50% of the students said that the problems were neither difficult nor easy, and around 35% expressed the problems were difficult. In rounds 3 and 4, the previous percentages swap. Regarding the extension questions, close to 50% of the students said that the problems were neither difficult nor easy in all the rounds. Moreover, the percentage of students admitting the questions were easy or very easy (around 10%) was higher than that of the problem solving state, again for all the rounds.

In any case, since just a few students claimed that the problems were too difficult, and 45-60% of the students were very satisfied with the problem and extension question complexities, the established problem difficulty degree can be considered as acceptable.

Table 7. The students' opinion about the difficulty degree of the problems and extension questions in each stage and round of the competition.

Question	Allowed answers	Responses			
		Round 1	Round 2	Round 3	Round 4
How difficult was the problem of the round?	Very difficult	0%	5%	3%	9%
	Difficult	35%	37%	**51%**	**50%**
	Neither difficult nor easy	**59%**	**47%**	43%	31%
	Easy	4%	11%	3%	10%
	Very easy	2%	0%	0%	0%
How difficult were the extension questions of the round?	Very difficult	2%	3%	6%	3%
	Difficult	35%	40%	39%	31%
	Neither difficult nor easy	**55%**	**44%**	**49%**	**44%**
	Easy	6%	13%	6%	13%
	Very easy	2%	0%	0%	9%

We also asked the students how difficult the fact of working in group was. As shown in Table 8, in all rounds, more than 80% of the students said working in group was not difficult at all. In the case of the extension question solving stage, there was a slightly higher number of students who admitted some difficulties. This is understandable, since the tasks of that stage required much more effort and coordination within and between teams, and also added pressure to finish them in a short period of time of 50 minutes.

Table 8. The students' opinion about the difficulty degree of working in group for each stage and round of the competition.

Question	Allowed answers	Responses			
		Round 1	Round 2	Round 3	Round 4
How difficult was working in group during the problem solving stage?	Very difficult	0%	0%	0%	0%
	Difficult	8%	16%	18%	9%
	Neither difficult nor easy	**84%**	**79%**	**76%**	**88%**
	Easy	6%	5%	6%	0%
	Very easy	2%	0%	0%	3%
How difficult was working in group during the extension question solving stage?	Very difficult	0%	0%	0%	0%
	Difficult	10%	29%	24%	9%
	Neither difficult nor easy	**77%**	**60%**	**58%**	**72%**
	Easy	11%	11%	12%	9%
	Very easy	2%	0%	6%	9%

Finally, we asked the students for the difficulty associated to the organization issues of the extension question solving stage. As explained in Subsection 4.2, in this stage, the students had to split each team into sub-teams, solve a couple of exercises, attend different meetings to discuss the obtained solutions, and integrate the outcomes of such meetings, in only 50 minutes. The stage is thus very dynamic, making the students to move around different locations in the classroom. Despite these obstacles, as shown in Table 9, only around 5% of the students expressed that organization issues in the classroom has been difficult. This is, without any doubt, due to the fact that the teacher controlled exhaustively the process, supervising the students' work, and announcing the changes of tasks and locations[5]. Obviously, the percentage of students who found the organization issues as easy or very easy increased over time. In round 4, there was no student saying the stage was difficult, and 81% of students admitted it was easy or very easy. In fact, as already mentioned, during this last round, the teacher did not had to control and manage the stage tasks at all, since the students themselves were perfectly taking care of them.

Table 9. The students' opinion about the difficulty degree of organization issues in the classroom for each round of the competition.

		Responses			
Question	**Allowed answers**	**Round 1**	**Round 2**	**Round 3**	**Round 4**
How difficult were the organization issues (task changes, meetings, etc.) in the classroom during the extension question solving stage?	Very difficult	0%	0%	0%	0%
	Difficult	4%	5%	6%	0%
	Neither difficult nor easy	**69%**	39%	24%	19%
	Easy	21%	**51%**	**64%**	**69%**
	Very easy	6%	5%	6%	12%

5.3. Utility

One of the most important components we wanted to evaluate from the competition was its learning utility, i.e., its contribution to the students' learning process. Without focusing on assessing the explicit (quantity and quality of) learning goals (concepts and skills) achieved by the students in/with the activity, we were interested in analyzing the influence of the activity on the students' learning process itself. We believe the achievement

5 In the appendix section, at the end of the paper, the reader can find an example of meeting location sheet provided to the students.

of explicit, personal learning goals was evaluated through the different exams, tests, exercises and labs of the subject. We further discuss this issue in Section 6. Here, we propose to evaluate the competition utility in two ways: firstly, in terms of how the students felt they had contributed to their team mates' learning process, and secondly, regarding how the students perceived the others had contributed to their own learning process.

Table 10 shows the students' satisfaction with their contribution and collaboration with their team mates. In general, almost all the students (around 90%) were satisfied or very satisfied. In the last two rounds, the degree of satisfaction was a bit lower in some cases. Due to the higher difficulty of the tasks in these rounds, those students with more knowledge and expertise took more responsibilities within the teams, and some of the other students felt their contribution was lower than in the previous rounds. We noticed cases of leadership during the tasks done in the classroom, and in some of the comments provided by students in the intermediate questionnaires. It is important to note that the emergence of leaders was positive thanks to the cooperative learning based design of the activity. The "leaders" were very interested in doing the team tasks as good as possible. In this context, since the success of a team did depend on the work done by all its members, the leader worried about and helped to their team mates, usually explaining them how to do the tasks correctly, and addressing their questions and doubts. In a reciprocal way, the team mates, motivated by the interest and effort of their leader, tried to do their best for the team. This is, in our opinion, one of the most notorious positive results we obtained through the presented competition.

Table 10. The students' satisfaction with their contribution and collaboration in their teams for each round.

		Responses			
Question	**Allowed answers**	**Round 1**	**Round 2**	**Round 3**	**Round 4**
How satisfied are you with your contribution and collaboration in the team?	Very unsatisfied	0%	0%	2%	2%
	Unsatisfied	2%	7%	10%	13%
	Satisfied	**63%**	**57%**	**54%**	**47%**
	Very satisfied	35%	36%	34%	38%

In a somehow opposite way to the previous analysis, we asked the students for their satisfaction with the competition as an activity to allow and/or help them achieving individual learning goals. Specifically, we asked them how useful the team work had been for their learning process. In this case, we are interested in analyzing the students' responses with respect to their positions in the competition ranking. We want to check whether or not the activity profits are influenced by the different contest results. Or in other words, we want to check whether the competition was beneficial or harmful for all or some students (those in the first/last ranking positions). For such purpose, we use a different representation of the students' responses. As shown in Table 11, the 5 allowed answers are sorted from a negative to a positive connotation, and are assigned values from 1 to 5, accordingly.

Table 11. Allowed answers and values for the students' opinion about the competition utility on their learning process/goals.

Question	Allowed answers	Values
How useful was the team work for your learning process/goals?	Not useful at all	1
	Not useful	2
	Useful	3
	Rather useful	4
	Really useful	5

With this representation, we first analyze the competition utility in the different rounds and stages. We compute the average response values; results close to 1 mean the competition is seen as not useful at all, whilst results close to 5 mean the competition is seen as really useful by the students. Table 12 shows the obtained results. It can be seen that in general the completion was considered as rather useful. We observe there are not significant satisfaction differences among the rounds, but a slightly higher satisfaction in the extension question solving stage. This may evidence that students appreciate doing cooperative activities in the classroom, quite distinct to the theory lectures they are used to have.

Table 12. The students' values of the competition utility on their learning process in each round and stage.

	Problem solving stage	Extension question solving stage	Round (average)
Round 1	3.83	3.87	3.85
Round 2	3.53	3.68	3.61
Round 3	3.70	3.73	3.72
Round 4	3.72	3.91	3.82
Average	3.69	3.80	3.75

Once verified there were no differences on the students' perception of the competition utility during the rounds, we proceed to check whether or not there were differences on the competition utility for the students with respect to the ranking position of their teams. In each round, we compute the average utility values for the teams. Based on these average values, we sort the teams in a decreasing order. Table 13 shows the obtained results. The row associated to a round contains the list of 10 teams sorted by their average satisfaction. The integer numbers in the cells correspond to the ranking positions of the teams. For instance, in round 1, the team who assigned the highest utility value to the competition was the team in the 4th position. If the competition ranking had affected the students' perception of the competition utility, we could expect e.g. that the teams in the last ranking positions (8th-10th) would assign the lowest utility values. As shown in Table 13, this does seem to be the case. It is true there is a slight tendency of top ranked teams to assign higher utility values –the average raking position for the 5 highest utility values is 4.6 (4.8), and the average ranking position for the 5 lowest utility values is 6.5 (6.2). However, we believe this tendency is not significant enough to represent an evidence of a harmful activity. We shall support this statement in subsequent subsections with additional ranking based analyses of other evaluation components.

Table 13. The teams' ranking positions sorted by decreasing average utility value assigned to the competition in each round and stage.

	Problem solving stage (out of the class time)									
	Higher utility									**Lower utility**
Round 1	4	2	7	3	8	10	1	5	9	6
Round 2	4	9	6	2	5	8	10	1	3	7
Round 3	4	2	1	5	10	3	6	8	7	9
Round 4	4	2	9	3	1	8	6	7	10	5
Averages	4.0	3.8	5.8	3.3	6.0	7.3	5.8	5.3	7.3	6.8
	4.6					6.5				

	Extension questions solving stage (in the classroom)									
	Higher utility									**Lower utility**
Round 1	1	4	10	9	3	8	2	7	5	6
Round 2	4	2	8	1	9	5	7	10	6	3
Round 3	1	7	3	2	9	4	5	10	6	8
Round 4	9	2	1	5	6	8	10	4	7	3
Averages	3.8	3.8	5.5	4.3	6.8	6.3	6.0	7.8	6.0	5.0
	4.8					6.2				

5.4. Motivation

The students' motivation, its evolution through the competition rounds, and its dependency with the team ranking positions, are very interesting and important components to evaluate. After each round, in the intermediate questionnaires, we asked the students how their motivation degree to continue participating in the competition was. Fortunately, as show in Table 14, in all the rounds, only around 5% of the students were not motivated enough, whilst around 75% of the students said they had been highly or very highly motivated. Moreover, we observe a significant increasing of the motivation after round 3. This could be due to the change on the problem statement form we did for the second half of the contest. In fact, some students commented in the questionnaires that they really liked to use code provided by the teacher, and thus implement more complex, useful, and realistic programs.

Table 14. The students' motivation to continue participating in the activity for each round.

Question	Allowed answers	Responses		
		Round 1	Round 2	Round 3
How is your motivation to address the next round in the competition?	Very low	0%	2%	0%
	Low	4%	5%	5%
	Neither low nor high	23%	26%	21%
	High	**66%**	**56%**	**62%**
	Very high	8%	11%	12%

Similarly to the analysis of the competition utility for the students' learning process, in the following, we analyze the students' motivation in the competition with respect to the ranking positions of their teams. Table 15 shows that, fortunately, there are not divergences on the motivation degree of students in the first and last ranking positions of the contest during the different rounds. Note that the average raking position for the 5 highest motivation values is 5.3, and the average ranking position for the 5 lowest motivation values is 5.7. Hence, in the last rounds, the students in the last ranking positions were still motivated to continue participating in the competition, although they knew they had no or few chances to win. This evidences that we achieved our goal of organizing a healthy competition where students are focused on the learning process instead of on the victory, and are motivated to achieve their learning goals. In the next subsection, we shall show that the students also enjoyed much participating in the competition.

Table 15. The teams' ranking positions sorted by decreasing average motivation to continue participating in the competition after each round and stage.

	Problem solving stage (out of the class time)									
	Higher motivation									Lower motivation
Round 1	4	2	3	7	5	8	10	1	6	9
Round 2	4	9	1	5	6	3	8	2	7	10
Round 3	8	3	6	10	7	4	1	2	5	9
Round 4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Averages	5.3	4.7	3.3	7.3	6.0	5.0	6.3	1.7	6.0	9.3
	5.3					5.7				

To better clarify whether the students' motivation to continue participating in the competition was due to the achievement of learning goals, and not to winning the competition, we asked the students for several motivation reasons, which are shown in Table 16. Specifically, we asked the students to evaluate 3 motivation reasons related to their learning process and goals –learning computer programming, passing the subject, and obtaining a high mark in the subject–, and 2 motivation reasons related to winning the competition and its surprise prize. The students had to evaluate all these reasons by assigning relevance numeric values from 1 (very insignificant) to 5 (very important).

Table 16. Allowed answers and values for the students' opinion about their motivation to continue participating in the competition.

Question	Allowed answers	Values
How important are the following issues to continue participating in the competition?	Very insignificant	1
	Insignificant	2
	Neither insignificant nor important	3
	Important	4
	Very important	5

Table 17 shows the students' average relevance values for the different motivation reasons in each round. It can be seen that the most important motivations of the students were passing the subject (4.71) and learning computer programming (4.54), whilst winning the competition and the surprised prize were in general evaluated as neither insignificant nor important, with 3.15 and 3.02 relevance values, respectively. Note also that over time, the motivation for learning achievements increases and the motivation for winning the competition decrease

Table 17. The students' average relevance values of the motivation reasons for continuing participating in the competition after each round.

	Motivation reasons				
	Learning computer programming	**Passing the subject**	**Obtaining a high mark in the subject**	**Winning the surprise prize**	**Winning the competition**
Round 1	4.42	4.69	4.51	3.29	3.12
Round 2	4.65	4.68	4.39	2.92	3.26
Round 3	4.54	4.76	4.54	2.84	3.06
Round 4	N/A	N/A	N/A	N/A	N/A
Average	4.54	4.71	4.48	3.02	3.15

We finally analyze the motivation reasons of students with respect to the ranking positions of their teams. Table 18 shows the average relevance values assigned to the considered reasons, ordered by the teams' ranking positions. We do not find differences on the ranking based relevance values for learning motivation reasons, but see an obvious higher motivation for the top ranked teams (1st-3rd) for winning the competition.

Table 18. The teams' average relevance values assigned by the students to the different motivation reasons, ordered by ranking positions.

	Motivation reasons				
Ranking position	**Learning computer programming**	**Passing the subject**	**Obtaining a high mark in the subject**	**Winning the surprise prize**	**Winning the competition**
1	4.61	4.81	4.46	3.31	3.62
2	4.32	4.67	4.30	3.43	3.55
3	4.88	4.76	4.57	3.08	3.01
4	4.74	4.67	4.53	2.64	2.82
5	4.39	4.78	4.89	2.61	2.72
6	4.22	4.44	4.83	2.89	2.39
7	4.20	4.60	4.43	2.67	2.33
8	4.47	4.92	4.13	2.45	2.13
9	4.44	4.78	3.78	2.22	2.11
10	4.73	4.67	4.65	2.54	2.28
1-3	4.60	4.75	4.44	3.27	3.39
4-6	4.45	4.63	4.75	2.71	2.64
7-10	4.46	4.74	4.25	2.47	2.21

5.5. Enjoyment

At this point, we have seen that the conducted competition was balanced in terms of duration and difficulty, and was evaluated as useful and stimulating by the students within their learning process. The next question we wanted to address was whether the students also had fun in the activity. In both intermediate and final questionnaires, we asked the students for their degree of enjoyment. On average, only 14% of the students did not have fun in the activity. Table 19 shows the allowed enjoyment degree values they could expressed, from very boring to very funny.

Table 19. Allowed answers and values for the students' opinion about their enjoyment in the competition.

Question	Allowed answers	Values
How funny was the round?	Very boring	1
	Boring	2
	Neither boring nor funny	3
	Funny	4
	Very funny	5

Table 20 shows the average enjoyment degrees expressed by the students in the intermediate questionnaires after each round. It can be seen that they had more fun in rounds 1 and 4, whose topics were controlling the turbines of a hydroelectric plant, and accessing and exploiting information about the road network in a GPS device. They also enjoyed round 3, in which they had to implement several simple graph algorithms on a social network. The enjoyment in this round, however, was lower because of its higher difficulty. The topic of rounds 2, which was developing a program to manage the stock of a pharmaceutical company, was the less appreciated by the students. The final questionnaire, on the other hand, shows a slight different result, with a lower enjoyment for round 1. In any case, it seems clear that the students had more fun in the second part of the competition. This could be due to both the problem topics and statement forms. Finally, we have to note that the enjoyment in the extension question solving stage, which was done in the classroom, was higher than that in the problem solving stage. This was explicitly expressed by some of the students in the personal comments provided in the questionnaires.

Table 20. The students' average enjoyment values in each round and stage of the competition.

	Problem solving stage	Extension question solving stage	Round (average)	Final	Topic
Round 1	3.83	3.87	**3.85**	2.95	2.82
Round 2	3.53	3.68	3.61	3.05	2.91
Round 3	3.70	3.73	3.72	**3.18**	2.93
Round 4	3.72	3.91	**3.82**	3.07	**3.07**
Average	3.69	3.80	3.75	3.06	

In this case, we also wanted to check the students' enjoyment with respect to the performed roles. As expected, the evaluators seem to be those that more fun had in the activity (Table 21). The *evaluator* was the most dynamic role, and although it carried the highest workload in the classroom, it was the best appreciated role by the students. In any case, we do not find significant differences between the students' enjoyment with respect to their roles, so we may say that all participants were happy with the tasks they were in charge in each round.

Table 21. The students' average enjoyment values, for each role considered in the competition.

Role	**Average**
Evaluator	**3.12**
Speaker	3.02
Writer	3.04

Finally, we extend the enjoyment analysis by taking into consideration the ranking positions of the teams. We show the results in Table 22. Surprisingly for us, the students belonging to the teams in the last ranking positions seem to be the ones that had more fun in the competition, especially in the extension question solving stage. Note that the average raking position for the 5 highest enjoyment values is 5.6, which is greater than the average ranking position for the 5 lowest enjoyment values, i.e., 5.4. We hypothesize that this could be due to the fact that top ranked teams were somehow more stressed and focused on winning the competition, and thus enjoyed less the activity. We did not considered stress as an evaluation component, and we did obtain no comments about it from the students. In any case, the differences of enjoyment values with respect to ranking positions are small, so we could conclude that we designed a funny activity. We remind that this was not obtained in the first edition of the competition (Hidden for review), and thus was one of our main goal for the contest presented herein.

Table 22. The teams' ranking positions sorted by decreasing average enjoyment in each round and stage of the competition.

	Problem solving stage (out of the class time)									
	Higher enjoyment									**Lower enjoyment**
Round 1	4	8	3	2	5	**10**	7	9	6	**1**
Round 2	8	4	6	5	**1**	3	**10**	2	9	7
Round 3	**10**	6	5	2	**1**	8	3	4	7	9
Round 4	5	3	2	**10**	8	**1**	9	6	4	7
Averages	6.8	5.3	4.0	4.8	3.8	5.5	7.3	5.3	6.5	6.0
	4.9					6.1				

	Extension questions solving stage (in the classroom)									
	Higher enjoyment									**Lower enjoyment**
Round 1	4	**10**	7	6	3	2	8	5	9	**1**
Round 2	4	3	6	5	9	2	8	**10**	**1**	7
Round 3	8	**10**	3	6	5	2	4	**1**	7	9
Round 4	5	6	9	**1**	2	4	3	**10**	8	7
Averages	5.3	7.3	6.3	4.5	4.8	2.5	5.8	6.5	6.3	6.0
	5.6					5.4				

5.6. Social Atmosphere

Another important component taken into account in our evaluation is the social atmosphere surrounding the competition. As shown in Table 23, most of the students agreed there was a good or very good social atmosphere within and among the teams. It is also notorious that this generalized opinion increased in strength over time, even though the students were competing against each other. We did not find discrepancies in the students' opinions on the social atmosphere for the tasks done out of the class time and in the classroom. We thus believe the students could manage group conflicts in the problem solving state. Nonetheless, for future editions of the competition, we plan to conduct a supervision of the individual tasks done by each team member out of the class. We discuss this in the last section of the paper.

Table 23. The students' option about the social atmosphere surrounding the competition in each round and stage.

Question	Allowed answers	Responses			
		Round 1	Round 2	Round 3	Round 4
How was the social atmosphere in the team during the problem solving stage?	Very bad	0%	0%	0%	0%
	Bad	0%	0%	0%	0%
	Neither bad nor good	6%	5%	18%	16%
	Good	**58%**	**82%**	**67%**	**62%**
	Very good	36%	13%	15%	22%
How was the social atmosphere in the team during the extension question solving stage?	Very bad	0%	0%	0%	0%
	Bad	0%	0%	0%	0%
	Neither bad nor good	6%	10%	12%	6%
	Good	**67%**	**66%**	**64%**	**66%**
	Very good	27%	24%	24%	28%

5.7. Cooperative Environment

To conclude our analysis, we propose to evaluate aspects related to the cooperative and competitive nature of the proposed activity. In this subsection, we evaluate several issues concerning the cooperation between team members. In the next subsection, we shall evaluate the effects of incorporating a competitive environment in the classroom.

We asked the students a couple of questions about the work done within their teams. First, we asked them whether or not they were satisfied with the results obtained by their teams. Second, we asked them how balanced the workload among the teams' members had been. Table 24 shows the allowed answers, and corresponding values, for the above questions.

Table 24. Allowed answers and values for the students' opinions about their satisfaction with their teams' work, and about the workload balance among team members.

Question	Allowed answers	Values
How much satisfied are you with work done by the team?	Very unsatisfied Unsatisfied Satisfied Very satisfied	1 2 3 4
How much balanced was the workload of the members of the team?	Very unbalanced Unbalanced Balanced Very balanced	1 2 3 4

Table 25 shows the average satisfaction values. In general, the students were quite satisfied with the work done by their teams. This satisfaction is a bit lower in the rounds of the second half of the competition. As explained in Subsection 5.1, some students recognized they should had to spend more time in finding better solutions to the more difficult problems addressed in the above rounds.

The table also summarizes the students' opinions about the balance of the workload among the teams' members. The results show that in general there were not unbalanced situations. This conclusion, however, may be biased by the fact that in the extension question solving stage, the tasks were equally assigned and supervised by the teacher. A supervision of the tasks done in the problem solving stage should be conducted as well. In any case, thanks to the cooperative learning based design of the competition, we could guarantee that at the beginning of a classroom stage, all the members of a team had at least to know what had been done in the precedent stage out of the class time.

Table 25. The students' average satisfaction with the work results and workload balance in their teams for each round.

	Work satisfaction	Workload balance
Round 1	3.32	3.22
Round 2	3.29	3.31
Round 3	3.18	2.97
Round 4	3.18	3.09
Average	3.24	3.15

In addition to the work satisfaction and workload balance within each team, we also wanted to measure the degree of collaboration and help among team members. We asked the students how much cooperation did exist in their teams. Table 26 shows the allowed answers and corresponding values.

Table 26. Allowed answers and values for the students' opinions about the degree of collaboration and help within their teams.

Question	Allowed answers	Values
Which was the degree of collaboration and help among the team members?	Very low	1
	Low	2
	Neither low nor high	3
	High	4
	Very high	5

Table 27 shows the average collaboration values in each round and stage. These results indicate that, in general, there was a quite high degree of collaboration within the teams –an overall average value of 3.56. However, they also may evidence two weaknesses of the competition. First, the students' collaboration in the problem solving stage (3.38) was significantly less than in the extension question solving stage (3.75). This confirms the need of defining and supervising specific cooperative learning tasks for out of the class time. In Section 5, we shall discuss this limitation and propose several ideas to address it. Second, the collaboration tends to decrease over time. We do not have a clear explanation for this issue. For instance, we may argue that more collaboration is needed in the last two rounds since they are the most difficult ones but, on the other hand, we could also argue that in these rounds, less collaboration is needed since the students' knowledge and expertise are higher, and they thus can be more autonomous and independent to do their tasks. In any case, we cannot confirm whether this collaboration decreasing behavior was indeed harmful for the students.

Table 27. The students' opinions about the degree of collaboration and help within their teams in each round and stage.

	Problem solving stage	**Extension question solving stage**	**Round (average)**
Round 1	3.75	3.90	3.83
Round 2	3.34	3.69	3.52
Round 3	3.24	3.70	3.47
Round 4	3.19	3.72	3.46
Average	3.38	3.75	3.56

Analyzing the degree of collaboration with respect to the ranking, we do not find any insight that higher collaboration occurred in first or last ranked teams. In fact, as we can see in Table 28, for the problem solving stage, the average raking position for the 5 highest collaboration values (5.7) is greater than the average ranking position for the 5 lowest collaboration values (5.3), while, on the contrary, for the extension question solving stage, the average raking position for the 5 highest collaboration values (5.0) is lower than the average ranking position for the 5 lowest collaboration values (6.0).

Table 28. The teams' ranking positions sorted by decreasing average degree of collaboration in each round and stage of the competition.

	Problem solving stage (out of the class time)									
	Higher collaboration									**Lower collaboration**
Round 1	5	9	4	3	**10**	**1**	2	5	8	7
Round 2	8	9	6	3	**10**	4	5	2	**1**	7
Round 3	**10**	3	**1**	2	8	6	5	4	7	9
Round 4	3	8	4	**1**	6	**10**	2	5	9	7
Averages	6.5	7.3	3.8	2.3	8.5	5.3	3.5	4.0	6.3	7.5
	5.7					5.3				

	Extension questions solving stage (in the classroom)									
	Higher collaboration									**Lower satisfaction**
Round 1	**1**	5	**10**	2	9	3	4	7	8	6
Round 2	3	8	2	5	9	**10**	**1**	5	7	4
Round 3	3	**1**	8	**10**	2	5	7	4	9	6
Round 4	**1**	6	4	3	8	9	2	5	**10**	7
Averages	2.0	5.0	6.0	5.0	7.0	6.8	3.5	5.3	8.5	5.8
	5.0					6.0				

Finally, we explicitly asked the students for their opinion on doing cooperative group activities in the classroom. As shown in Table 29, there was a generalized agreement: 96% of the students said cooperative group activities are beneficial or very beneficial, and the remaining 4% of the students said this type of activities is neither harmful nor beneficial.

Table 29. The students' option about whether group activities in the classroom are harmful or beneficial.

Question	Allowed answers	Responses
What is your opinion about doing cooperative group activities in the classroom?	It is very harmful	0%
	It is harmful	0%
	It is neither harmful nor beneficial	4%
	It is beneficial	**76%**
	It is very beneficial	20%

5.8. Competitive Environment

In this subsection, we reach the evaluation component that motivates the study presented herein, namely the competitive nature of the proposed learning activity. At this point, nonetheless, according to the results and conclusions derived from the ranking based analysis of previous components (utility, motivation, enjoyment, and collaboration), we already can claim that the designed competitive environment was not harmful for the students. We showed that in general there were no significant differences on the above components' evaluation values within teams in the first and last ranking positions during the competition rounds. The students were thus focused on the learning process and goals underlying the activity, and not on the contest's outcomes (victory and prizes). However, thanks to the existing healthy competitive environment, the students enjoyed participating in the activity, and were motivated to do their best on behalf of their teams.

Despite these observations, in the final questionnaire at the end of the contest, we explicit asked the students for their opinion about whether or not the competitive environment was harmful or beneficial for them. Table 30 summarizes the obtained responses. It shows that 57% of the students said a competition in the classroom is beneficial or very beneficial, whilst 41% of the students said it is neither harmful nor beneficial. Only one student (the remaining 2%) stated that a competition in the classroom is harmful. In the questionnaire, she commented there were some conflicts within her team in the second round. We believe this could be a reason of her opinion about the competition. In any case, this is a particular incident; in general, it seems that students were happy with the proposed activity.

Table 30. The students' option about whether competitive activities in the classroom are harmful or beneficial.

Question	Allowed answers	Responses
What is your opinion about doing this activity as a competition?	It is very harmful	0%
	It is harmful	2%
	It is neither harmful nor beneficial	41%
	It is beneficial	**50%**
	It is very beneficial	7%

To reinforce this claim, we finally asked the students whether they would recommend the competition to be done again in the subject, and in other subjects. As shown it Table 31, all the students (including the one who said that competitions are harmful) suggested doing the competition in the subject next year, and 93% of the students suggested doing this type of competitive activities in other subjects.

Table 31. The students' suggestions for doing the competition in the subject again, and in other subjects.

Question	Allowed answers	Responses
Would you recommend this competition to be done in the subject next year?	No	0%
	Yes	**100%**
Would you recommend this type of competitive activities to be done in other subjects?	No	7%
	Yes	**93%**

6. DISCUSSION

The competition presented herein was designed upon the lessons learnt in a previous experience (Hidden for review), whose results were encouraging. The *duration* and *difficulty* of the proposed tasks were evaluated as adequate by 81% and 69% of the students, respectively. The activity *utility* to achieve individual learning goals was evaluated as useful by 71% of the participants, and the *cooperative* and *competitive* environments of the activity were evaluated positively by 94% and 71% of the students, respectively. The bad result was that 41% of the students did not *enjoy* the competition, especially during the last rounds. Despite this result, in the end, 82% of the participants recommended continuing organizing the competition in the subject. In the new edition of the competition, we obtained better results. Around 75% of the students were satisfied with the *time* spent in the activity, and the others admitted the time spent was insufficient, but recognized they would not have needed too much more time to complete the tasks properly. Just a few students claimed that the problems were too difficult, and around 60% of the students were very satisfied with the *difficulty* of the tasks. Regarding the activity *utility*, around 90% of the students were satisfied or very satisfied. In this case, the *cooperative* and *competitive* environments were evaluated positively by nearly all the students, and only 14% of the students did not *enjoy* the activity. At the end of the activity, all participants suggested continuing organizing the competition in the subject.

In the academic years 2009-2010 and 2010-2011, in which the above editions of the competition took place, there were significant increments on the number of students who passed the subject, specifically from 71% to 77%, and on the number of students who regularly were attending the lectures after the competitions, from 60% to 80% approximately. We cannot assure these facts were only caused by the changes made to the competition structure, but believe they were influential to some extent.

Independently of the improvements obtained in terms of a higher number of students who passed the subject, based on the analysis results reported in this paper, we could claim that the changes made to the competition really were beneficial for the students. Some of these changes were based on elements and characteristics of Cooperative Learning. They can be summarized as follows. First, the students were assigned different roles and tasks within their teams during the contest rounds, and the success –score– of each team depended on the correct realization of individual tasks by the team's members (*positive interdependence*). This originated collaboration and help among team mates. Next, the students had to complete specific tasks for presenting, discussing and evaluating solutions (*face to face promotive interactions* and *social skills*). This fomented the development of transversal competences such as group work and effective oral communication. Finally, the students had to complete questionnaires of individual and group assessment during the competition (*individual accountability* and *group processing*). This helped to engage the students in the activity, focusing on the learning process and goals, instead of on contest outcomes –victory and prizes. Other changes were the development of different types of problems and exercises, to avoid decreasing motivation and enjoyment of students; and the teacher's assignment of students to teams, to avoid unbalanced workload situations where some students do not work, but are concealed by classmates, with whom they had consolidated friendship relations.

The conducted analysis, on the other hand, evidenced certain limitations and weaknesses of the proposed learning activity. First, there was a lack of supervision and evaluation of individual tasks done out of the class time, which did not allow us to assure all the members of a team collaborated equally. To address this problem we could e.g. assign specific tasks to students, such as preparing work agendas and writing meeting reports. Second, there was a lack of plans to prevent and manage team conflicts. Addressing this problem, we could avoid cases of student demotivation and non enjoyment in the activity.

7. CONCLUSIONS AND FUTURE WORK

In this paper, we have presented a learning activity consisting of a team competition. Aiming to clarify whether competitions are positive or not in education, and attempting to develop a valuable, stimulant, and enjoyable activity in the classroom, we designed our competition by following principles derived from previous studies, and by incorporating characteristics and elements of the well known Cooperative Learning methodology. Specifically, we identified the following attributes a competition in the classroom should have to be 'healthy' (non harmful) for students. It should be undertaken for a symbolic value, letting students to focus on the learning process instead of on the content outcome. It should be conducted in a relative short period of time, in order to avoid losing the interest of some students, especially those in the last positions of the contest ranking. To challenge the students, and reinforce their motivation to continue participating, the competition should provide diverse topics and tasks to do, and should be characterized by all participants feeling like they have a chance to win. It should avoid unbalanced workload among students, and assure positive interdependence, in order to avoid situations where participants leave the activity. Finally, it should promote face to face interactions and social skills, and control (assess) the individual accountability and group processing.

To identify and analyze the benefits and drawbacks of the competition, we proposed a number of evaluation components and methodologies, which could be used to design and assess other types of collaborative learning activities. In particular, we analyzed the following components: a) duration, to evaluate whether the time spent by students on each task was adequate; b) difficulty, to evaluate how complex the activity tasks and structure were; c) utility, to evaluate whether the activity was really useful for the students' learning process and goals; d) motivation, to evaluate whether the competition was interesting and challenging for the students; e) enjoyment, to evaluate how much fun the students had in the activity; f) social atmosphere, to evaluate how the students' social interactions and skills were developed; g) cooperative environment, to evaluate how the collaborative nature of the activity was appreciated by the students; and h) competitive environment, to finally evaluate how the competitive nature of the activity was appreciated by the students.

We implemented and evaluated the competition in real case study, on a subject introductory to Computer Science and computer programming, with 60 Chemical Engineering students. By asking the students to fill several questionnaires during and after the competition, we obtained assessments of the proposed evaluation components. An exhaustive analysis of these assessments showed that we effectively conducted an activity that was not harmful for the students, independently of the position of their teams in the contest ranking. Moreover, in addition to letting students to focus on the learning process and goals, instead of on the competition outcomes (victory and prizes), the activity fomented the acquisition of transversal competences, such as working in group and effective oral communication, and originated a very good social atmosphere and friendship relationships among students.

We thus believe that the proposed designing principles and evaluation components may serve to educators as a reference guide to organize other types of cooperative activities in the classroom. In our case, we are interested in incorporating gaming elements into the learning process, as done for example in (Becker, 2001; Chang et al., 2003; Philpot et al., 2005). Indeed, the idea of competition is usually linked to gaming, and games are often pleasing for any kind of student. We also plan to adapt and extend our approach to an e-learning environment. We are interested in developing software tools that help the teacher to design, manage, and evaluate the activity, and the students to do the activity tasks in a more efficient way.

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APPENDIX I: EXAMPLE OF PROBLEM STATEMENT

<University name hidden for review>, Faculty of Science
Chemical Engineering Degree, Applied Informatics 2010-2011

Cooperative activity

Problem 1: Hydroelectric plant

Description

In a hydroelectric plant, a hydraulic turbine exploits the mechanical energy of the water flowing through it to produce a rotating movement which, transferred to an axis, activates a generator that transforms the mechanical energy into electric energy.

The hydroelectric plant of Vallebonito does have two turbines G_1 y G_2, each of them with different water flows (F_1, F_2) and temperatures (T_1, T_2), which vary on time.

Each turbine is connected to two **sensors**. One of the sensors records the water flow through a turbine, measured in cubic meters per second (m^3/s). The other sensor records the turbine's temperature, measured in Celsius degrees (°C).

For certain flow and temperature values from the turbines' sensors, it is required to activate a number of **alarms**. In particular, the following alarms are established:

- $\mathbf{A_{1,F}}$ if $F_1 < 10$ m^3/s
- $\mathbf{A_{1,T}}$ if $T_1 > 50$ °C
- $\mathbf{A_{2,F}}$ if $F_2 < 25$ m^3/s
- $\mathbf{A_{2,T}}$ if $T_2 > 75$ °C

Your team is asked to develop a software **controller** to be invoked periodically. The controller will receive the sensors' records, and based on such records, will have to return a binary signal whose values represent action codes to be processed by other devices in the plant.

Specifically, the following binary **output codes** are defined:

$A_{1,F}$	$A_{1,T}$	$A_{2,F}$	$A_{2,T}$	Output code
0	0	0	0	0000
0	0	0	1	0001
0	0	1	0	0010
0	0	1	1	0011
0	1	0	0	0100
0	1	0	1	0101
0	1	1	0	0110
0	1	1	1	0111

$A_{1,F}$	$A_{1,T}$	$A_{2,F}$	$A_{2,T}$	Output code
1	0	0	0	1000
1	0	0	1	1001
1	0	1	0	1010
1	0	1	1	1011
1	1	0	0	1100
1	1	0	1	1101
1	1	1	0	1110
1	1	1	1	1111

where $A_{i,F}$ is 1 if alarm $A_{i,F}$ is activated, and 0 otherwise, and $A_{i,T}$ is 1 if alarm $A_{i,T}$ is activated, and 0 otherwise.

Tasks

You are asked to design and implement a Matlab program able to:

- control the water flow and temperature records from each turbine, generating the corresponding signals $A_{i,F}$ y $A_{i,T}$, and
- return the binary output code corresponding to the generated signals $A_{i,F}$ and $A_{i,T}$.

It is important to develop a modular and generic program, easily extensible and reusable in other hydroelectric plants with a larger number of turbines.

APPENDIX II: EXAMPLE OF EXTENDED QUESTIONS STATEMENT

<University name hidden for review>, Faculty of Science
Chemical Engineering Degree, Applied Informatics 2010-2011

Cooperative activity

Problem 1: Hydroelectric plant - extension

Sub-team and role assignment

The numbers in the tables are the member identifiers in the team.

Sub-team A		
Evaluator	**Speaker**	**Writer**
1	2	3

Sub-team B		
Evaluator	**Speaker**	**Writer**
4	5	6

Meetings of evaluators

The numbers in the tables are the team identifiers in the competition.

Meeting 1		
1	2	3

Meeting 2		
4	5	6

Meeting 3			
7	8	9	10

Question to be solved by sub-teams A

Your software controller activates a number of alarms for certain water flow and temperature record values from the sensors of the two turbines in the hydroelectric plant.

You are asked to modify the controller program in order to also receive water flow and temperature records measured in Dam^3/min (1 Dam = 10 m) and °K (0°K is equivalent to –273.15°C).

The new version of the program could thus receive water flow records F_1 y F_2 measured in either m^3/s or Dam^3/min, and water temperature records T_1 y T_2 measured in either °C or °K.

The metric unit used for each input record should be identified by using additional arguments in your program/functions.

In case the received record values are measured in Dam^3/min and/or °K, the program has to internally convert them into m^3/s and °C.

Question to be solved by sub-teams B

Your software controller activates a number of alarms for certain water flow and temperature record values from the sensors of the two turbines in the hydroelectric plant.

You are asked to modify the controller program in order to also supervise a third turbine, whose water flow and temperature records are F_3 y T_3 respectively, and whose corresponding alarms are the following:

- $\mathbf{A_{3,F}}$ if $F_3 < 15\ m^3/s$
- $\mathbf{A_{3,T}}$ if $T_3 > 65$ °C

The binary output codes of the new controller should thus take into consideration the activation of 6 alarms $\mathbf{A_{1,F}}$, $\mathbf{A_{1,T}}$, $\mathbf{A_{2,F}}$, $\mathbf{A_{2,T}}$, $\mathbf{A_{3,F}}$ and $\mathbf{A_{3,T}}$.

In case all the alarms are activated at the same time, the program should print on screen an emergency message, and invoke a function called *evacuation* (that would activate a security system in the plant).

APPENDIX III: EXAMPLE OF EVALUTION REPORT

<University name hidden for review>, Faculty of Science
Chemical Engineering Degree, Applied Informatics 2010-2011

Cooperative activity

Problem 1: Hydroelectric plant – evaluation report

Meeting number	

Fill the following table with your personal data:

Your team's name / identifier	Your sub-team (A or B)	Your name	Your signature

Evaluation meeting I – question asked to <u>your sub-team</u>

Fill the following table with your evaluation of the solutions obtained by the other teams participating in the meeting.

Other teams' names / identifiers	Evaluation marks (numeric values in [0-10])	Brief arguments for your evaluation marks

Evaluation meeting II – question asked to <u>the other sub-team</u>

Fill the following table with your evaluation of the solutions obtained by the other teams participating in the meeting.

Other teams' names / identifiers	Evaluation marks (numeric values in [0-10])	Brief arguments for your evaluation marks

APPENDIX IV: EXAMPLE OF MEETING LOCATIONS IN THE CLASSROOM