AN EXAMPLE OF HEALTHY COMPETITION IN EDUCATION

Iván Cantador

Escuela Politécnica Superior
Universidad Autónoma de Madrid
28049 Madrid, Spain
ivan.cantador@uam.es

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, enjoyable and stimulating activity in the classroom, we propose a team competition founded on techniques from the well-known Problem-based Learning and Cooperative Learning teaching strategies. Evaluating the competition in a case study with 60 first-year Engineering grade students, we show that we effectively conducted an activity that is valuable and not harmful for the students, independently of their position in the contest ranking.*

Keywords: Education, Gamification, Competition, Problem-based learning, Cooperative learning

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. It is controversial whether they 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 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. 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 (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). 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. Based on Shindler's definition and previous conclusions we obtained developing a competition in the classroom (Cantador & Conde, 2010), we state that competitions in education have to be undertaken for a symbolic value, be conducted in a relative short period of time, provide diversity on topics and tasks to do, be 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 this study, we combine such issues with problem-based and cooperative learning techniques, as explained in the next two sections.

2. PROBLEM-BASED LEARNING

Problem-based Learning (Schmidt, 1983; Hmelo-Silver, 2004) is a teaching strategy in which students learn about a subject in the context of complex, multifaceted, and realistic problems. By working through a combination of learning strategies to discover the nature of a problem, understanding the constraints and options to its resolution, defining the input variables, and understanding the viewpoints involved, students learn to negotiate the complex sociological nature of the problem and how competing resolutions may inform decision-making. In this context, the teacher (known as the tutor) acts as a facilitator of learning by providing the appropriate knowledge basis about the problem, modeling the problem resolving process, and monitoring the learning during such process. The tutor has to encourage and support the students, building their confidence to take on the problem and stretching its understanding.

Since the tasks to be solved are manifold and complex, problem-based learning activities are developed by groups of students. Problem-based learning is thus inherently social and collaborative in methodology. Students are encouraged to take responsibility for their group, and organize and direct the learning process with support from the tutor.

Trough problem-based learning, students acquire the following skills: *solving real-life problems*, *efficient problem solving*, *independent learning* (effective self-directed and self-motivated learning skills and proactive thinking), *self-monitoring*, and *team work*. These skills differ from those acquired with traditional teaching, and thus imply alternative evaluation techniques, such as *self-assessment*, *peer assessment*, *oral presentations*, and *collaborative reports*.

In this paper we propose a team competition composed of several rounds. In each round, groups of students will have to solve a given problem during a week, and afterwards, in the classroom and during one hour, they will be requested to address new small problem requirements, which will involve developing extensions of the proposed problem solution. The students will also have to monitor and assess their own work and that of other groups participating in the contest. We will also show that the activity evaluation will be conducted by using a combination of self, peer and tutor assessment strategies. In the peer assessment strategies both oral presentations and written reports will have to be done by the students.

3. COOPERATIVE LEARNING

Cooperative Learning (Johnson et al., 1988; Brown and Ciuffetelli, 2009) is a teaching strategy 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. The learning process of a particular student is thus 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, 2004). Hence, 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.

In order to being effective, Brown and Ciuffetelli (2009) establish five fundamental elements that a (formal) cooperative learning activity should have, which are presented next. 1) *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). 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. 2) *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. 3) *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. 4) *Social skills*. Students have to develop and exploit skills like leadership, decision making, trust building, effective communication, and conflict management. 5) *Group processing*. The members of each group have to analyze and assess how well goals are being achieved, and whether cooperation is being really effective. 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?

The team competition presented in this paper was designed to satisfy the above five elements of cooperative learning.

4. PROPOSED COMPETITION

The proposed competition was performed in a subject called Applied Informatics, which is taught to 1st-year Chemical Engineering grade students, and represents an introductory course to computer programming. A total of 60 students participated in the competition. The participation was not mandatory, scored with an extra maximum mark of 1 point in the subject grade, which was evaluated in a scale of 0 to 10 points. The registration process was done by each student via an online form, created by the teacher with the Google Docs tool[1]. Once the registration stage was completed, before starting the competition, the

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

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 grades in the subject. The teacher then announced the teams and their members. 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.

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) that should be used by the programs to implement, requesting the students 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 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 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*, 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.

Stage 3 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. Hence, the students have to accomplish the following tasks:

3.1. **Sub-team, role and question assignment**. 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 meetings have to be done, and c) report sheets in which 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. 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.

All the above information –question statements, team meeting locations, sub-team and role assignments, and solution and evaluation sheets– is provided in printed documents gathered in a plastic folder to each team.

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 presents the solution obtained by her sub-team A. all evaluators conclude their presentations, they discuss the different solutions. Then, each evaluator assesses the solutions of the other sub-teams, assigning them numeric grades between 0 and 10, and writing a short paragraph arguing such grades.
- *Meetings of evaluators belonging to sub-teams B of 3-4 teams*. These meetings are equivalent to those done by evaluators of sub-teams A.
- *Meetings of non-evaluators*. The rest of the 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 teams*. The evaluators of several sub-teams A 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 grades and writing a short paragraph arguing such grades.
- *Meetings of evaluators belonging to sub-teams B of 3-4 teams*. These meetings are equivalent to those done by evaluators of sub-teams A.
- *Meetings of non-evaluators*. The rest of the members (speakers and writers) of each team have meetings for finishing discussing the solutions obtained by the team. The writers conclude the reports with the solutions obtained by their sub-teams.

Table 1 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.

	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

Table 1.Meeting assignment of the teams (1-10) in the different competition rounds.

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 process, especially when announcing time progress, task changes, and meeting locations. Nonetheless, of a particular interest is the fact that in the last round, 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 interact. 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 grades to all the main problem and extended question solutions. With the grades provided by the teacher and students, a score value is computed for each team, as explained below.

Once the competition ended, at a short ceremony in the classroom, the teacher announced the winners of the contest. They received surprise prizes, consisting of small board games and bags of sweets, and kind congratulations and applauses from the rest of the students. It has to be noted that the winners gave sweets to all participants, evidencing the good social atmosphere and friendship relationships originated during the competition.

The performance (scoring, ranking) of participants in a competition round was evaluated as follows. Let G be the groups of students 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 $\mathrm{eval}(\mathrm{s}, \mathrm{r}) \colon \mathrm{S} \times \mathrm{R} \to [0,10]$ 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 $\mathrm{score}(\mathrm{g_a}) \colon \mathrm{G} \to [0,10]$ defined as:

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

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, $\theta_{\mathrm{eval\_t}}$, the other groups g's evaluations on the active group's responses, $\theta_{\mathrm{eval\_g}}$, 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 $\lambda_P, \lambda_A, \lambda_B \in [0,1], \sum_{\mathrm{i}} \lambda_i = 1$. In the conducted experiment, the values of the fixed parameters were $\theta_{\mathrm{eval\_t}} = 0.5, \theta_{\mathrm{eval\_g}} = 0.3, \theta_{\mathrm{dif}} = 0.2$, 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, as they stated in further evaluation questionnaires.

5. EVALUATION OF THE COMPETITION

The evaluation of the competition was done by analyzing personal assessment data provided by the students through various online questionnaires. Specifically, they were asked to voluntarily fill intermediate questionnaires 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 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 suggestions. The choice questions were designed in order to evaluate whether the proposed competition was really a healthy valuable, stimulating and enjoyable activity in the classroom. For such purpose, we established the following generic evaluation dimensions: *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?

Variables such as the topics, round stages, and problem statement forms, together with others, such as the teams' ranking positions and the members' roles, were taken into consideration in the analysis of results for each of the above evaluation dimensions.

Because of a lack of space, we do not report the questionnaire items we used, and the large number of statistics we analyzed from the students' responses. Next, we just summarize main 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 year in which 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 attended the lectures, 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.

Based on our analysis, we could claim that the competition really was beneficial for the students due to the following issues. First, the students were assigned distinct 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 a 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 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.

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