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Stimulating students' engagement in mathematics courses in non-STEM academic programmes: A game-based learning activity

It is of utmost importance to innovate in current teaching practices at higher education in order to enhance learners' involvement, comprehension, cooperation and motivation. In non-STEM (science, technology, engineering and mathematics) programmes, students tend to display a negative attitude towards mathematic-related courses. Aiming at overcoming this, game-based learning is regarded as a potential means of improving students' confidence and increasing their motivation. In this study we propose a teamwork activity inspired by game-based learning, presented in the form of a competition. To test the suitability of the activity, we report its implementation in the subject of Mathematics 1, taught as part of the Business Administration Degree at Universitat Internacional de Catalunya (Spain). We hope that the underlying idea of the activity as well as the encouraging results obtained stimulate lecturers to implement game-based learning activities in their courses.

Keywords: higher education, university mathematics education, mathematics, teaching practices, active learning, game-based learning, teamwork

Introduction

The teaching of mathematics in higher education has suffered a shift in recent years, moving from traditional lecturing to teaching methodologies based on active learning. Active learning consists of engaging students in the learning process (Prince, 2004; Sesen & Tarhan, 2011). Through active learning and student-centred methodologies students learn by applying knowledge in activities, which improves their performance during the activity and also after completing it (Bell & Kozlowski, 2008; Michael, 2006). This teaching methodology helps learners get involved in the learning process and improve their achievements in mathematics courses (Freeman et al., 2014; Laursen, Hassi, Kogan, & Weston, 2014; Wieman & Gilbert, 2014).

Although active learning has been demonstrated to be a useful method for introducing mathematics, the benefits of traditional methods do not have to be underestimated (Pritchard, 2010; Sfard, 2014). Following Kirschner (2015) and Prince (2004), we posit that a balance between active and traditional learning is a good option, promoting in this way learner engagement and including activities in the teaching where students can apply the concepts learned in class.

There is a wide variety of activities that can be used to implement an active learning methodology. Games are an example. There is empirical evidence that the use of games with educational purposes facilitates the learning processes (Pivec & Dziabenko, 2004; Wilson et al., 2009) as well as improves students' confidence (Ku, Chen, Wu, Lao, & Chan, 2014). Hays (2005) defines games as competitive activities that take place in a certain context and that have a specific goal, a set of rules and restrictions, that promote interaction among participants.

This interaction among participants can be strengthened by working in teams. Teamwork itself is considered an essential soft skill that should be enhanced at universities (Ruizacárate Varela, García-García, González-García, & Casado-Sánchez, 2013). The cooperation that team working promotes provides students with opportunities to share ideas and knowledge, to ask and answers questions, and in this way to reinforce their understanding (Lee, Huh, & Reigeluth, 2015; Michael, 2006). Indeed, most professional activities require working in teams; therefore, introducing activities in class that promote students' interaction with others in order to reach a common goal is excellent training.

Many students possess low confidence towards the learning of mathematics. This situation holds true particularly for students in non-STEM (science, technology, engineering and mathematics) programmes, who tend to display a negative attitude towards mathematic-related courses, and this prejudice might even lead them to give up pursuing more mathematics knowledge despite this being a fundamental skill in our daily life. Game-based learning is regarded as a potential means of improving students' confidence and increasing their motivation.

The literature on game-based learning activities in the teaching of mathematics in higher education courses is scarce. Moreover, most of the few studies addressing this issue use games in an on-line context (Naik, 2015). The result is a shortage of studies reporting non-digital applications of the game-based method, despite the advantages it provides when such technologies are not accessible, or when there is no need to introduce digital tools in the class for the specific purpose of the activity. Moreover, the literature on the use of mathematics in non-STEM programmes is very limited, and there is an urgent need to report experiences found to be successful in other academic disciplines. Aiming at covering this gap, in this study we propose a teamwork activity inspired by game-based learning, presented in the form of a competition. To test the suitability of the activity, we report its implementation in the subject of Mathematics 1, taught as part of the Business Administration Degree at Universitat Internacional de Catalunya (Barcelona, Spain). Specifically, this activity consists of engaging students working in groups on a competitive basis to solve exercises about concepts learned during the course.

The results obtained reveal that the activity was positively welcomed by students, who expressed a high degree of satisfaction not only with respect to the acquisition of mathematical knowledge but also the teaching methodology used.

The remainder of the paper is structured as follows. First, we concisely review the existing literature on game-based learning, and specifically, how game-based learning has been implemented in higher education. Second, we describe in detail the activity presented here and justify its need. Next, we present the main results. Finally, the paper closes stating the conclusions and discussing the main implications of the results obtained.

Game-based learning

In the interest of heightening students' motivation, teaching methods have undergone a significant shift in recent years, moving from the traditional classroom lecture which characterises conventional instruction, towards more sophisticated techniques where experiential learning unleashes creativity into the learning process. Within this context, the use of instructional games provides educators with an interactive means of conveying knowledge in a more relaxed and stimulating way.

A game "is an immersive, voluntary and enjoyable activity in which a challenging goal is pursued according to agreed-upon rules" (Kinzie & Joseph, 2008: 644). Games can indeed be introduced into the classroom. Although prior research into which specific attributes of games have an impact on learning outcomes does not converge, there is a consensus that because of their applied and dynamic nature, instructional games lead to greater cognitive, skill-based, and attitudinal gains (Wilson et al., 2009). However, it is important to note that games will be instructionally sound only if they are designed to support specific learning objectives and are incorporated logically into the syllabus (Hays, 2005). In this respect, the lecturer will need to dedicate time and effort to successfully align an enjoyable activity with the knowledge to be transmitted.

Research examining the effectiveness of educational games in enhancing students' interest and further increasing their learning is abundant. Indeed, experiences reporting the introduction of game-based learning activities at different levels of education (elementary school, high school and higher education) and in a variety of disciplines can be easily found. However, most of these studies focus on educational computer games (Naik, 2015). With the rapid advancements of communication technologies, it seems that technology-based learning is here to stay. The use of technology applications in education offers an eclectic range of methods (e.g. virtual simulations, discussion boards, role-playing, and shared spaces) all aimed at engaging students in their learning process. At the same time, they allow instructors to track students' progress in an almost-automated way. Furthermore, technology-based learning offers geographical reach and scalability of training efforts.

A recent work by Hwang and Wu (2012) reviews the status of digital game-based learning research published during the period 2001-2010 in the top seven major technology-based learning journals. From this period, 137 articles are identified. Filtering by educational level (higher education) and academic discipline (mathematics), only five papers remain.

Although the advantages of digital game-based learning have been widely discussed in the literature (Hwang, Hung, & Chen, 2014), one of the most important challenges it might accentuate is the "digital divide" paradigm. On the one hand, some educational centres might not have enough resources or financial liquidity to acquire technology-enhanced environments to support teaching (Warschauer, 2004). An alternative solution might be developing in-house programs and software; however, the programming of such games requires highly skilled developers which are prohibitively expensive. On the other hand, some learner populations have low computer literacy skills, and their work will be less diligent than it would otherwise be (Clewley, Chen, & Liu, 2011; Ku et al., 2014). Therefore, we argue that computer digital game-based activities may not be beneficial to all learners.

Non-digital games, such as card games in their multiple variations, are also useful means to operate with numbers, match concepts, and recognise patterns (Van Eck, 2006). Following this rationale, Naik (2015) elaborates the advantages of non-digital games for mathematical purposes, and reports his experience in the use of games such as jigsaws, bingo, crosswords, rummy, and Sudoku. His findings support the argument that the use of games as a co-instructional teaching strategy is sound. In an earlier work, Naik (2014) compared digital versus non-digital games, and concluded both approaches add value to the learning environment, but that the effective adoption of one or the other will depend on a number of factors that need to be controlled (i.e. attitudes towards new technologies, teachers' skills, level of students, institutional requirements).

According to Csikszentmihalyi (1990) there are several components that make an activity enjoyable: (i) a challenging activity that requires skills, (ii) the merging of action and awareness, (iii) clear goals and feedback, and (iv) the transformation of time. Therefore, following the work of Burguillo (2010), we argue that the potential of game-based learning can be enhanced if the game acquires a competitive dimension. Games displayed in the form of a competition are found to engage students more easily and increase their learning performance. Other specific advantages of using a competitive approach include collaborative work inside the group and a sense of "challenge" versus "duties".

Description of the activity

Main purpose

The core goal of the game-based learning activity proposed is twofold: to help students review and apply the concepts introduced in class, and to improve students' confidence and speed when resolving mathematic problems. By working in groups on a competitive basis students are challenged to cooperate to reach the correct solution before the other teams do so.

To test the suitability of such an activity, the empirical application considers the subject on Mathematics 1, included in the first semester, first course (from September to December) of the Programme in Business Administration Degree offered at Universitat Internacional de Catalunya (Barcelona, Spain). The activity consists of two sessions that take place in October: the first at the beginning of the month and the second at the end. It is a compulsory task for all students attending classes.

Sample

The activity was first implemented in the academic course 2011/12, achieving a high degree of student participation. Table 1 shows the number and percentage – with respect to the total number of students enrolled in Mathematics 1 – of students who participated in each session of the activity for the period 2011/12–2015/16. For the last academic course (2015/16) of a total of 86 students enrolled in Mathematics 1, 77 of them (89.5%) participated in the first session of the activity and 79 (91.9%) in the second one. The main reasons for non-attendance were illness or participation in a federated sports competition.

Insert Table 1 about here

Detailed description

When preparing for the final exam of Mathematics 1, it is important to have acquired the knowledge and the speed required for solving the exercises correctly and within the stipulated time. In order to promote both aspects, while increasing cooperation among students, a teamwork activity inspired by the philosophy behind the game-based learning method was designed. Considering the specific features of the use of games for teaching purposes, Table 2 shows how each of these characteristics is addressed in our approach.

Insert Table 2 about here

The activity is structured in two sessions, very similar in format, but different in the content they cover. While the first session reviews the first chapter of the course syllabus and consists of solving a series of derivatives, the second session, based on the second chapter, requires students to have a solid knowledge in immediate integrals.

The week prior to each session of the activity, the lecturer informs students of the activity and asks them to review the corresponding content – either derivatives or integrals – taught in class. The lecturer also recommends students bring their notes or useful material to class the day the competition will take place.

At Universitat Internacional de Catalunya, classes last two hours. The days the activity takes place, the sessions are structured as follows. During the first 55 minutes, a normal class takes place and student attendance is recorded. Next, during the 10 minutes of the break, the lecturer groups students into teams of three or four, taking into account their average grade in the continuous evaluation, trying, on the one hand, to ensure a similar degree of mathematical knowledge among teams and, on the other hand, to promote cooperation inside each team, so that best students can help the ones with more difficulties in Mathematics for a proper understanding of the activity.

The student with a higher continuous evaluation grade in the team is designated by the lecturer as the team leader, and will be in charge of representing the team and reporting to the lecturer any problem during the activity. Because this activity takes place one month after starting classes, dividing students into teams is a good way to get them to know one another and see other ways of working. After the 10-minute break, the lecturer explains the rules of the activity and specifies the teams and the leaders. Next, students in the same group sit together. This process takes about 10 minutes. Once students are ready to start the activity, the sheets containing the statements are distributed face-down. When all students have the statement, they can turn over the sheets and start solving the different questions posed. The maximum time allowed to complete the exercises is 45 minutes. Teams are encouraged to start the activity with a brief brainstorming where each student indicates which problems he/she could solve best. Based on these preferences, the team leader will then decide which exercises to assign to each team member. Table 3 summarises the structure of these sessions.

Insert Table 3 about here

Both sessions are presented as a competition among teams and consist of 10 exercises. In session one, there are 10 derivatives to be solved with a level of difficulty slightly higher than the ones solved in class. In session two, the statement comprises 10 immediate integrals with a proposed solution for each one that can contain two, one or zero mistakes. Students are asked to identify whether the solution is correct or incorrect, and if the latter, indicate which the mistakes are.

During the development of the activity students can make use of any material they wish for solving the exercises, with the exception of calculators or software that automatically provide the solutions. At the end of the activity, each team has to hand in to the lecturer one sheet with the resolution of the derivatives in session one, and the mistakes marked and corrected in the case of the integrals in session two. The procedure for reaching the solution would not be considered when grading this activity. The final solution given is the only thing that matters.

The scores of the activity are provided to students the next day. The correct solutions are posted on the online platform of the course (which uses Moodle). Students are encouraged to ask questions regarding the exercises at the beginning of the next class. This class serves as a debriefing session where students are given the opportunity to reflect both on their learning and experience with the game, and check whether the expected objectives have been achieved.

The scores of the activity are scaled from 10 to 6, with intervals of 0.5. This way, the best team obtains a 10, the second one a 9.5, the next one a 9, until 6. If there are more teams, all the ones obtaining worse results get a 6. To rank the teams from the best to the worse, the number of correct answers is taken into account. If there is a tie in the number of correct answers between teams, the team who finished the activity earlier is awarded first place.

Results

During the development of the activity, students expressed great interest and motivation, mainly because of the competitive nature of the activity. In order to capture in a formal way students' opinions, a survey was designed. Table 4 summarises the items included in the questionnaires and the responses obtained.

Insert Table 4 about here

Because we have data for five academic years, we calculated an estimate to determine the weighted average feedback of the activity: first, for each of the five academic years in which the activity was implemented, we multiplied the number of students that filled out the survey by their responses (feedback); second, the five previous products were added; lastly, we divided the result by the total number of students that answered the survey for the period under analysis (120).

Considering this weighted score, it can be observed that, in general terms, the aspect that students rank highly is the lecturer's organisation, preparation and structure of the activities (weighted average = 4.39). On the contrary, the item that receives the lowest score is the helpfulness of the work carried out by the lecturer with respect to the improvement of students' knowledge, skills or attitudes (weighted average = 4.17). Nevertheless, it should be noticed that all scores are above 4 (in a scale from 1 to 5), indicating that students are highly satisfied.

As for the impact of this activity on students' academic records, it is worth signalling that before the introduction of the activity (course 2010/11) students enrolled in Mathematics 1 got an average grade of 4.9 in the exam of the first chapter, and 5.6 in the exam of the second chapter. After implementing this activity, students have gradually improved their academic records. For instance, the next academic year 2011/12 students obtained an average grade of 6.3 in the first chapter, and 6.7 in the second chapter. We believe that this activity has indeed helped students to prepare the content in advance, so that when studying for the final exam, part of the syllabus has already been reviewed and evaluated during the course.

Conclusions and discussion

The main objective of this paper is to describe the usefulness of a game-based learning activity in a mathematics course addressed to business and management students. The activity that we propose has been designed in such a way that it is expected to help students review and apply the concepts introduced in class while improving their confidence and speed when solving mathematic problems.

Game-based learning activities have a structure that perfectly suits the requirements of the intended action. First, by working in teams students are able to cooperate, share ideas and obtain a deeply understanding of the content, which boosts their confidence. Second, given the competitive base of the activity, students are challenged to reach the correct solution as soon as possible, therefore enhancing their speed at solving exercises. Third, students are used to games. It is thus easy for them to understand the elements that characterise it (purpose, context and rules).

The positive results obtained, not only in acquisition of knowledge on resolution of derivatives and integrals, but also regarding the satisfaction expressed by students, encourage us to continue using this activity in subsequent editions of the courses.

Despite the encouraging results, there is still room for improvement. For instance, in order to make sure students check the correct way of solving the exercises contained in the activity once the competition has finished, it would be worthwhile considering including one of these exercises (in a similar structure) in the final exam. This way, students would not see this activity as an "isolated" or "desegregated" activity.

Because one of the expected outcomes of the activity is team collaboration, in order to reward those teams in which students clearly cooperate, 0.5 extra points can be given if team members show a genuine interest in helping one another to better understand and solve the exercises.

Regarding students' feedback, the specific questionnaire for this activity needs to be improved to better capture students' progress and feedback in a more comprehensive way. This questionnaire should also include a blank space for additional comments, so that students can freely indicate which of the aspects of the activity they liked most and worst, and give them the possibility to suggest new ideas.

We hope that the underlying idea of the activity as well as the encouraging results obtained stimulates lecturers of other subjects to implement game-based learning activities in their courses. Game-based learning methodologies are a tool for motivating students. The competition is an attractive formula to make learners more involved in understanding the content of the subject. It further challenges students and makes them cooperate with the members of their team to achieve a superior output collectively. We believe this approach to be an excellent combination of fun and rigour that leads to learners studying without being fully aware of it.

Our study suggests the usefulness of introducing activities such as the one described here for teaching subjects as challenging as mathematics at a higher education level. This particularly applies to academic disciplines such as social sciences where mathematics is not a main core, but is essential in order to induce rigidity and reflective thinking into our intellectual life. It is therefore of the utmost importance to innovate in the current teaching practices to enhance learner involvement, comprehension, cooperation and motivation. In this respect, it is crucial to first understand who our students are, what their expectations are and what they enjoy doing. Only after understanding their real needs would instructors be able to design activities aligned with their interests but also consistent with the fundamentals of mathematics that need to be transmitted. At this point, it is important to remark that not all professors have the appropriate skills for designing such activities. It is therefore necessary that universities take a leading role in this process and promote courses and training programmes aimed at developing the necessary skills. The academic offer of universities is increasingly competitive and globalised; therefore universities should find how to differentiate themselves from others. A focus on innovative teaching methods is one strategy for doing so.

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Table 1. Participating students in each session (number and percentage with respect to the total class size).

Course	Session one	Session two
2011/12	64 (76.2%)	54 (64.3%)
2012/13	56 (78.9%)	51 (71.8%)
2013/14	60 (87%)	58 (84.1%)
2014/15	72 (87.8%)	62 (75.6%)
2015/16	77 (89.5%)	79 (91.9%)
TOTAL	329 (83.9%)	304 (77.6%)

Table 2. Characteristics of a game and how these were introduced in the activity.

Characteristics of a game	Characteristics of the activity
Context	It takes place in class.
Objective	To obtain a higher grade.
Rules	The number of correct answers and the speed in the resolution are taken into account. The activity cannot start until all teams have the statement. The maximum duration is 45 minutes. Any material can be used except of calculators and programs that directly provide the solution.
Interaction	Team work and cooperation among the team members.

Table 3. Timetable of the day of session.

Order	Activity	Duration
1	Normal class. Attendance is recorded.	55 minutes
2	Break. The lecturer groups students into teams.	10 minutes
3	Rules. The lecturer explains the rules of the activity, indicates the groups, and designates the team leaders. Students sit together in teams. The sheets containing the statement are distributed.	10 minutes
4	Core activity. Tasks are distributed and the activity is developed.	45 minutes
5	Discussion of the scores and how to solve the exercises	10 minutes (at the beginning of the next session)

Table 4. Students' feedback (scale from 1 – lowest to 5 – highest).

Questions	2011/12	2012/13	2013/14	2014/15	2015/16	Weighted average
The activity was well organised, prepared and structured	4.13	5.00	4.10	4.29	4.77	4.39
The lecturer encourages student to participate in the activity	4.25	5.00	3.73	4.29	4.57	4.21
Teaching resources were appropriate in that they facilitate learning	3.81	5.00	4.00	4.29	4.47	4.22
This activity has helped me improve my knowledge, skills, or attitudes	3.88	4.33	3.93	4.29	4.57	4.17
Students' response rate (number and percentage)	16 (19%)	9 (12.7%)	40 (58%)	7 (8.5%)	30 (34.9%)	102 (26%)