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Research Notes

Teaching operations research to undergraduate management students: The role of gamification

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ABSTRACT

Gamification has been successfully applied in some educational environments, however there is a lack of studies considering gamification applied to Management university courses. In this paper, the experience of applying gamification in an Operations Research/ Management Science course taught to undergraduate management students will be described. The use of challenges, points, personalized feedback, badges and leaderboards was considered to implement the most important game mechanics and related dynamics. It was possible to observe an increase of students' participation in classes, an increase in the percentage of approved students and a better assessment of the course made by the students. Some recommendations on how to implement an Operations Research course for management students are also given.

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1. Introduction

Games have been a fundamental part of human civilization, and the first written history of human gameplays can be traced back more than three thousand years ago (McGonigal, 2011). In modern society a vast majority of the population is playing games, feeling rewarded by participating and taking action in games and feeding needs that real world is unable to satisfy (McGonigal, 2011; Reeves & Read, 2009). Everyone that has already played some game has felt the sense of being totally focused in something, engaged in every single moment, having a feeling of accomplishment and success (McGonigal, 2011; Reeves & Read, 2009; Yee, 2006). And if this passion is shared with many other people, games also give us the feeling of belonging to a community (McGonigal, 2011). Gamification is present in our daily lives, although sometimes we do not even recognize it. One of the most disseminated examples of the use of gamification with the objective of changing people's habits is the *Piano Staircase* at the Odenplan subway in Stockholm. The main idea was to convince people to use the stairs instead of the escalator or elevator, and make the use of stairs a funny thing by turning it into a giant piano (TheFunTheory, 2009). Each step of the staircase would play a musical note when it was stepped on. Another example is *Superbetter*, aiming at helping people recover from an illness and achieving health goals by belonging to a community and playing a game (McGonigal, 2016). The badges that are given to acknowledge your achievements when you contribute with reviews in *Tripadvisor* are a tool to convince you to keep contributing with more and more reviews (staying enrolled in the game).

Hundreds of millions of people play regularly online massive multiplayer games (Reeves & Read, 2009). About 67% of teenagers regularly play online games, and players aged 18 to 22 play on average around 25 h per week (Williams, Yee, & Caplan, 2008). Students that are now entering university are more and more acquainted with gaming experiences. They

like to have instant feedback on their actions, as well as being able to progress in the game even if things are not done in a perfect way all of the times (Reeves & Read, 2009). And most of them are engaged in such a way in some of these games as they will never be in any of their university courses. Gamification has already been successfully applied in different educational environments (Caponetto, Earp, & Ott, 2014; de Sousa Borges, Durelli, Reis & Isotani, 2014; Dicheva, Dichev, Agre, & Angelova, 2015; Hamari, Koivisto, & Sarsa, 2014), but there is a lack of studies considering gamification applied to Management university courses. This paper describes the experience of having a gamified version of an introductory operations research (OR) course taught to the first year students of a bachelor's degree in management, and the results achieved. This paper is organized as follows: after this introductory section, section 2 presents a literature overview. Sections 3 and 4 present the methodology and materials used, including a brief description of the course. In section 5 a comparison between the gamified and non-gamified versions of the course is made. Section 6 presents main results. Section 7 presents some advices on how to gamify an OR course. Section 8 acknowledges the limitations of the current work, and suggests possible paths for future work. Section 9 presents some concluding remarks.

2. Literature overview

2.1. Gamification

Gamification can be defined as the use of game elements and game-design techniques in non-game contexts (Werbach & Hunter, 2012). But what characterizes a game? There are several different definitions, although they converge in some points (Miller, 2013): a game is played by choice; it encompasses goals, rules, feedback, challenge, surprise, understanding. Game playing is associated with trial, error, failure and eventual success through practice, experience, reflection and learning (Buckley & Doyle, 2014). An introduction to the basics of gamification can be found in the published work of Robson, Plangger, Kietzmann, McCarthy and Pitt (2015), in two very interesting books by Kapp and co-authors (Kapp, 2012; Kapp, Blair, & Mesch, 2014) and a collection of papers considering very different features on gamification (Reiners and Wood, 2015).

Bedwell, Pavlas, Heyne, Lazzara and Salas (2012) propose nine attribute categories associated with games: Action language; Assessment; Conflict/Challenge; Control; Environment; Game fiction; Human interaction; Immersion; Rules/goals. Table 1 presents a brief description of each one of these attributes (Bedwell et al., 2012; Landers, 2014).

According to Landers (2014), core to the definition of gamification is the fact that the game is not created in gamification because a pre-existing process (such as a classroom or training program) already existed. It is this pre-existing process that is augmented with features borrowed from games (Landers, 2014). Gamification is a process that aims at increasing both intrinsic and extrinsic motivation (Buckley & Doyle, 2014), and having people engaged in working activities. Motivation can be interpreted as the desire to be involved in the activities (Kim, Park, Cozart, & Lee, 2015). Behaviors can be understood as being intrinsically motivated if they are the result of self pleasure and satisfaction (Deci, Vallerand, Pelletier, & Ryan, 1991). Extrinsically behaviors are performed considering a related consequence (Deci et al., 1991). It has been shown that especially intrinsic motivation can be responsible for promoting in students an interest in learning (Deci et al., 1991). More information regarding the effect of students' motivation on the learning outcomes can be found in Clark, Howard, and Early (2006).

The word *engagement* can have different meanings in different environments. Deater-Deckard, Chang and Evans (2013, page 22) define engagement in the learning context as *"a collection of mindfully goal-directed states in which motivation arising from positive emotions serves to grab and sustain the learner's cognitive and motor competencies, typically requiring some level of effort"*. In the gamification context, *engagement* refers to the active participation of the players throughout the game. If a player is engaged with the game, he will be motivated to address the challenges ahead, and will not think of dropping out. A deeper discussion about the definition of *engagement* and the effect of *engagement* in education is out of the scope of this paper (see, for instance, Bryson & Hand, 2007; Christenson, , Reshly andWylie, & Eds., 2012; Kahu, 2013). Motivation and engagement do not always go hand in hand (Kim et al., 2015): there can be motivation without engagement, since the latter comes from the effort and metacognitive regulation that one puts into the process.

Each of the game attributes described in Table 1 can be represented in a game by different concrete features, usually known as the game components. The most obvious gamification components are usually known as the PBL Triad (Werbach &

Table 1
Attribute categories of games (adapted from Bedwell et al., 2012; Landers, 2014).

Game Attribute	Definition
Action Language	Communication between the player and the game itself; the method by which the players make their intent clear to the game.
Assessment	The measurement of achievement within the game, feedback given throughout the game, the way in which game progress is tracked.
Conflict/Challenge	Presentation of problems in games, the nature, difficulty and uncertain aspects of these problems.
Control	The degree to which players are able to alter the game, and the degree to which the game alters itself accordingly.
Environment	Representation of the physical surroundings in which the player is immersed during the game.
Game fiction	The nature of the game world and story.
Human interaction	The degree in which players interact with other players in space and time.
Immersion	The player's perceptual and affective relationship with the game fiction.
Rules/goals	Clearly defined rules, goals, information on progress toward the goals.

Hunter, 2012): Points, Badges and Leaderboards. PBL materialize game attributes like assessment and rules/goals. Werbach and Hunter (2012) have examined over 100 implementations of gamification in several different contexts, and concluded that the majority of these systems included PBL. They are simple to use, powerful, practical and relevant. Points are mainly used to keep the score of the players, and simultaneously provide feedback. Badges are a visual representation of some achievements and they can be extraordinarily flexible. There have been studies on the effect of badges in learning contexts (Abramovich, Schunn, & Higashi, 2013) showing that badges directly related with the students' skills can lead to an increase in intrinsic motivation. Leaderboards allow players to see how they stand when compared with others. Extra care has to be taken when using leaderboards, because they can be powerfully demotivating for the players at the bottom (Werbach & Hunter, 2012). There is some controversy in using these PBL elements (see, for instance, Hanus & Fox, 2015), but actually they are the easiest ones to implement when you do not have access to an online platform truly dedicated to gamification, or a room equipped with computers. Points, Badges and Leaderboard, when used with care, are a very good place to start (Werbach & Hunter, 2012). Other game elements are *avatars* (that materialize immersion and game fiction), social graphs (related to human interaction), virtual goods (related to game fiction, assessment), among others. PBL, in conjunction with these other game elements, are tools that implement the basic game processes (mechanics) that drive the players to move forward in the game and that guarantee player engagement. These game mechanics are things like challenges, feedback, rewards, and cooperation. In turn, game mechanics are a way of achieving the desired dynamics of the game (Fig. 1). To define a gamification strategy it will be important to delineate what are the objectives of the game, what type of behavior are we aiming at, who are the players and what are going to be the activities. Activities materialize the attributes of conflict/challenge, control, human interaction, rules/goals. Regarding activities, it is very important to remember that they will have to generate feedback that in turn will be one of the main drives of motivation.

When structuring a gamified approach, one of the things that one should have in mind is that extrinsic rewards can be demotivating (Deci, Koestner, & Ryan, 1999, 2001; Werbach & Hunter, 2012). Extrinsic rewards can give the idea that the task is not worth doing just for itself, that it is not possible to have any joy in performing the task, so the only motivation found is based on the extrinsic reward. It is possible to reach the limit where the extrinsic reward is not valued enough to compensate for the effort of realizing the task. Extra care should be put in the design of the extrinsic rewards when considering a learning context, because students should, ideally, consider the learning process rewarding by itself. Extrinsic rewards should be seen as a way of achieving *internalization*: the transformation of extrinsically motivated behaviors into intrinsically motivated ones (Deci et al., 1991). If, for instance, external and tangible rewards (like badges) are given unexpectedly to students after finishing some task, it is less likely they will be detrimental to intrinsic motivation (Deci et al., 2001). Rewards that are not contingent on performance (task-noncontingent rewards) will also have a minor effect on diminishing intrinsic motivation (Deci et al., 2001).

Gamification can also present some drawbacks. One of the drawbacks has just been referred: focusing too much on extrinsic rewards can influence negatively intrinsic motivation. Making the adherence to a gamified process compulsory instead of volunteer can also jeopardize the desired results. It is also necessary to assess whether the players are not "gaming the game" (Werbach & Hunter, 2012): taking advantage of the gamification process but creating their own rules. One example is a driver that knows that the traffic light will turn red if he is in excess speed, so he slows down right before the speed sensor and then speeds up when he knows there will not be enough time for the traffic light to turn red. The desired behavior (motivating drivers to slow down) will not be achieved. Callan, Bauer and Landers (2015) consider several potential problems that one should be aware of before applying gamification in the working place.
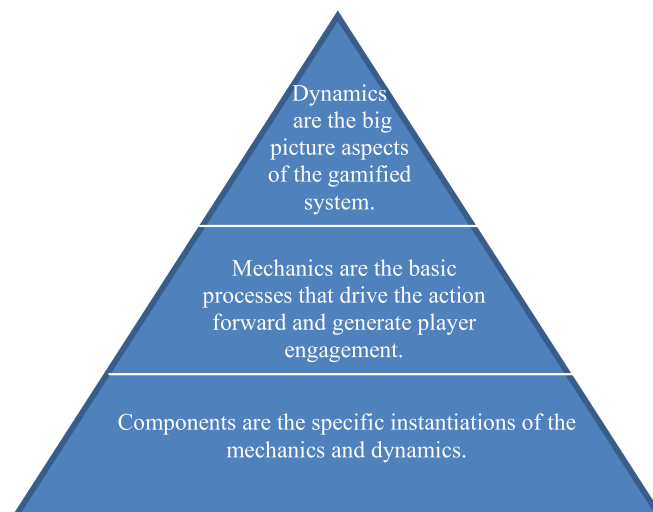

Fig. 1. The game element hierarchy (adapted from Werbach & Hunter, 2012).

2.2. Gamification, game-based learning and serious games

Gamification in learning should not be confused with the use of classroom games (Griffin, 2007). Game-based learning refers to the use of games to support teaching (Perrotta, Featherstone, Aston, & Houghton, 2013). Gamification is a much newer concept, and it is really more than learning through play. The use of games in the classroom is one of the many activities that can be included in a gamified course, but gamification goes beyond: the students themselves will be engaged in a game from the first to the last lecture of the course, where they are players with many challenges ahead to overcome. Actually, the idea of active learning (Cochran, 2015; Cochran, Greenberg, & Smith, 2005, pp. 237–256) can be perfectly integrated into a gamified course. The main idea of active learning is to achieve students' engagement through participation in exercises, and not relying in passive transfer of information through lectures. In gamification, engagement is achieved by making each student a player in a game. Through the realization of a number of activities, with different levels of difficulty and requiring different skills, the game will ultimately facilitate the acquisition of the desired contents and development of modelling and analytical thinking skills. A concept strongly related to Gamification is the concept of *serious games* (games in which education, rather than entertainment, is the primary goal) (Landers, 2014). Landers (2014) summarizes the commonalities and differences between the two concepts in the following way (page 3): "*they both incorporate game elements; they differ in that (serious) games incorporate a mixture of all game elements, whereas gamification involves the identification, extraction and application of individual game elements or limited, meaningful combinations of those elements.*" The objective of both is similar (improving learning outcomes), but the way to do it is different. In gamification, games do not assume the role of instructor and the goal is to change a contextual learning behavior or attitude (Landers, 2014). Kapp et al. (2014, page 56), also define the difference between *game* and *gamification*: "*In gamification, while elements of games such as points, badges, freedom to fail, and challenge are used, the intent is not to create a self-contained unit—not to create a game. The intent is to use elements from games to encourage the learners to engage with the content and to progress toward a goal*".

2.3. Gamification and learning

Gamification has already been successfully applied in different educational environments, and it is possible to find literature reviews on this subject (Caponetto et al., 2014; de Sousa Borges, Durelli, Reis and Isotani, 2014; Dicheva et al., 2015; Hamari et al., 2014). Authors agree that gamification is nowadays a popular topic in the academic community. Bedwell et al. (2012) present a taxonomy linking games to learning. Although they refer to serious games, the taxonomy presented can be easily borrowed to characterize gamification features (Landers, 2014). One of the advantages of using a common taxonomy is the fact that it can leverage the study of the effects of different game attributes in learning (Bedwell et al., 2012). Considering the different game attributes defined (Table 1), it is then possible to link each one of these attributes to specific learning outcomes.

Sheldon (2012) describes his experience with the gamification of a course on game design. Stott and Neustaedter (2013) introduce the concept of gamification and present three case studies, concluding that there is not a once-size-fits-all model for the successful gamification of a course. Barata, Gama, Jorge and Gonçalves (2013) describe a gamification experience in a Multimedia Content Production master course, and they conclude that it improved students' participation and motivation, although lecture attendance did not increase. Buckley and Doyle (2014) study the effect of gamification in student motivation, finding that gamified learning interventions have a positive impact on student learning. On the contrary, Hanus and Fox (2015) reached the conclusion that students in a gamified course (using only gamification elements of badges and leaderboards) showed less motivation and lower final exam scores than the ones in a non-gamified class. Domínguez et al. (2013) have designed a gamification plug-in for an e-learning platform and reached the conclusion that although students engaged in the gamified experience had better scores in practical assignments and in overall score, having also a greater initial motivation, they performed poorly on written assignments and participated less on class activities. Lee and Hammer (2011) summarize the risks and benefits of gamification in education: it can motivate the students to engage in the classroom, inspire students to learn and give teachers tools to effectively reward the students' efforts. Nevertheless, it can also absorb teacher resources, and make students think that they should only make an effort if there is a reward associated with it. Furthermore, if play is compulsory, is it still a game (Lee & Hammer, 2011)? Iosup and Epema (2014) describe their experience with gamification applied to graduate and undergraduate courses in a technical university. They conclude that the use of gamification is correlated with an increase in the percentage of approved students and in the students' participation in activities and assignments. They considered gamification as personally rewarding for the lecturer, even considering the cost regarding time spent adapting the course.

From the available literature, the described experience more closely related with operations research/management science learning is given by Wood and Reiners (2012) that consider gamification in logistics and supply chain education. Poole, Kemp, Williams and Patterson (2014) consider a gamification experience in business education. Students answered a survey at the end of the course, and it was possible to conclude that they had higher levels of involvement, more participation and more positive emotional reactions.

3. Methodology

As can be seen by the existing literature, the conclusions that can be reached regarding gamification in education are not convergent, although most of them show some interesting results especially regarding students' engagement. This justified the experience of having a gamified version of an introductory operations research course taught to the first year students of a bachelor's degree in management. Actually, the learning contents that are usually present in OR related courses lend themselves easily to a more active learning way of teaching, and it is rather straightforward to design several different activities to challenge students.

The question that motivates this empirical research is "Does gamification have an impact in the learning outcomes of students?". In order to try and answer this difficult question, a gamified version of the course was structured and taught during two semesters in two consecutive school years. This gamified version was then compared with the non-gamified version in the two previous school years. Since it is very difficult to objectively characterize and quantify learning results, the research methodology is mainly descriptive, although quantitative results are shown whenever possible. The research undertaken is exploratory. It will try to infer whether students are more engaged with the course and if this results in better learning outcomes. This is done by analyzing students' behavior and participation in the proposed activities, as well as considering the comments they made about the course. Quantifiable data is limited to final assessment grades and record of students' attendance to classes. Final assessment grades can be considered as a proxy to assess learning outcomes (although with severe limitations, as discussed in section 8), and students' attendance and participation in the proposed activities can be interpreted as a proxy of students' engagement.

4. Materials

In this subsection the structure of the gamified and non-gamified versions of the course will be described.

4.1. The course

Modelling in Management is a course taught to first year students of the Bachelor's degree in Management. For most students, this is their first contact with operations research. The intended student learning outcomes are defined according to Bloom's revised taxonomy (Anderson, Krathwohl, & Bloom, 2001; Bloom & Krathwohl, 1956). This is illustrated in Table 2. The contents that are taught during the course, and the number of classroom hours assigned to each content, are shown in Table 3.

Contents are taught using a mix between lecture-based instruction and problem-based learning, as it has been shown that this mix can lead to a better learning outcome (Carriger, 2015, 2016). The contents are first delivered to students in lectures, where the main concepts are introduced. Then students are invited to participate in problem-solving activities, by themselves or in teams, with the teacher having the role of facilitator.

Every year around 150 students are enrolled in this course. These students are divided in three classes, and each class has 4 h of lectures per week (2 lectures of 2 h each), during one semester (15 weeks). The term "lecture" is used in a general manner, meaning the time spent in the classroom with a group of students, where different types of activities can be carried out. The classrooms do not have computers, so it is not possible to have each student or group of students performing activities that require an intensive use of computers.

Class attendance is not mandatory. All course materials that are worked in the classroom are made available to students by using Moodle platform. The final grade is translated into a 0—20 scale, where all students that achieve 10 or higher will be approved. Students can choose between continuous assessment or assessment by final exam only. Students that choose continuous assessment have also access to the final exam (where they can try to be approved if they were not in the continuous assessment, or they can try to improve the grade if already approved).

In the beginning of each year, a quick and anonymous survey made by the lecturer asks the students simple questions as: *Do you think this course will be important for your professional career? Do you feel confident with quantitative methodologies? Do you think this course will be as difficult, less difficult or more difficult than others?* The answers do not differ very much from one year to the other. About 90% of the students feel that this course will not be important for their professional career and they think the course will be difficult, but at the same time they hope to improve their analytical thinking skills.

Table 2
Student learning outcomes according to Bloom's revised taxonomy.

At the end of the course students will be able to:	Bloom level
Identify situations where mathematical models can help managers make better decisions	Remembering
Describe and interpret a mathematical model, clarifying the underlying assumptions and the model's limitations	Understanding
Use the most appropriate model for concrete decision-making tasks	Applying
Formulate mathematical models for decision support	Analyzing
Evaluate the application of a mathematical model, checking its correctness and its adequacy for the decision making problem to tackle	Evaluating
Construct and combine different mathematical models in unseen situations, creating tools for improvement of the decision making process	Creating

Table 3
Contents.

Contents	Classroom hours
Introduction to Modelling in Management	4 h
Linear programming models	10 h
Special cases of linear programming models: transportation models	8 h
Integer linear programming	4 h
Special cases of integer linear programming: location, scheduling, generalized assignment problems	6 h
Introduction to networks: shortest path, minimum spanning tree, maximum flow, travelling salesman, routing problems, social networks.	6 h
Introduction to project management: critical path method	4 h
Decisions under uncertainty: decision trees	4 h
Introduction to game theory	6 h

Table 4
Examples of some of the activities.

Activity	Description	In/out of the classroom	Individual or Group
Solve a production plan optimization problem (Cochran, 2015; Pendegraft, 1997)	The students are divided in groups. They are given a set of LEGO pieces and a problem to solve. They can try to solve the problem by trial-and-error but they are also invited to formulate the problem and solving it using a general solver.	In the classroom	Group
Participating in the Energy Game (Beliën, Colpaert, De Boeck, Eyckmans, & Leirens, 2013)	Several activities, from discovery of the problem data, establishment of objectives, formulation and calculation of the optimal solution.	Both in and out of the classroom	Group
Written Test	Deciding on the best models for representation of different problems, formulating problems, etc.	In the classroom	Individual
Game Theory Battle	Game theory into practice, by having students organized in pairs, each one owning a disco bar and having to decide the best entrance price.	In the classroom	Individual
Sudoku	Coming up with an integer programming formulation for solving Sudoku	In the classroom	Individual
Looking for real problems	Each student should look for an OR related problem either searching on the internet or in some friends company, in the university and so on. This problem had to be presented to the class.	In and out the classroom	Individual
Diet problem	Each student had to formulate and solve the diet problem for himself.	Out of the classroom	Individual
OR in music, press, movies, etc	Find OR related issues in movies, music, television series, books, etc.	Out of the classroom	Group
Helping colleagues	Using the Course Forum and answer doubts of colleagues	Out of the classroom	Individual

This paper reports the experience of lecturing this course in four different semesters. In two semesters the traditional, non-gamified version of the course was taught. In the other two the gamified version was implemented. The changes between the gamified and non-gamified course will be briefly explained.

4.2. Before gamification

Continuous assessment is traditionally made by defining a set of activities in the beginning of the semester, with each activity contributing with a given percentage to the final grade. Students usually performed two tests: one at the middle of the semester, another at the end of the semester, each one graded in a 0–10 scale. The final grade would be the sum of the grades obtained in each of these tests. A set of activities was also defined, and these activities could complement the written tests: the written tests would be worth 75% of the final grade, and the rest of the assessment was made through a set of diverse activities (see Table 4 for some examples). The students were not obliged to perform the activities proposed, but if they did they would get the best one out of the two grades: tests only or tests plus activities. One drawback of this approach is that students could not recover "lost points" if they performed badly in one assessment activity. If a given student failed in the first test, for instance, he knew that even if he scored high in the subsequent activities the final grade would not be very good. This is one of the reasons why students that did not achieve good grades in the first test would give up and stopped attending classes. Another drawback is that students usually studied for the tests only and not as the contents were being taught, and they were not consistent regarding class attendance. In the second half of the semester, the attendance of students to classes usually drops to about half of what it was in the beginning of the semester.

4.3. Applying gamification

Huang and Soman define the application of gamification as a five step process as depicted in Fig. 2 (Huang & Soman, 2013):

Fig. 2. Gamification process (Huang & Soman, 2013).

In this particular course, the target audience is composed of first year students of management, that lack modelling skills and analytical thinking, and that are convinced that the course will be difficult. Students are most used to expositive lectures, and there can be some resistance to convince them to fully participate in classroom activities. The classes have a relatively large number of students, which can jeopardize the realization of some activities. The classrooms lack computers.

Learning objectives have been defined in section 4.1. It is important to equip students with modelling skills and analytical thinking and reasoning. The educational contents are structured into different stages, that are properly explained to the students. The interrelations between the contents are also explained.

Students will be able to know how they are progressing in their learning path through the use of points (as explained below) and through personalized feedback. The rules of the assessment and of the course operation are clearly explained.

Regarding game components, Points, Badges and Leaderboard have been considered. The justification for this choice has to do with the fact that the classroom is not equipped with computers and there is not at our disposal an online platform dedicated to the gamified course. The online platforms used are Moodle and Facebook (as explained later on), but these are not platforms truly dedicated to gamification. Furthermore, Points, Badges and Leaderboard are a good starting option when you have to deal on your own with an average of 150 students per semester. These game elements allow the implementation of the most important game mechanics and related dynamics in a learning environment: the use of challenges such that the students' achievements are translated into points; the choice of challenges tailored by the level achieved so far by the student; feedback regarding the activities the students are enrolled on, that should be immediate or in short feedback cycles; recognition by giving rewards through the use of badges assigned to students that outstand themselves in a given activity; control of the progress throughout the game; freedom to fail, since there will always be the chance to do another activity and to recover lost points.

4.3.1. Points

The gamification way of thinking begins with the way students are assessed. Most of the students usually choose continuous assessment, because they feel that having a single final exam is more risky.

In a game, players begin by having 0 points and start at level 0. As they progress in the game, they earn points and reach higher levels, where the activities are also more demanding. If a player fails, this usually is not that important, because he will have opportunities to repeat the activity, try to do it better and reach the next level. In a game, all players have freedom to fail. Game design encourages players to try, without fearing the consequences of failing (Stott & Neustaedter, 2013). This concept is incorporated in the assessment procedure.

During the semester, the 0—20 scale is totally forgotten. Every student begins with 0 points. A set of activities is planned during the semester that will allow each student to earn points and increase the level they belong to. Students know that the greater number of points the better, and that it is not necessary to have the maximum number of points possible to achieve the maximum grade (failure is allowed, without completely jeopardizing the final outcome): as many activities are proposed during the semester, and they know that it is not necessary to participate in all of them to achieve the maximum grade, they also know that a weak performance in one activity can be compensated by a good performance in another one.

At the end of the semester, the points earned by each student are converted into a 0—20 scale. This conversion is made by guaranteeing that it is easier to reach the approval level (10) or to go from 10 to 11 than from 15 to 16, for instance. Table 5 gives one example of this conversion (this is really changed every year since the number of activities and the activities themselves are also changed from one year to the next).

4.3.2. Badges

Badges are given to students in many different situations: if they have a particularly noticeable participation in the classroom, if they have an extraordinary participation in one activity, and so on (see Fig. 3 for examples). The badges are virtual, in the sense that they are assigned using Moodle, and everyone can see which students have earned which badges.

Table 5
Points to final grade.

Points	<1000	1000—1050	1050—1100	1100—1200	1200—1300	1300—1500	1500—1700	1700—2100	2100—2700	2700—3500	>=3500
Final Grade	Fail	10	12	13	14	15	16	17	18	19	20

Fig. 3. Examples of badges.

4.3.3. Leaderboard

Leaderboard was used, but with care. Only the top best students are shown. The reason for this is not to expose the students that are not doing so well, so that they don't feel demotivated for being the ones with the less number of points. The leaderboard was made available on Moodle, and also in a Facebook page.

4.3.4. Activities

These activities are not mandatory, they have different levels of difficulty (associated with the number of points they will be able to gain), different objectives and different characteristics. All activities will allow students to earn points, if they conduct the activities within the time window defined. Some activities are going to take place in the classroom, others they will have to do outside the classroom. Some activities have to be performed in groups, while others are to be performed individually. Depending on the activities, the points that the students earn can be dependent on the performance of the student, but there are also activities where students receive points for participating only (irrespectively of their level of achievement). These latter tasks can be thought of as *onboarding activities* and their objective is to keep all students engaged, even the ones that are having more difficulties (they will allow the use of rewards not contingent on task performance but on engagement). Some of the activities have already been described in Table 4.

Although the course is gamified, students can choose between participating or not in the proposed activities (the game is optional), since they can always choose to be assessed by a final exam only.

The schedule of the planned activities is not known in advance by students. The surprise factor is also important. Not knowing if a given activity will or will not take place in a given lecture will give them the incentive of trying not to miss classes.

One very important thing regarding activities is *feedback as soon as possible*! In a game, the engagement is also achieved by giving immediate feedback. For some activities, immediate feedback is not possible, but feedback is given in the next class at the latest. Another important thing is that feedback is not only giving points. It is also of the utmost importance to give personalized comments regarding the achievements. These comments are always constructive and, sometimes, advising the student to schedule an office hour with the lecturer.

The language used is also very important. The word *exercise* has been completely erased from the classes and replaced by the word *challenge*, considering the challenges that the students have to overcome throughout the semester.

4.3.5. Online participation

In many gamification applications, online participation in group activities plays an important role. Most of the students use online social networks platforms, and it could be interesting to try to include something similar in the gamified version of the course. This was done in two ways: by using Moodle platform, and designing Forums in which the students can interact (actually, some activities had to do with the interaction in these forums); creating a Facebook page for the course (Fig. 4).

In this Facebook page, leaderboard and badges were also published, and information related with the course contents was also posted. This was a page that did not have the "formal" contents of the course, but more informal information related to classes' preparation or with daily news that somehow were related with the course. Contrary to what could be expected, only about 50% of the students "liked" this page, and even these students did not interact with the page often. Probably most of them use Facebook strictly for personal life, and did not like to have Facebook also linked with course work.

5. Comparison between the gamified and the non-gamified course

The gamified and non-gamified versions of this course will be compared by looking at four teaching semesters. In the last two, the gamified version has been implemented, whilst in the first two the non-gamified version was considered. It is important to notice that, in each semester, all three classes were treated exactly in the same way. It would not be fair to students to have different classes with different assessment rules and a different teaching structure. So, the gamified course that took place during two semesters is compared with the non-gamified course that took place in the other two semesters. One question that should be considered is whether there are important differences between students attending this course from one semester to the other. It is assumed that there are not. This assumption is based on the fact that this is a first year
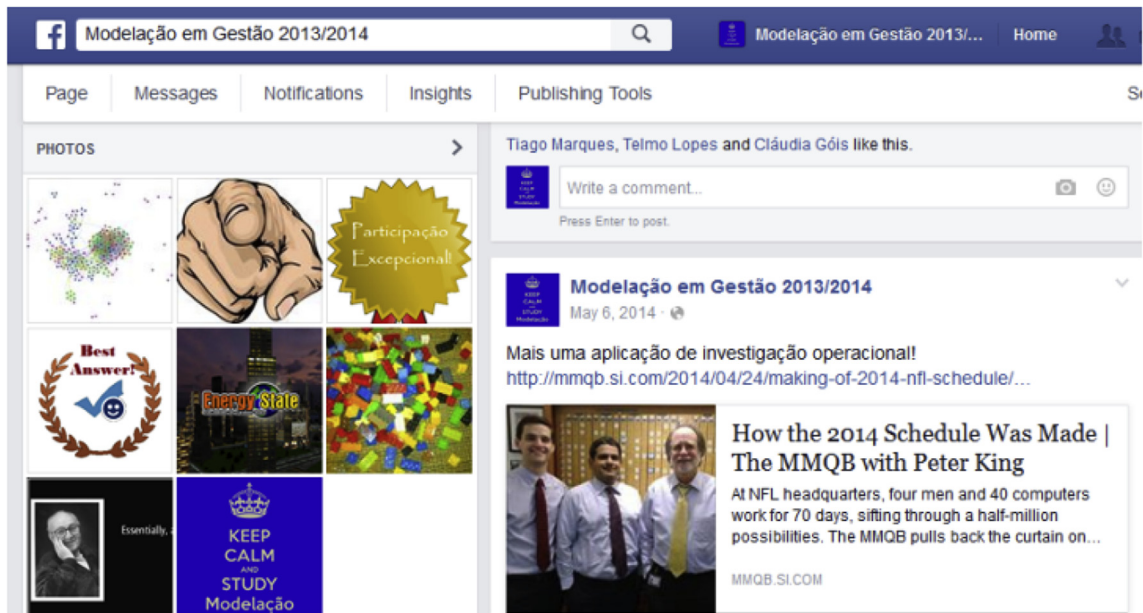
Fig. 4. Facebook page.

course, so most students have just begun their university degrees. To have access to this university degree, they have been assessed by national exams that, throughout the years, have kept the same objectives, assessment criteria and content. The grades of the students enrolling the management degree have not changed in the last years (DGES, 2016). So we can assume that the background of the students and their pre-acquired knowledge can be considered as comparable among different teaching semesters (meaning that changes in the course results are more likely related with changes within the course rather than preexisting conditions related with the students).

The gamified and non-gamified versions of the course have similarities and differences: both of them offer continuous assessment, and the type of exercises and activities that are done in and outside the classroom are similar. The main difference resides in the fact that the final grade in the 0—20 scale is completely forgotten during the semester, while in the non-gamified version it is always present since all proposed activities are graded considering this final scale. Another difference has to do with the fact that the planning of the proposed activities is not known beforehand by the students in the gamified version. Moreover, a larger number of activities are proposed to students, none of which mandatory, and sometimes they can even earn points by participating only (which keeps them much more motivated for participating). Table 6 summarizes the main features of the gamified and non-gamified versions of the course.

Table 6
Comparison between the gamified and non-gamified courses.

	Non-Gamified	Gamified
Assessment	Choice between continuous assessment or final exam. Every activity is directly related with the final grade in the 0—20 scale.	Choice between continuous assessment or final exam. Activities will allow students to earn points. Points will only be translated to the 0—20 scale at the end of the semester. Some activities allow a student to earn points by participating only, irrespectively of his performance.
Activities	Activities are optional. The number and timing of activities is made known to students at the beginning of the semester. The weighted average of the grades of the activities will be equal to 20.	Activities are all optional. The number and timing of activities is not known beforehand.
Classes	Not mandatory.	Not mandatory.
Feedback	Each activity is graded in the 0—20 scale.	Each student knows the points received on each activity, but will also receive personalized comments on their performance. The existence of badges allows recognition by their peers of the students' achievements.

6. Results

One of the most important results obtained with the gamified version of the course was the significant increase of students' participation in classes. The number of students attending regularly classes increased in about 20%, and students were always willing to participate in the proposed activities.

Considering the set of students that attended one of the semesters of the non-gamified course versus the set of students that attended one of the semesters of the gamified course, the percentage of students that were approved in the course increased from 70% to 86%. Fig. 5 presents a histogram showing the distribution of grades in the 2015 semester.

A t-test was performed to see if the difference between the average grades of the students attending the gamified and non-gamified versions of the course was significantly different. As shown in the next table, the average grade is indeed significantly different between the two sets (see Table 7).

Considering only the students that were approved, the average grade was around 14 (out of 20) in either set.

It was also important to know what the students' opinion was regarding the gamification assessment methodology: 96% of the students think the course assessment is beneficial for students. In this final survey made by the lecturer, students had also the opportunity to leave some comments regarding the course. Some of the comments of the students were:

−The type of assessment and the organization of the course are truly beneficial for students, since it helps us to accompany the course during the whole semester, contributing for better results.
−The fact that the course is oriented towards the resolution of practical cases, and the existence of so many different activities, challenge us to reflect instead of trying to do things mechanically.
−I enjoyed this course very much! The assessment method encourages us to be more participative and to work harder.
−I think that the skills that I have developed will be an asset in my professional career. The way in which the course is organized stimulates the learning process and the student's engagement.

At the end of each semester, students are asked to give suggestions of improvements regarding the assessment methodologies by the bachelor's degree coordinator. Students did not suggest any improvement measures regarding this course.

Every year students are asked to participate anonymously in an online official survey, conducted by the University services, where they can assess both the course and the lecturers. One interesting feature to report is that there are not noticeable differences in the assessment made regarding the lecturer in the four semesters considered, although there are differences regarding the way students assessed the course itself. Figs. 6 and 7 are print screens of the University survey results for the course considering one semester where the non-gamified version of the course was taught and another semester with the gamified version. The scale used is 0–5. In the non-gamified version of the course 69% of the students considered the effort they had to spend in the course adequate. In the gamified version this number raised to 84%. There is an improvement in all the items considered, but it is interesting to notice that the greatest improvements can be seen in items 7, 10, 11 and 12 that have to do with assessment and with students' participation in the learning process, personal development and performance.

Figs. 8 and 9 show the results regarding the assessment of the lecturer made by the students. As can be seen, there are almost no differences between the gamified and non-gamified version of the course, meaning that the changes felt by students are due to the way the course was organized and not due to a different attitude of the lecturer towards the students.

7. Implications & recommendations for OR educators

The gamification of an operations research course will mainly depend on the number of students enrolled, the subjects to be taught, and the computational resources available in and outside the classroom. If you are lucky enough to have classes
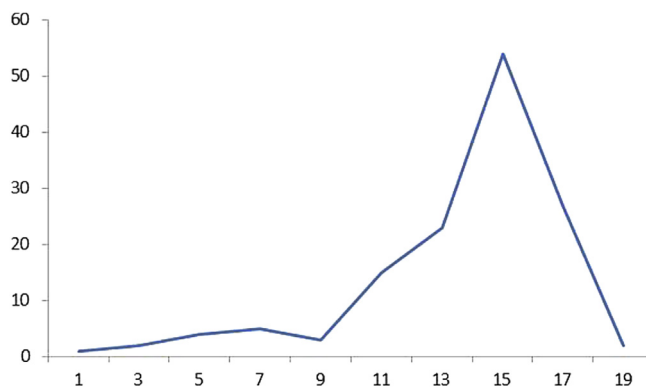

Fig. 5. Histogram of final grades.

Table 7
Average grades.

	Gamified	Non-Gamified
Mean	13,467	10,843
Variance	11,586	16,797
Hypothesized Mean Difference	0,000	
t Stat	7361	
P (T ≤ t) two-tail	0,000	
t Critical two-tail	1966	

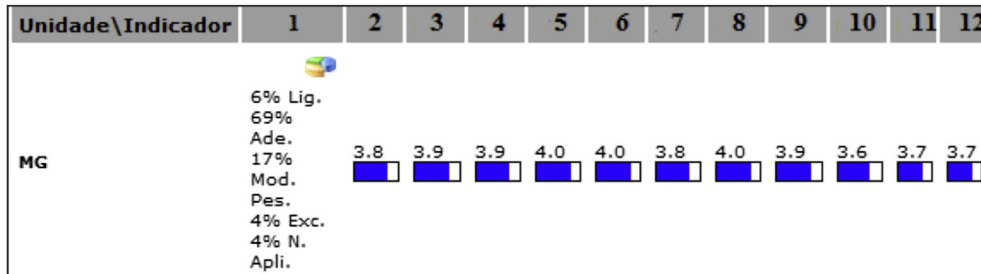*t*-Test: Two-Sample Assuming Unequal Variances.

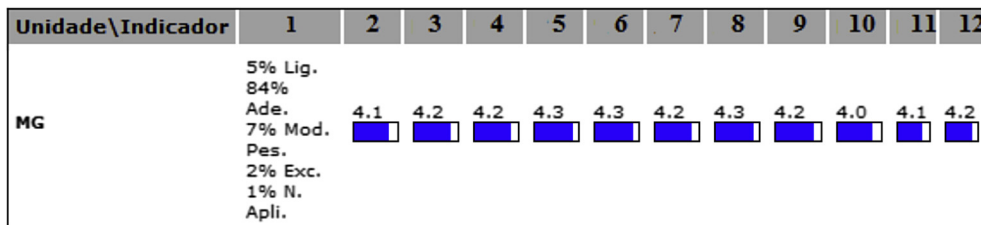**Fig. 6.** Course results for the non-gamified version.

Fig. 7. Course results for the gamified version.

Legend:
1. Adequacy of the required student's effort
2. Adequacy of the available learning materials
3. Average assessment of the quality of the learning process
4. Student's perception of what they were able to achieve
5. Clarity of the expected learning outcomes and the contents
6. Coordination with other courses
7. Clarity and adequacy of the assessment methods and criteria
8. Good articulation between theoretical and applied contents
9. Adequacy of the number of students per class
10. Student's perception regarding their active participation in the learning process
11. Student's perception regarding the development of their own critical and analytical thinking
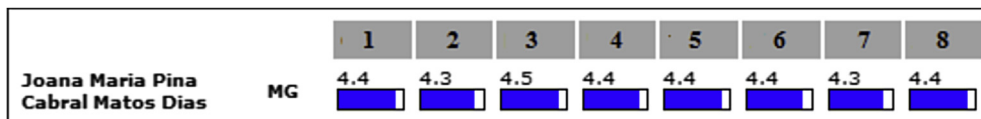12. Student's global assessment of their own performance

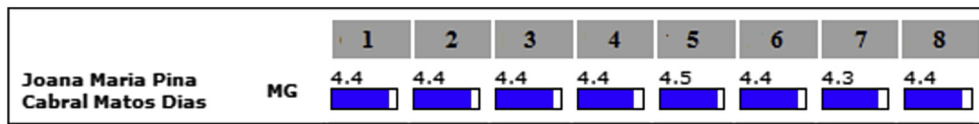**Fig. 8.** Results for the lecturer in the non-gamified version.

Fig. 9. Results for the lecturer in the gamified version.

Legend:
1. Global appreciation of the quality of the lecturer in the learning process
2. Availability of the lecturer to interact with students, support students and their self-learning
3. Clarity in delivering contents and answering questions
4. Accordance with the course contents and learning objectives
5. Adequacy of the information transmitted in each class and the available time
6. Encouraging the active and critique involvement of students in the classroom
7. Encouraging self-learning outside the classroom
8. Availability for answering questions outside the classroom

with a small number of students, if subjects to be taught lend themselves easily to the definition of practical challenges and if you have at your disposal computational resources during classes, then you are in a fruitful ground and it will be possibly worth it to gamify your course!

The number of students enrolled, and the number of teachers associated with the course, will have a huge importance in how ambitious you can be. Almost immediate feedback to students is one crucial aspect that promotes engagement, and this is directly related with the ratio teacher/students.

The first step will be to look at the contents to be taught and to highlight those that are purely theoretical and those that can boost class situations where students can have the main role.

For those contents that are purely theoretical, it is sometimes not possible to eliminate completely some more traditional types of lectures. But it will also be possible to engage students in activities where they have to do some research in terms of looking for concepts, definitions, practical applications of the theoretical contents, and so on. This will be much easier if they can have access to computers in the classroom. If you feel that the more theoretical contents are the ones the students like the less, or have more difficulties in the learning process, then it is a good idea to design some activities where they can earn points by participating only: if they feel from the start that they will not be successful, they will not be motivated for participating unless their performance is not crucial.

With contents that lend themselves easily to the design of classroom dynamic situations, it is possible to witness students more willing to engage in more difficult challenges if these challenges are more "convincing" from a real-world point of view than when only dummy illustrative problems are given. They like to feel that the challenge that is being proposed could really be a problem to be faced in real life.

It is also a good idea to promote group activities first, and only then individual activities on the same related topic. This will help students facing more difficulties getting on board, since they will have the support of a group at the start, and they also feel the responsibility of not letting their own team down.

Define which type and set of badges you would like to assign to students. These badges should be the recognition of the students' achievements and help students understand what you expect from them.

The use of virtual goods can also be very interesting. Students can earn these virtual goods in some activities, instead of points. Or they can earn them by achieving some defined landmarks. These virtual goods can then be changed, for instance, by advantages in some challenges (giving them access to some guidelines that no one else knows), allowing them to pick their own team in a group challenge, or giving them the opportunity of choosing the next activity to be proposed to the class.

There is no recipe or tool that could be developed that would come up with the best gamification version for each existing course. This is one type of situation where some base guidelines should be followed, but then experience and trial-and-error will make an improved gamified version of your course semester after semester.

8. Limitations of the presented research and suggestions for the future

In the presented research two different versions of an operations research introductory course were described and compared. One limitation of this study is the fact that this comparison is made considering students that are enrolled in this course in different semesters of different school years. Despite the fact that the information available about the students background does not point out differences among groups that could influence the results obtained, it is still possible that some variables that are not being controlled in the study could influence the outcomes. The optimal situation would be to

compare different groups of students in the same semester, with groups being randomly built. This alternative brings, however, serious ethical problems.

Although the assessment made by the students regarding the lecturer was similar in the different semesters, it is also possible that the improvement in the outcome of the students could have been influenced by the increased engagement of the lecturer, herself, in the teaching and learning process of the gamified version of the course.

Considering future research directions, a longitudinal study should be performed, studying the impact of gamified courses in the students' outcomes in the long run. Many of the skills that the students should acquire throughout the course will be necessary in other courses. Assessing and comparing the results obtained by the students during their path towards obtaining their degree could help understanding if the effects of a gamified course are confined to the course itself or if the impact is broader. Further research is also needed regarding the development of methodologies that allow an objective assessment of learning outcomes. Grades can be seen as a way of measuring these learning outcomes, but they cannot truly represent the development of skills and knowledge that has really occurred. There are many uncontrolled variables that can affect the students' final grades (personal problems, anxiety felt during exams, among many others).

Research in the field of education, and gamification in particular, ought to be interdisciplinary, counting with the participation of psychologists, science education specialists, technological experts, alongside teachers.

9. Concluding remarks

Gamification could be a very useful tool for motivating students. The contents that are usually taught in operations research/management science courses are easily adapted to such a framework. The best thing would be to have a dedicated online platform so that gamification in teaching could reach another level. Each student could have an *avatar*, many different interactive activities could be delineated and the social interaction between students could be leveraged, virtual goods could be associated with the achievement of goals and the students could truly get a feeling of how they are advancing in the course, and in which level they are currently in. Although Moodle can support some gamification elements, like progress bars, display of quiz results and badges, for instance (Henrick, 2015), Moodle is not the best platform to support a truly gamified course.

The downside of choosing such a gamification approach is the very significant increase of workload related to the course. This has mainly to do with the fact that feedback on so many activities has to be given, as soon as possible and continuously throughout the semester, compared with having to assess written tests twice a semester.

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