# Deep Gamification of a University Course

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**Abstract**

*In this work it is presented the implementation of a new learning and evaluation methodology inspired by Game Design to the Linear Algebra course at Instituto Superior Técnico (IST). The Linear Algebra course at IST is a first semester freshman course, which has a repetition on the second semester for students that have previously failed. For these students a methodology based on game progression, on-demand evaluation and flipped classroom was applied. Results show a modest increase in success ratings from the previous year and a high student satisfaction.*

**Keywords**

*Gamification, Linear Algebra course, Flipped classroom, Game-like Assessment.*

## 1. INTRODUCTION

In Instituto Superior Técnico (IST), the Engineer School of University of Lisbon, the course on Linear Algebra[1] is a first semester freshman horizontal course, attended every year by more than a thousand students. On the Taguspark campus, enrollment is of the order of 300 students per year. On the second semester there is a repetition of the course (the "alternative semester") for the students that failed a passing grade in the previous semester(s). While the passing rating for the first semester is consistently above 60% in general and above 70% for first time students, the passing ratings for the alternative semester are usually below 40%. (see Figure 1).
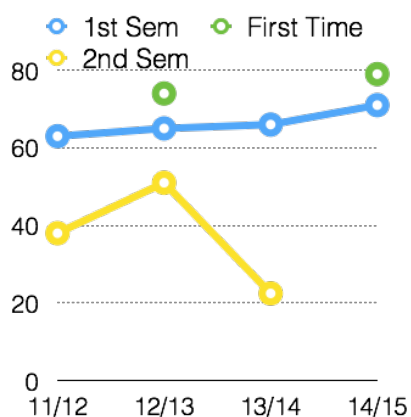


**Figure 1**

The traditional teaching and evaluation method consists of weekly lecture classes (either 3x1h or 2x 1.5h), and one recitation class (1.5h). There are three assessment tests, roughly, one at the end of each month of classes, with the first two tests counting for 25% of the grade

each, and the third for 50% of the grade. On the second semester the students have to do this course as an extra course besides the usual classes and workload, with a very negative impact in class attendance and final results. After having navigated through the course (without passing) in the first semester, the students usually have some grasp on the first (and simplest) topics of the course, with the effect that they start missing the lectures, and then do not come back…

## 2. GAMIFICATION IN EDUCATION

Gamification is the introduction of game elements in non-game settings [Martinho et al, 2014]. In fact some game elements (like goals or external motivation through scoring systems) are already present in learning activities. But adding others, like evolved reward structures, competition (e.g. leaderboards, achievements) and cooperation (e.g. group objectives, group work, discussion foruns) mechanisms, immediate feedback or progression, it is possible to create powerful learning outcomes [Kapp et al, 2012]. Note that Gamification is not the same as using a Serious Game as a learning tool because, by definition, a gamified setting is not a game. There are some previous experiences of gamification in education, using several different approaches [Labouriau, 2011; Sheldon, 2010; Tekinbas et al, 2014]. Techniques can be though at two different levels. In a *shallow* level or *thin layer* of gamification, the core teaching and learning processes are not substantially changed. There are still lectures, readings, projects and exams. But the language changes to making quests, crafting items, defeating bosses with the grade given in Experience Points (XP). An example of such an approach is given in [Sheldon, 2010]. Another possible shallow gamification technique is to give stars, badges and prizes for activities in the course, use leaderboards, or yet use game-like interface components. Shalow gamification has been the target of some criticism because it can be seen as manipulative and making excessive use of external motivation [Bogost, 2014]. Shalow gamification can be

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[1]    https://fenix.tecnico.ulisboa.pt/cursos/leic-t/disciplina-curricular/1529008374040

seen as a layer that is put above and on top of the core processes, without changing their essence.

In contrast to shalow gamification, there is deep gamification. Deep gamification can be defined as introducing game elements that change the core processes of the activity. A seminal example of that approach is given by Quest to Learn, an innovative school for grades 6 to 12 that started in 2009 in New York City [Tekinbas et al, 2014], where the whole curriculum was planned using game design techniques. While shalow gamification needs mainly programing and visual design skills, deep gamification uses mainly game design skills, because it is necessary to design the game mechanics at the core of the activity.

## 3. GAMIFYING LINEAR ALGEBRA AT IST

IST is the leading Engineering school in Portugal, and its Department of Mathematics is very conservative. Thus, an attempt to use total gamification (shallow plus deep) would be difficult to be approved. As the author believes deep gamification is indeed the more powerful of the two kinds, an option was done to only propose deep gamification techniques, with a small exception. The target processes to be gamified were chosen to be progression and assessment.

### 3.1 Progression

The traditional course progression is based on a fixed sequential rhythm given by the lectures and test dates, which is monolithic and is always moving forward without pause. If a student falls sick or has a test or a project delivery for another course, the natural tendency is to skip classes and study during a week, thus gaining a knowledge gap in Linear Algebra, which will affect all her or his subsequent activities in the course. On the other hand, in a single-player game and many non-persistent multi-player games, the rhythm is flexible and defined by the player. Also, the game only advances to the next level after the player shows some prescribed proficiency at the current level.

To use game-like progression, the course was divided into modules. Five mandatory core modules (Systems of

**Figure 2**

Linear Equations, Matrices, Determinants, Linear Spaces, Eigenvalues and vectors) and two optional out of a possible nine, having to do with advanced topics or applications (e.g.: Graphical Computation, Markov

Chains, Infinite Dimensional Spaces). The core modules were connected so that some modules could only be done after others, but allowing for some liberty for each student to choose her or his own path (see Figure 2). The students could also go on their own rhythm (see below), and the first two modules were easier, with the difficulty ramping up for the two last core modules.

### 3.2 Learning and Assessment

Traditional learning and assessment involves attending lectures to learn the concepts, apply those concepts to problems in the recitation class, (ideally) study at home and try to solve more exercises, and then submit to discrete evaluation tests. In general, there is a second chance if you fail some test or other assessment, but no more.

Contrasting with this, in a game the player learns by trying (and failing). The player learns with the mistakes she or he commits, everything she or he does counts for scoring or progression and usually can repeat the same level again and again, looking for a better score, and learning more about the game in the process.

To use game-like assessment in the course, a flipped classroom strategy was used. The students would prepare outside the class, using a collection of short videos covering the subject matter or books. The videos already existed, having been produced by the IEEE academic Portugal initiative [IEEE, 2014]. There were more than 60 videos, mostly from 5 to 15 minutes duration, covering most of the subject matter. The two books were the standard books used in the Linear Algebra course at the Taguspark campus [Lay, 2011] and Alameda campus [Magalhães, 1998].

There would also be a 1.5h of seminar each week, where the teacher would talk about the subject matters that student wanted to learn about, and the students would practice in the recitation classes. There was a period for assessment every week, where each student could make tests for up to two modules of their choice, as long as they had been approved in an online quiz on the subject matter. The tests had a simple grading system (nothing, Bronze, Silver, Gold), but the questions would be similar to the ones on the normal course. There would be quick feedback on the results and in the next recitation class the students could see their mistakes and do more exercises or practice tests. Students could repeat module testing as many times as they wanted. While it may seem that 1.5h a week for testing is a waste of "contact time", this is not the case. The test classes can be seen as recitation classes on steroids, there existing studies that point learning by testing to be superior to other methods [Karpicke and Blunt, 2011].

The course final grade would be calculated directly from the modules results, with approval on all modules with Bronze level translated to a 10/20 (minimum passing grade) with each module with better grade giving a bonus to the final grade. Students with grades above 17/20 would have an oral exam to be able to attain 18/20 or above.

For compatibility conditions, there was the possibility of a Final Exam, for students that preferred the traditional evaluation method.

### 3.3 Presentation

While the proposal presented to the Department of Mathematics in the end of 2013 had the word "Gamification" on the title and also included shalow gamification techniques, during the discussions, it was clear that there was confusion between the concept of gamification with the use of serious games to teach mathematics and a fear to associate the Linear Algebra course with games, perceived as a childish activity. There were also concerns that the syllabus was being changed, due to some advanced subjects being in optional modules. The above points led to the rejection of the initial proposal.

Taking that reaction into account, the 2014 proposal had the word "Gamification" removed from the title (but not the text) as well as most shalow gamification techniques. The removal had a non-planned benefit, which was that the students were not aware that this new methodology was gamification. In some sense, using only deep gamification, allowed for the experiment to avoid gaming-related biases. There were also changes to the modules, with all the old syllabus included in the core modules.

While these changes led to the approval of the experiment by the Department of Mathematics, the changes made the course harder to pass than the regular one, as the student needed to obtain a passing grade in all core modules, and not just a passing grade on the whole of the sylabus (which allows traditionaly, in the limit, for the student just to cover part of it).

### 4. IMPLEMENTATION

As described above, the approval process for this new methodology was a very complex one. The initial proposal for the academic year 2013/2014 was refused by the Department of Mathematics on grounds that it changed the course matter, due to some advanced topics being optional. For the academic year 2014/2015 there were protracted negotiations, and finally, the day before the classes were about to start, there was a meeting under the aegis of the Executive Board of the Pedagogical Council of IST (body constituted by professors and students and responsable for the pedagogical policy in the institute), where an agreement was reached to move along with the experiment. There were two negative effects on the implementation with the late approval of the new methodology. The first was the impossibility of timely divulgation among older students, which were a prime target group. The other had to do with material preparation (module contents, study materials, assessment tests, etc) which the teacher was unable to properly do before the start of the semester, with all implication on some lack of chosen study material and excessive workload he had during the semester, just to prepare the around 60 forty minutes tests necessary.

From the 80 enrolled students, around 30 were almost completely absent. It was necessary to accompany the other 50 in their individual paths, with individualized on-line tests management, specific written tests and corrections. All together, this course took as many hours of effort as would take to prepare a new course.

Participation of the students during the semester was variable, with around 50 students active in the first weeks, to less than 15 in the week after Easter, which coincided with other courses midterms, to back around 20 until the end of the semester, with some students having already finished by the 11th week (theoretically, it was possible to complete the seven modules in just four weeks).

### 5. RESULTS

In the end, student pass rates were slightly superior to the previous year (30% vs 22%). The numbers are in Figure 3.
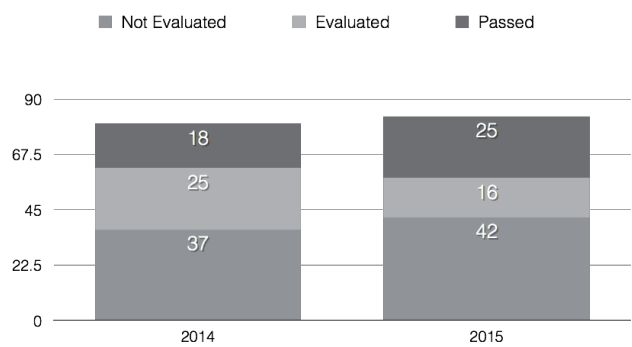


**Figure 3**

The late decision regarding the use of the new method and the inherent difficulties of spreading the word about it for the students to plan their effort was a contributing factor for the increase of non-evaluated students (I considered as evaluated a student that did at least 3 Modules or tried the Exam. There were 10 students trying the exam, but none managed to get a passing grade.

### 5.1 Student Survey

A student survey was done using IST's LMS, before the final evaluation date, and got 14 answers. While not completely representative of the universe, it is representative of the active students. Below we analyse the answers to the questions posed.
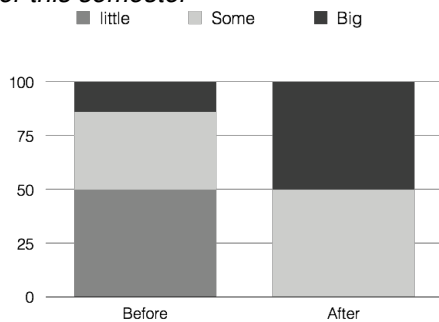
*5.1.1 Do you think your knowledge of LA to be better or worst by using the new methodology vs the traditional way?*
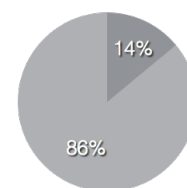


To this question 86% of the students answered that they learned more with the new method, and none said she or he had learned less.

### 5.1.2 Comparing the interest on LA subject before and after this semester

little    Some    Big



When asked to rate the interest they had on LA subject mater before and after this semester, one can see that there was a substancial increase in student interest.

When asked the reason why the interest changed in an open question, there were seven answers, pointing that the way the subject was divided allowed for better understanding of the diferente subjects and their connections, and that the seminars has been more useful than the traditional lectures.

### 5.1.3 What did the students particularly like in the way the course was implemented?

To this open question there were several interesting answers. Some of the more representative (out of 12) are reproduced below:

"Weekly tests reinforced the regular study and the resolution of questions one might have, allowing for a faster understanding of the subjects and the conclusion of modules at a constant rhythm. This evaluation method also allowed for a great flexibility regarding other obligations and the opportunity to repeat any module was very didatic"

"The possibility of failing more than once in a particular module made me understand it, each week better"

"Independence of study, and the possibility of finishing early"

"Liberty of choice regarding test dates and subjects being evaluated"

"It allowed me to better manage my time and divide it with other courses"

### 5.1.4 What did the students particularly dislike in the way the course was implemented?

To complement the previous question the students were asked about what they had disliked most. Only 6 answers pointed actual negative comments. One student did not like the on-line quizzes, but did not explain why. Another commented that there were too few lectures. A third that it was difficult to manage the time by himself. The other three talked of the difficulty of finding the right learning materials for each module, and that some test questions were too different from the ones presented as practice questions.

### 5.1.5 What was the impact of the way the LA course functioned on time available to the other courses

● Positive    ● Very Positive    ● No Effect
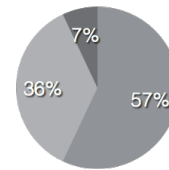


All but one of the surveyed students reported that the new methodology had a positive or very positive effect on the time available to other courses.

### 5.1.6 Considering everything, do you prefer the traditional or the new format of the LA course?

The answer to this question is the more relevant to understand if the students think the deep gamification of LA as a positive thing, or a negative thing.

● Traditional    ● New
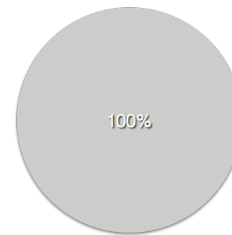


The students were unanimous in prefering the gamified version of LA.

## 6. CONCLUSIONS

Gamification has been a hot topic in the last few years, with a lot of discussion on its novelty (medals have existed for a long time) and actual effects. Contrarily to most trends, we presented here an experience of deep gamification. As explained in Section 3.3, the students were not aware that the course had been gamified, which allowed one to see the effects of game-like progression and scoring in a non-game and unbiased environment. The course was not easier, as the students must have a passing grade in each of the modules, and could not resort to just studying half the subjects and try their luck. Rapid feedback was very important as it made possible for the students to learn from their mistakes and allowed for better understanding of the subject matter.

Proposal approval delays made it impossible to properly publicize the new method to the target group it could be more useful to, the older students. Almost all students who seriously tried to do this course managed to pass, and were very happy with the course. That is a success, as attested by the student survey.

Things to improve on an eventual rerun of the gamified course would be advanced notification to the students about the new methodology, some changes to the

division of subject matter to better balance the different modules and more prepared subject contents to help the students learn each module.

## 7. ACKNOWLEDGEMENTS

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