APLICATION OF A GAMIFICATION LEARNING SYSTEM IN MECHANICAL ENGINEERING STUDIES

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ABSTRACT

The purpose of this study is to examine the effects of using a gamification tool as a new teaching strategy. Specifically, Kahoot! is evaluated as a tool for enhancing student learning. We test the tool empirically in a university class setting in an engineering degree, namely as part of the laboratory sessions of the subject Mechanism and Machine Theory during two consecutive academic years. The students were randomly divided into three different groups (control group, gamification group and writing group) and their results were evaluated depending on the learning method applied during the class. In terms of gamification, this project introduces real-time feedback to stimulate the interest of students and help them use the typical tools and methodologies of game-based learning. The analysis of their performance in the laboratory exam shows significant differences between the group that used gamification and the groups that did not. The study concludes that game-based elements and competitive activities enhanced student performance and recommend their use in educational environments to support the learning process.

1 INTRODUCTION

In recent years game design elements have started to be used for non-playful purposes [1]. Although the term is still being revised conceptually, gamification can be defined as using game-based mechanics, aesthetics and thinking to engage people, motivate action, promote learning, and solve problems [2]. In education, the idea is to motivate and stimulate students by using activities other than traditional ones, and facilitate – almost without them being aware – teaching-learning itself, especially in a social context in which student engagement needs to be increased [3].

Bearing in mind that the objective is to gamify the process not the outcome, it must be clear that gamification is not a panacea: it provides new tools but it is not the solution to all problems or applicable to all situations. Rigorous studies are required to fully examine the effects of gamification and determine how learning is best achieved.

In general, gamification techniques have positive effects on the involvement and motivation of students [3]. Gamified learning environments contribute to the learning and teaching process by raising levels of engagement, creating enjoyable learning environments and ensuring active participation [4–6]. However, some studies have not identified any significant effects on learning or have even detected worse academic results when students are forced to use game elements [7, 8]. The present study aims to provide new evidence on the effects of gamification in the classroom.

Personal response devices (PRDs) appeared at the beginning of the 21st century and they consist of an emitter and a receiver that, together with the corresponding software, enable teachers to ask their students a multiple-choice question (the question is projected on a screen) and students to send an answer using their individual control or *clicker*. Clickers provide a simple way to generate an atmosphere of student interaction that can enhance teacher-student communication. These systems increase attention levels, discussion, participation and engagement.

Kahoot! is a free virtual tool that has gained in popularity among teachers for its user-friendly nature and its ability to establish working dynamics in the classroom. It is highly appreciated by students. *Kahoot!* allows teachers to create surveys, questionnaires, puzzles and debates, and obtain students' answers in real time. Various studies on *Kahoot!* agree that this tool improves participation and the positive relationship between class members [9–11].

Mechanism and Machine Theory is a core subject taught in the fourth semester of the Degree in Industrial Engineering at Universitat Politècnica de Catalunya. It is one of the first times that the Industrial Engineering students have come into contact with the world of mechanical engineering. The evaluation of the laboratory sessions prior to this subject had not given expected results: the percentage of students who passed the practical exam was very low, and the teachers considered it a problem since it suggests that students were not able to put into practice the knowledge they had acquired in the theory classes. On average, the percentage of students passing the course is 70%, whereas the percentage passing the practical examinations is 40%, notably lower.

We hypothesize that the introduction of gamified feedback will help to highlight the most important concepts at the end of each laboratory session, and therefore, improve the learning process. The second hypothesis of this study is that the first of these two factors (gamification) is more important than the second (the feedback itself). In order to test this hypothesis, the questions that the students in the gamification group were asked were also presented to another experimental group in which students did a written test without using *Kahoot*!. The solutions of the test (feedback) were also provided after the practical session.

2 METHODOLOGY

The present study uses an empirical-analytical methodology to study gamification as a tool in laboratory sessions. The subject Mechanism and Machine Theory has a large number of students each semester (between 270 and 320) so the students were randomly distributed into 11 laboratory groups taught by 4 different lecturers. The aim of our intervention was to improve learning in the laboratory sessions.

A test questionnaire has been introduced as a feedback tool. Quick feedback helps students become aware, and they have greater perception of what has happened in the laboratory. This feedback has been introduced as a test questionnaire that has to be answered in the last 15-30 minutes of each session.

Two different feedbacks are analyzed. The first uses *Kahoot!* questionnaires. Since *Kahoot!* is a fast response system for the student, it is expected to be effective at improving knowledge retention and skill acquisition. The second uses a traditional questionnaire which, therefore, involves no competition or cooperative learning. To determine the effect of introducing not only a feedback tool but a feedback gamification tool, the laboratory groups were divided into three groups:

- An experimental group given feedback through the *Kahoot!* questionnaires– (Gamification group, GG). These learners use the mobile version of the app.
- An experimental group given a written test at the end of the session (with the same questions as in *Kahoot!*), acting as reinforcement and feedback, but without the other components that *Kahoot!* may have (Writing group, WG).
- A control group subject to no intervention (Control group, CG).

The students were divided up in this way to avoid teacher and timetable factors. Table 1 summarizes the number of students in each group. Note that some students do not participate in the laboratory sessions.

Table 1. Overall number of students for each group and academic year

Number of students	**2016-17**	**2017-18**
Gamification Group – GG	37	41
Writing Group – WG	115	86
Control Group – CG	113	100
Not attending	41	56
Total	306	283

Academic performance was assessed by comparing the marks of students in each of the pedagogical groups. The mean mark, standard deviation and number of students who passed the exam were calculated for each evaluation. In this work we focus on three laboratory sessions. Along the text, M_{lab1} is the mark for the first laboratory exam (assessing sessions 1, 2 and 3). A Student's T-Test was also used to find significant differences between the experimental (GG and WG) and the control (CG) groups.

Therefore, for the GG the relation between the *Kahoot!* test score and the grades in M_{lab1} was studied. Likewise, for the WG, the relation between the writing test score and the grades M_{lab1} was examined. To this end, linear correlations were calculated and Pearson, Spearman and Kendall coefficients determined.

Finally, whether or not there was a teacher effect was studied (that is to say, whether a particular student gets a better or a worse mark depending on the teacher who has taught the subject). Therefore, the students were grouped according to the lecturer who taught the sessions and a Student's T-Test was used to determine significant differences between the four groups.

3 RESULTS

Because feedback is now a part of laboratory sessions 1, 2 and 3, differences in the laboratory exam 1 marks (M_{lab1}) can be expected among the three groups. During the academic year 2016-17, 62.16% of the students who took part in the gamification passed the exam while only 54.87% of the control group and 58.26% of the writing group did the same. Similarly, during the academic year 2017-18, 87.80% of the students who took part in the gamification passed the exam while in the control group and the writing group the percentages were 74.74% and 77.91%, respectively.

Moreover, it can be seen that for laboratory exam 1 (M_{lab1}), the mean grade obtained by the students who took part in the gamification sessions (5.59±2.43, academic year 2016-17; and 6.90±1.68, academic year 2017-18) is more than one point higher than the control group (4.50±2.17, academic year 2016-17; and 5.75±2.30, academic year 2017-18). However, this difference is not so clear for the writing group (4.71±2.37, academic year 2016-17; and 5.57±2.24, academic year 2017-18). A Student's T-test between GG and CG demonstrated that there is a significant difference between these two groups (p-value < 0.05). The differences between the WG and the CG group are not statistically significant.

Figure 1 shows the boxplot obtained for M_{lab1} for both academic years and for each teaching methodology. The central block is delimited by the position of Q1 and Q3 quartiles and the line representing the median is drawn in the box. It can be seen that the median is also higher for the gamification group than for the writing and control groups.

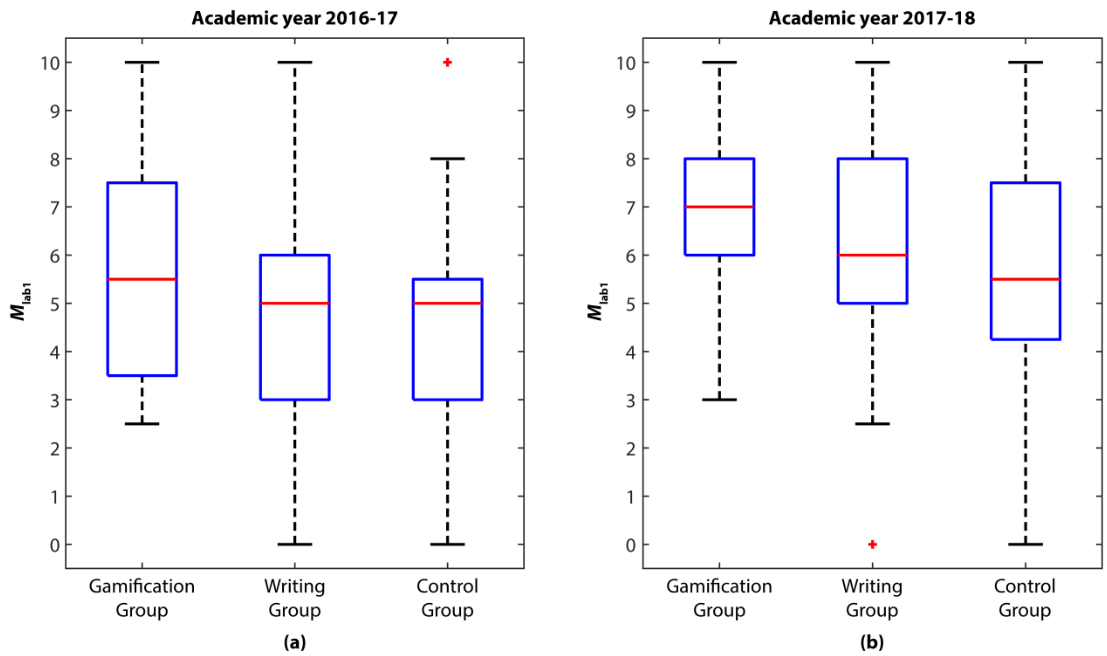

Fig. 1. Boxplot of laboratory exam 1 marks. (a) Academic year 2016-17 (b) Academic year 2017-18.

Differences between GG, CG and WG are not presented for other evaluation marks obtaining during the course. This could be a way to ensure that students are randomly distributed among groups. Differences only appear when a gamification methodology is applied.

The relation between the grades obtained in feedback tests and the laboratory 1 exam was studied. As well as the *Kahoot!* score (based on both correctness and speed of the answers), the grade the students would have be given in the final exam was calculated. Figure 2 shows, the relationship between the calculated *Kahoot!* grades ($M_{Kahoot!}$) and the grades obtained by students on the laboratory exam 1 (M_{lab1}) for the gamification group (GG). Similarly, Figure 3 shows the relationship between the writing test marks (M_{WT}) and the ones obtained in the laboratory exam 1 (M_{lab1}) for the writing group (WG). The graphs also show the polynomial regression line that adjusts these values and the corresponding R^2 parameter.

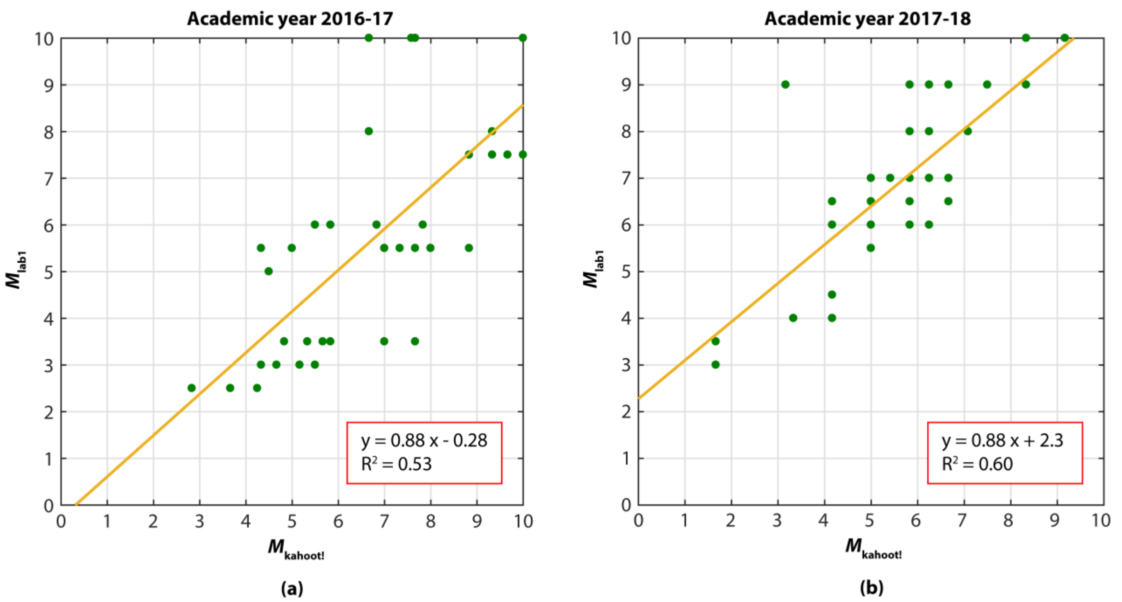

Fig. 2. Scatter graph of the lab exam 1 marks (M_{lab1}) versus the Kahoot! marks ($M_{Kahoot!}$). (a) Academic year 2016-17 (b) Academic year 2017-18.

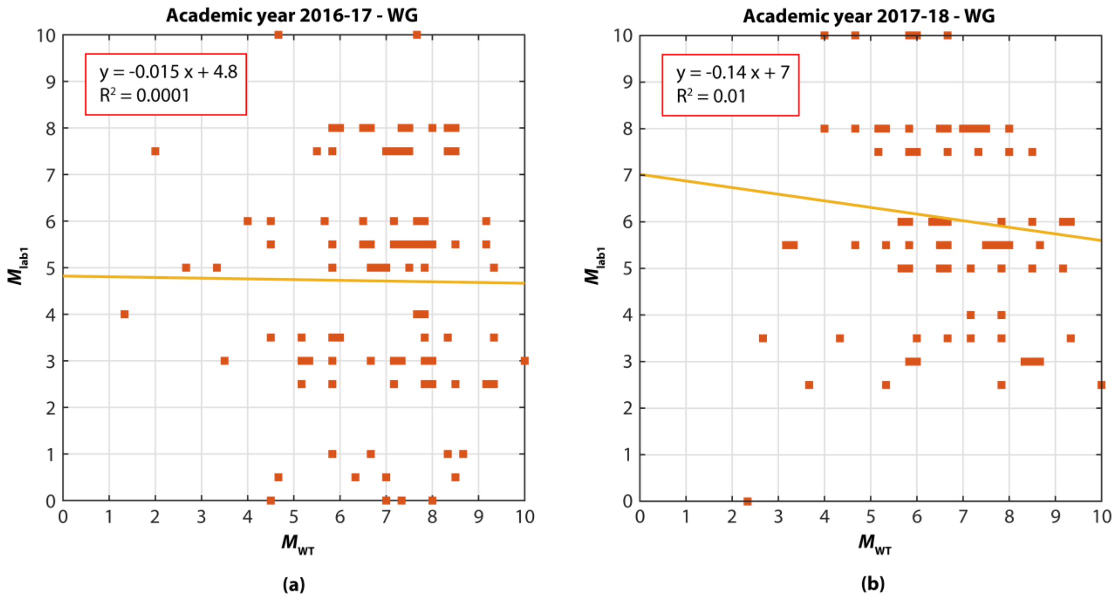

Fig. 3. Scatter graph of the lab exam 1 marks (M_{lab1}) versus the writing test marks (M_{WT}). (a) Academic year 2016-17 (b) Academic year 2017-18.

Three different correlation coefficients (Pearson, Spearman and Kendall) and the p-values of the statistical tests were calculated. For GG, the p-values were much lower than 0.05, so there is a significant positive correlation between the marks obtained in the *Kahoot!* test and the ones obtained in the laboratory 1 exam (correlations between 0.5 and 0.7 depending on the indicator used). However, the correlations for the writing group are not significant.

The teacher effect was also analysed. As explained above, the sessions are taught by four different lecturers. For this analysis, students were grouped according to the lecturer who taught their laboratory session. However, the Student's T-test does not detect any significant differences between the four groups studied (p-value > 0.05). Therefore, it cannot be affirmed that the teaching staff has an effect on the grades of the students.

4 SUMMARY AND ACKNOWLEDGMENTS

The main goal of this study was to analyse whether a gamification tool could improve learning in the laboratory sessions of the subject Mechanism and Machine Theory. For this purpose, during two consecutive academic years, we divided the students into three groups each of which was subject to a different methodological intervention. At the end of the first three sessions, the gamification group (GG) answered a *Kahoot!* questionnaire; the writing group (WG) answered the same questionnaire but on paper, and the control group (CG) was not given a test of any sort.

The results show that:

- The gamification group had a higher success rate in the laboratory exam (Laboratory exam 1) than the control group. Moreover, on this evaluation, the average grade of GG students was statistically greater than the average of

CG students. Furthermore, the grades of the other evaluations do not show these differences. It can be seen that gamification has a positive effect on grades.

- The writing group shows no significant improvement with respect to the control group. When the feedback is not gamified, it does not enhance academic results. These results suggest that gamification is the key to the improvement not the feedback itself.
- A statistically significant positive correlation was detected between students' Kahoot! scores and laboratory exam 1. This correlation fulfils one of the initial objectives of the study, which was to provide students with tools (questionnaires) for self-evaluation so that they could better manage their learning process.
- No significant differences were detected in the grades of the various groups who did laboratory exam 1. This reveals that it was not the lecturer of the laboratory session who marked the difference but the intervention itself.
- As has been mentioned, there was a need to elucidate whether *Kahoot!* is effective or not. The reasons why it seems to improve active student learning, participation and retention of concepts or why it is no guarantee of better learning need to be determined. In the light of the results presented, in general it seems that gamification has provided a (modest) increase in the teaching-learning process in the laboratory practicals of the subject Mechanism and Machine Theory.
- Finally, from a general perspective, further educational research is needed to evaluate whether enjoyment and, in this case, the use of game-based student response systems really help with teaching and learning or are simply more fashionable at present in the field of education.

The authors would like to thank the students who participated in the study.

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