GAMIFICATION TO FIGHT LACK OF MOTIVATION AND HETEROGENEITY IN ENGINEERING

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Abstract

Results of the experience of the application of gamification to Engineering courses at the University of Málaga, Spain, are presented. The goal is to fight the lack of motivation and reduce the background unevenness detected in these degrees. A detailed description of the implementation is provided, dividing it into three phases: preparation, execution and monitoring. Results of the games (statistics) and students' feedback collected so far are shown for three different courses. They indicate that a good design of the games and award system is necessary to avoid loss of interest from the students. Moreover, adaptation to the context of the course (e.g., number of students) is crucial to guarantee success.

Keywords: Engineering, Gamification, Heterogeneity, Learning, Motivation.

1 INTRODUCTION

One of the main problems detected by the authors during their lectures in Engineering at the University of Málaga, Spain, is the students' lack of motivation. They are usually well motivated for practical activities, but they do not show the same interest for theoretical contents. Additionally, this is worsened by large differences in the students' skills: some of them present excellent marks and background, while others started the degree with the minimal required grade. For instance, the average cut-off mark in Engineering degrees at the University of Málaga in the academic year 2014-2015 was 6.93/10 [1]. In Spain, there are many universities whose cut-off grades in Engineering are the minimum (5/10) [2]. This situation leads to an uneven background with respect to new contents and, ultimately, makes it hard for the professor to keep everyone focused during the lesson.

Gamification, in general, refers to the “use of game mechanics in non-gaming contexts” [3]. In education, it is a strategy to convert the learning process into a funny experience, by incorporating game elements [4]. The goal is that the students work of their own accord and that the course contents are presented in a more practical way, which leads to significant learning improvements [5-7].

In order to address the previously mentioned problems of lack of engagement and background unevenness we have incorporated the use of gamification in some courses in Engineering at the University of Málaga. The main objectives of this work are the following: (i) to increase the motivation of the students through games, which can foster cognitive skills and a healthy competition, (ii) encourage the continuous effort, (iii) improve the cooperation and interpersonal relationships while seeking a balance among groups, and (iv) promote the loyalty of the students to the subject.

Specifically, we have developed a variety of group games in different courses along the term. Groups are set up according to the results obtained from an initial level test, in order to reduce skill differences among different groups and improve cooperation. They are kept unchanged during the course. In this contribution, the employed methodology and results of this experience are presented in this contribution, concretely. Therefore, the remainder of this paper is structured as follows: Section 2 outlines the methodology implemented for the study proposed in this paper, the results of which are widely discussed in Section 3, further taking into account some statistical indicators, such as for example, difficulty index. Section 4 concludes the paper and presents our future purpose.

2 METHODOLOGY

Our study's methodology is specifically structured based on three main phases (see Fig. 1): preparation, execution and monitoring. The first phase consists in designing and implementing a set of artefacts related to (i) satisfaction surveys, either of students and professors, so as to take a much more comprehensive view of the learning process, the difficulty of the technique and the
execution process; (ii) the games themselves, which have to be adapted to the particular cases of each type of engineering and of each subject; and (iii) the rules of each game. In contrast, the execution phase includes several procedures related to the management of the knowledge before test, during and after, in order to assess the evolution of the cognitive skills, the level of motivation and the degree of learning; all of them also working in the monitoring phase.

To explain each state of our methodology in detail, in the remainder of this section we describe the features of the submitted processes, as well as the benefits and problems that can be found.

2.1 Preparation

This phase focuses on specifying the satisfaction surveys to be carried out in each game milestone, which are designed based on common and general requirements to all the engineering implied (concretely two: computer sciences and telecommunication) and the subject-matters involved. These designs will be presented to all students through effective online platforms (e.g. Moodle) or interactive online tools (e.g. Google Forms) that further permits a flexible connection from anywhere, at anytime and in anyhow, as well as feedback states provided by students for improvements. A part of the process also includes a satisfaction survey to be completed by each professor so as to assess the progress of the students and the effectiveness of the learning process.

Other of the didactic elements to prepare within this state are precisely the games to be made during the current course, which do not necessarily have to be common to all the engineering and the subject-matters implicated. The reason is clear: the approach and type of game can vary according to the subjects, the contents to be taught and the motivation degree extracted from satisfaction surveys. This also means that the design of the game methodology can be different each time (e.g. trivial, quizzes) and knowledge results can vary according to the interaction with other students, the heterogeneity of each team, the application context, the personal conflicts and motivation, etc.

The design of the games entails, in turn, that each professor responsible must identify those parts that best fit the technique of gamification or those parts that require a special reinforcement for the improvement of cognitive performance. Namely, depending on these contents, the professors can identify, define and design the type of competitive game, which can be designed and presented in a digital format and through the current ICT tools, such as Socrative [9] or Kahoot [10]. The core and construction of these games can be from the development of practical exercises and problem solving to interactive games such as, for example, trivia or quizzes.

As a previous state to the execution of the tests, the rules of each game must be defined, and the conditions of grouping, evaluation, penalty and contingency should be specified in case of problems, conflicts or abandonments. These conditions must always be visible and must remain immovable.
throughout the course for everyone to play under the same conditions and under the same rules of the game. Finally, it is important to specify in this preparation phase, a revisable contingency plan, contemplating, for example: personal conflicts or absences during the sections of the games affecting the rest of the members. For the former case, we consider the principles laid out in [8] which specifies some practical advice to deal with complicated situations and conflicts, distinguishing the different types of profiles that may appear in the affected groups. If this strategy does not work even so, then the members can expel the person causing the conflict by majority and with a wide justification of the action to the Professor. The expelled person will lose the accumulated points and will not be able to participate in more games. To the contrary, the absences can be controlled through attendance checks and in such a way that the absent participants will not be benefited of the points received from the game planned.

2.2 Execution

Before starting with the learning phase in which the student learns through the game and the interaction with other students, it is essential to find the way to establish heterogeneity in the own learning process. To do this, an initial knowledge test associated with the type of subject, has to be performed to allow the selection and grouping of entities. On the basis of this selection, three or four games have to be planned according to the goals defined during the preparation phase; however, the assessment process and the individual score only rely on the answers taken by the members of each team and only if their actions are correctly justified. In this respect, the evaluation can take two perspectives:

- **[STG1]** The Professor chooses after each item of the game, the member of the group who must give the answer, thereby forcing him/her to explain the solution they propose.
- **[STG2]** The Professor prepares, after the whole game, and thanks to the statistical capacities of the online tools such as Socrative, a list of the questions with the highest difficulty index so as to later proceed with the goals given in STG1.

Both methodologies can be applied according to the profile of the students and the type of context: number of students and the capacity of the classroom to allow groupings and teamwork. For example, and on the basis to our experience:

- **[STG1]** This strategy works better in small contexts with a reduced number of students.
- **[STG2]** This strategy is only effective for large contexts with a considerable number of students. This situation can imply large teams with an extended heterogeneity.

Nonetheless and related to STG1, if the Professor detects certain difficulty in a determined exercise (in the sense that there are few or no correct answers), this will be resolved in greater detail in class (similar to STG2), and once the game is over. On the other hand and depending on the Professor’s decision and his/her planification, each game will be priced according to two different criteria:

- **[AW1]** Have a first, second and third winning group, and all members of the winning groups will get a certain number of points, promoting motivation and interest in learning.
- **[AW2]** Take advantage of the online ICT tools to accumulate points in such a way that all the members sum score after the game, rewarding all the participants from a general point of view.

Any anomaly, conflict or problem related to **STG1 or STG2**, must be reviewed and managed by all the Professors implicated in the methodology, and this can entail a general revision of the plans specified in the preparation phase and the definition of new actuation rules or actions in the classroom.

2.3 Monitoring

As stated in the execution phase and so as to ascertain the initial capacity of the students and their previous knowledge, an initial test will be carried out with contents from previous subjects since the current ones have not yet been taught. This also means that the initial knowledge test should be based on questions related to the contents to be taught during the course but in relation to those previous knowledge that can certainly favor the understanding of the current subject-matters. With this initial procedure and with the selection of heterogeneous groups, the monitoring system is already prepared to collect information and assess the learning process throughout the entire course.

However, the monitoring process additionally includes a set of subphases that should also be discussed here. For example, the performance of each group will be evaluated at the end of each...
game session, preferably using an ICT tool so as to keep a record of hits, failures and punctuation. Apart from this, and to reinforce the knowledge during the continuous evaluation of each participant, not only the most difficult questions or exercises coming from the games are analyzed or discussed after each game item or session as stated in STG1 or STG2, respectively, but they could also be included as part of the final evaluation. To do this, a difficult index (D) is applied to detect which questions do not determine correct functioning within a set of tests, either because of a question is not well posed or because a large number of students fail. Certainly, this information is essential to determine whether or not those questions will be part of the final evaluation.

To calculate the difficult rate, the questions are divided into quintiles according to the overall students have correctly answered the question. Then, for each question in the game, the percentage of students in the first and last quintile that have hit is manually computed. The difference in these percentages is the difficult index D [11]. After computing D, it is possible to determine the degree of difficulty by considering:

- **D1**: \( D \geq 0.80 \) - the question is very easy;
- **D2**: \( 0.60 \leq D < 0.80 \) - the question is easy;
- **D3**: \( 0.40 \leq D < 0.60 \) - the question has an average difficulty;
- **D4**: \( 0.20 \leq D < 0.40 \) - the question is difficult; and
- **D5**: \( D < 0.20 \) - the question is very difficult.

However this manual procedure can be simplified by the capacities that some ICT tools provides in this aspect. For example, Socrative shows the rate of correct answers for a determined item with respect to all the groups implied in the game, thereby allowing the Professor to automatically determine, after the game and in-situ, which questions are really relevant for the monitoring process and the final evaluation.

### 3 RESULTS

Three subjects from two different engineering groups have been applied to this methodology, and the results are presented in this section. The application context is therefore different in each execution process and game, but all of them share common goals, methodology and even results. To summarize the procedure carried out by each professor, Table 1 briefly describes the technique applied, the context and the typology of the games.

<table>
<thead>
<tr>
<th>Professor</th>
<th>Engineering</th>
<th>Number of students</th>
<th>Initial know. Test</th>
<th>Teams and member in each team</th>
<th>Strategy applied</th>
<th>Games</th>
<th>Type of game</th>
<th>Award</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Telecomm.</td>
<td>30</td>
<td>YES</td>
<td>5 - 6</td>
<td>STG1</td>
<td>1</td>
<td>Quizzes and problem solving</td>
<td>AW1-2</td>
</tr>
<tr>
<td>B</td>
<td>Telecomm.</td>
<td>52</td>
<td>YES</td>
<td>15 - (3-4)</td>
<td>STG2</td>
<td>1</td>
<td>Quizzes and problem solving</td>
<td>AW1-2</td>
</tr>
<tr>
<td>C</td>
<td>Computer Science</td>
<td>64</td>
<td>YES</td>
<td>9 - 7</td>
<td>STG1 and STG2</td>
<td>2</td>
<td>Quizzes and problem solving</td>
<td>AW1-2</td>
</tr>
</tbody>
</table>

More specifically, Professor A performed, through a “manual” procedure and as part of the experiment, a unique test with mix of five questions and problems, with the students working in heterogenous groups to propose a solution. One member of the group that arrived at a solution first was chosen randomly and had to provide a well justified solution (STG1). Despite the class being relatively small (5 groups of about 6 students each), this strategy was criticized by the students mainly for two reasons. First, only the group that arrived at the solution first had a chance to answer, leaving other groups that arrived only slightly later at the solution with no reward at all. Second, the professor’s judgement of what would be a “well justified” solution was perceived as too subjective.

However, this manual procedure also allowed us to show that the use of the ICT tools are the most suitable way to apply this type of methodology, and for this reason the next experiments were modelled based on interactive systems with automated recordings of answers from all groups using,
for example, the Socrative tool. Indeed, Professor B designed and performed nine questions and one problem solving, using Socrative as ICT tool. The marks were calculated not only based on the order of the groups when answering the questions, but also on the number of correct answers. The equality of the groups was affected by the number of participants (Fig. 2 (a)) as some of them had not completed the initial test. To cope with this issue, students without initial test marks were assigned an average mark when grouping. Fig. 2 (b) shows that most of the questions were easy, according to the calculated difficulty index, one of them was very easy, two were difficult and just one question was very difficult.

Finally, Professor C with 64 students and 9 teams organized two games based on quizzes and a few questions related to problem solving. As can be noted in Fig. 3 (a), which shows the interest to attend to each game, the number of participants drastically drops due to the type of game set up as game 1, which includes two questions related to cryptography problems. Nonetheless, the cause of this absence, according to the satisfaction surveys, was not linked to the difficulty of the problems themselves but rather to the type of game, which was felt not to be a good match for the number of students and the application environment (STG1). For example, many students complained of the monitoring mode after each game item, since many teams finished just at the same time provoking conflicts and dislikes. For this reason, the strategy STG2 was later considered for game 2, for which the satisfaction surveys were even more relevant and positive.

With respect to the difficult index, we compute it following the most automatic solutions provided by Socrative so as to estimate the rate of success at the time. According to Socrative and Fig. 3 (b), there are several difficult questions of type D5 for game 1, principally because some of them corresponding to problem solving; whereas the hit rate increases considerably for the second game where there are no questions with set correct answers (of class D1-D3). In addition, and observing Fig. 3 (b), the hit rate reaches high values in game 2 improving the results obtained even for game 1, showing once
more that for reduced environments with large numbers of students it is the most optimal solution and regardless the significant decrease of attendance for game 2 as noted in Fig. 3 (a).

Additionally, satisfaction surveys for the games carried out by Professor B and Professor C show that a high percentage of students has learned or taught something from/to their group fellows, as we can see in Table 2. A very high percentage of students have learned something, however, in Games 1 and 2, just a 63% and 77% of students have taught something to their partners. We believe that it could be due to the heterogeneity of each group, where coexists students having different skills.

<table>
<thead>
<tr>
<th>Game</th>
<th>% of students that have learned something</th>
<th>% of students that have taught something</th>
</tr>
</thead>
<tbody>
<tr>
<td>Professor B - Game 1</td>
<td>96.0</td>
<td>63.2</td>
</tr>
<tr>
<td>Professor C - Game 1</td>
<td>89.3</td>
<td>76.8</td>
</tr>
<tr>
<td>Professor C - Game 2</td>
<td>96.3</td>
<td>92.6</td>
</tr>
</tbody>
</table>

Interestingly, in the first game of Professor C, we can observe an inverse correlation between the average degree of learning and the average perceived complexity of the game within groups, as we can see in Fig. 4.

![Figure 4. Correlation between the average learning and the average perceived complexity per group, for game 1 of Professor C.](image)

Lastly, from the beginning all the professors planned to compute the results of each game following the strategy AW1. However, a remarkable lack of motivation on the part of the students was perceived, opting then to change the strategy of compensation to AW2. This change resulted effective to return to the initial objectives of the methodology and address the learning process as planned.

4 CONCLUSIONS

In this contribution, the application and some results of the use of gamification to fight the lack of motivation and the background unevenness in some Engineering courses have been described.

The methodology has been detailed. Three phases have been carried out to implement the gamification in the courses. It is necessary an initial phase, Preparation, in which (i) the satisfaction surveys (ii) the games and (iii) the rules and contingency plan are designed. Then, in the Execution phase, the games have been executed in groups guaranteeing that the groups are heterogeneous (by carrying out an initial test), in order to help cooperation between students and reduce the initial unevenness. Two solving strategies and two award procedures have been implemented, since the
The context of each course requires different procedures. Monitoring of the results of the games has been preferably performed with ICT tools and we have made use of the difficulty index to detect the correct design and running of the games.

Results of the experience of three professors in three different courses have been presented. The need of adapting the game after analysing the students’ perception through the surveys has been highlighted. Moreover, the ICT tools have demonstrated to be better solutions for monitoring than manual procedures, since they automatically keep all the information, can provide useful statistics and give time to the professor to solve the games, avoiding unnecessary stress and conflicts among the groups. It has been also stressed that a bad design of the games or the award system and the no adaptation to the number of students can lead to a loss of interest, having an opposite effect to the aimed one. Interestingly, in one of the analyzed games, inverse correlation has been found between the average degree of learning and the average perceived complexity from each group.

Therefore, the implementation of gamification is not as simple as introducing games in the courses. There are many aspects to consider to guarantee success and the capability of adapting the games considering the feedback of the students or other professors has been proven crucial. Taking all these factors into account, gamification can indeed improve the engagement of the students in the lectures and foster cooperation.

It is expected that more results are available at the time of the conference.

REFERENCES


