PLMan: Towards a Gamified Learning System

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Abstract. Gamification is set to be a disruptive innovation in the field of education in the next years, as a way to encourage learning, since when the fun impregnates the learning process, motivation increases and stress is reduced. However, most experiences in learning gamification just remain on the surface, just offering a layer of standardized game elements such as badges, leader boards and medals. Instead, a deeper transformation of the learning process is needed, making up a true process reengineering. As a practical example, PLMan learning system is presented, an attempt to redefine the learning process in the context of a particular subject. It is based on a unique and simple type of problem: solving mazes of the PLMan game, an adaptation of the famous *Pac-Man* game. The maze, as the building block of our learning strategy, has a set of properties that allows us to introduce all the features of games in the learning process. From this experience some important lessons about the gamification of the teaching-learning process can be obtained: the importance of fun as a consequence of learning, the need of having an immediate feedback of our actions, the trial and error possibility as a major source of learning and progress, the relevance of experimentation and creativity as a means to develop the learners skills and the importance of autonomy to give the learners the control of their learning process. All these features are propellants for learning and a way to improve the motivation of learners.

Keywords: Gamification · Learning · Game learning

1 Introduction

Playing is learning. From our earliest childhood, we experience our environment to learn. As a result of this learning, we have fun and therefore, we call it *playing*. As we grow, the words *game* or *playing* seem unserious and we use *learning* instead, but playing and learning are the same thing. All this has not gone unnoticed by researchers in the field of learning and, as a result, research on the use of games in education is experiencing a particular boom. No researcher questions today about the ability of games to teach. The controversy focuses on what skills, contents or capabilities can be taught through games.

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In such a technological world like today's, the paradigm of massive games are video games. Numerous studies have demonstrated the ability of video games to teach, identifying what features make these games so educational as fun. Going one step beyond, can we use these features in other processes that are not games themselves? We call this gamification.

Gamification is defined as applying the principles of video games design, the use of the mechanics and the elements of a game in any process, beyond the specific context of video games. Many gamification proposals remain on the surface: they just provide a veneer to the process, adorning it with elements that give the aspect of the game: an attractive interface, badges, ratings, leader boards, medals... However, the process itself is unchanged. This supposed gamification actually does not include the key features that a game should have: fun, autonomy, tolerance to error, experimentation, progressivity, and so on.

From our point of view, the gamification must penetrate that surface and imbue the whole process. True gamification is a process rethinking to incorporate all the features of games to the core of the learning process. This is not a simple task that, like any other process reengineering, requires a thorough study of the process to be gamified. The aim of this paper is determining the key elements, strategies and features that make gamification a true process reengineering. To exemplify the results, a practical case is proposed: PLMan.

Section 2 presents the concepts and previous works about games and gamification. Our proposal about the features of a gamified system is presented in Sect. 3. Section 4 is devoted to explain the design and construction of a particular gamified experience. Finally, the conclusions and future work are presented in Sect. 5.

2 Background

2.1 Games and Gamification

The continued development and strong penetration in society of video games is unquestionable. Video games have changed the way our youth (and adults) conceive reality and interact with each other [12,20]. According to Prensky [16] computer games attract players for several reasons: they encourage participation, motivate users to gradually achieve small goals, offer immediate rewards or punishments, and allow the difficulty of each level to be adapted according to players abilities, age or knowledge of the game. The reflection that this reality provokes is straighforward: can video games be used in other contexts than entertainment to motivate people to do any activity? And if so, how can it be done?

Gamification comes out from this question. It is defined as applying the principles of video games design, the use of the mechanics, dynamics and the elements of a game in any process, beyond the specific context of video games [23]. Gamification was included in Gartner hype cycle about Emerging Technologies 2011. In 2012, it was included in the peak of inflated expectations, expecting to get

the plateau of productivity in a period between five and ten years. In 2013, gamification was considered in the peak of expectations but falling in 2014 in trough of disillusionment, and even disappearing in 2015. This was already foreseen in the Gartner consultants report *Gamification 2020: What Is the Future of Gamification?* [1], which considered that gamification was going to get to trough of disillusionment in 2013 and 2014, mainly because it is difficult to understand the design of video games and the strategies that motivate players, resulting in fake applications of gamification due to superficial applications of the concept. They even forecasted for 2014 that 80 % of applications based on this philosophy would fail to satisfy business needs due to a bad design. However, the correct application of the video games principles will have a strong impact in many fields, becoming a transforming force together with other emergent technologies.

Games and gamification can be very powerful tools for improving different processes, particularly learning process. Numerous studies indicate that games encourage learning, since when the fun impregnates the learning process, motivation increases and stress is reduced. As Koster [10] says, immediate feedback reinforces by endorphins and dopamine neurons and links involved in the accurate prediction, which gives the player the feeling commonly known as fun. Particularly the use of video games increases satisfaction while learning and memorization are also improved [14]. This is because a complete immersion of the players on the task being done occurs [3], allowing them to decide what to do at all times. It is important to add that during the game, immediately after each action, the player receives response information, enabling learning by trial and error.

Gamification is to take advantage of both the psychological predisposition of people to participate in games like the benefits of the own game to motivate and improve the performance of the participants. This approach applied to the educational world has a promising way to go [17].

2.2 Gamified Learning

Education is one of the fields where gamification will become a disruptive innovation, mainly in tech-based learning (eLearning) and lifelong learning. According to NMC Horizon Report 2013 [7], gamification was one of the two technologies experiencing growing interest in education in a mid-term (two to three years). The report states that using gamification and games in a wide way are two sides of the same coin. Recent reports, such as the one of 2016 [8], state that this stage is already overtaken and new terms, such as *Measuring Learning*, *Personalized Learning* and *Adaptive Learning*, appear. Those terms go deeper in the concept of gamification as a process redesign to adapt to learners' rythm.

Therefore, as international referenced reports say, we can conclude that the following years are crucial worldwide to determine if gamification, particularly its correct application to different experiences, will be able to consolidate the great expectations on it, in general, but also in education in particular, where it is expected that these years are the key point. That is why high doses of both research and clear justification of using gamification techniques are necessary,

based on quality indicators. A lot of analysed experiences, reports and aspects reflect the interest in gamification, but the evidence and, perfectly clear for experts, is that we are in front of the first steps, just isolated items that overlap, but, in the end, not facing the core of gamification: gamifying all the learning process. Reengineering the whole process is needed, taking into account since the beginning the principles of gamification in order to design a successful gamified experience. Nowadays, according to Kapp [9], there are two types of gamification: structural gamification and content gamification. Structural gamification is the application of game-elements to propel a learner through content with no alteration or changes to the content itself. The content does not become game-like, only the structure around the content [15]. Content gamification is the application of game elements and game thinking to alter content to make it more game-like.

For a discipline to be mature, the design methodology must be clearly defined and accepted. In gamification, nevertheless, many experiences fail because the solutions are just a mix of pieces from game components with no formal design process. There has been some effort to define design frameworks for gamification, and a complete review can be found in [13]. Some interesting experiences are the one of González et al. [5] that present a conceptual architecture for an Intelligent Tutorial System that includes gamification elements as key components, or the work of Domínguez et al. [2] that describes a gamification plugin for an e-learning platform, collecting quantitative and qualitative data in the process.

3 Gamification Proposal

3.1 The Essence of Games

There are several works that explore the essence of games, as a first step to transplant their lessons to gamification. Among them, one of the most frequently mentioned studies is the one by Werbach (Pyramid of the elements [22]), which is based in the article by Hunike et al. [6]. This analysis shows the game elements in a pyramid (Fig. 1) where the lower elements are the basis on which the higher ones are built.

This model states that the most important aspect in a game is at the top of the pyramid, the so-called *dynamics*. To be able to create these *dynamics*, elements of the lower step are needed, that is, the *mechanics* that, in turn, require the elements in the pyramid base, the *components*. Therefore, to produce *emotions* in the players (a *dynamic*), a game could use the *chance*, *rewards* and *challenges*, or any combination elements in the *mechanics* level. In turn, *challenges* could be made up of *achievements* and *points* to win a *combat*, for instance.

Obviously, all these elements are part of the essence of a lot of video games. However, not all elements are present in all games. For example, some classic games such as "The Secret of Monkey Island" [4] or "Alone in the Dark" [11], classified as adventure games, have no rankings, virtual goods or even points. Furthermore, the mere addition of game elements is not enough to have a funny motivating gaming experience, since there are games that include most of these elements but are not funny at all. So, are there other aspects to consider?

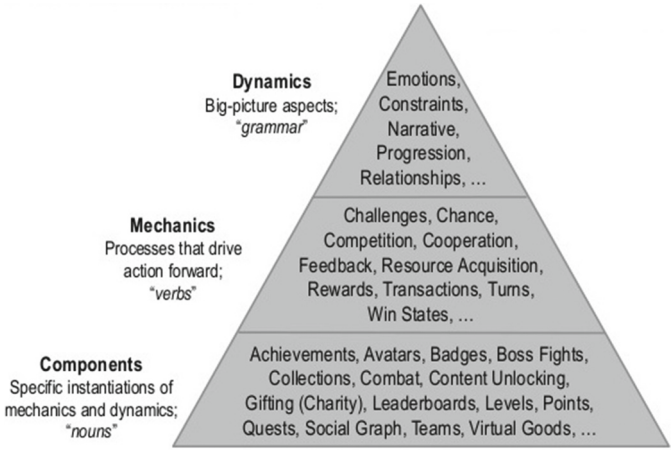

Fig. 1. Pyramid of the elements of Werbach

3.2 Motivation as a Principle

Motivation plays a central role in every gamification process, as one of the main propellants for human activity. Motivation can be informally defined as the set of reasons for a person to act in a certain way. There are two types of motivation: extrinsic and intrinsic motivation, and both should strongly influence the design of a gamified system. For good results, the elements must be designed in search of intrinsic motivation, always with an appropriate balance of extrinsic motivation (without overdoing it). All this is situated within a psychological theory known as the Self-Determination Theory [18]. This theory tries to explain the factors that influence the motivation, stating that there is a continuum from amotivation to intrinsic motivation, which passes through several intermediate levels of extrinsic motivation.

Making a summary of this theory, it can be said that there are three key factors for people to be in a state of intrinsic motivation to perform a task:

- *Autonomy:* they must perceive that they make the task willingly, not being forced, and always in position to control the process with their own decision criterion.
- *Competence:* it is imperative to feel that the task is feasible or practicable. Someone feeling incapable of performing a task cannot be intrinsically motivated to do it.
- *Meaning:* the task should mean something to the doer. If the task has no value or meaning for the person, it can be perceived as useless and it cannot generate intrinsic motivation.

As a conclusion, a necessary condition to obtain a successful gamified process is incorporating some of the main game elements (dynamics, mechanics and components) but a deeper redesign of the process is needed to produce intrinsic motivation by offering autonomy and meaning, and considering the proficiency level of the players.

3.3 Gamification of the Learning Process

A process is a set of interrelated activities that interact to achieve a result. In the context of education, the learning process is the set of activities that produce learning as a result. Reengineering a process is rethinking and redesigning its activities to better achieve the objectives of the process, usually with a lower cost. When dealing with the learning process, reengineering it implies that the rethinking and redesign are done to get better results in the learning outcomes as well as increasing the efficiency and effectiveness, in a broad sense.

To define the learning process it is necessary to determine the activities and the way they are related. In the following sections a study about the learning activities and their relations is presented, together with the main features that, from our point of view, are needed for a effective reengineering so that a deep gamification is achieved.

Learning Activities. Learning activities are the building blocks to construct a learning process. As a result of performing the learning activities, the student should have developed the expected capabilities and skills. For the learning activities to take part in an effective gamified learning experience, they should have the following features:

- *Meaning:* the activity must be linked to the subject to be taught, that is, the contents of the subject must be needed to correctly perform the activities. For instance, the activity "calculating the derivative of x^2" has a meaning in the context of learning derivatives, but it has no meaning for a History course.
- *Score:* there must be any way to assess how good is the activity result, that is, there must be a score or measurement of the degree of correctness of the result. For instance, the activity "solve a crossword puzzle" can be scored by indicating the percentage of correct words in the puzzle solution.
- *Automatic assessment:* this feature is related to the previous one. The possibility of automatically assess the results of the activity is crucial to obtain an immediate feedback from the system with no human intervention.
- *Progressiveness:* it should be possible to progressively increase the difficulty of the activity, so that there is the possibility of designing simple activities to train basic competences and complex activities to train advances competences. For example, the "crossword puzzle" activity can be designed to increase its difficulty by incorporating more complex words progressively.
- *Experimentation and creativity:* usually, learning activities are designed to have only one possible solution (the case of "multiple choice tests" is paradigmatic). However, the reality is not closed and usually has infinite possible interpretations. Providing activities with multiple solutions and paths to explore, allows experimentation, creativity and decision making.
- *Game "flavour":* if possible, it is interesting to give some aspect of game to the activity. A "crossword puzzle" is preferable to a "word definition" activity, for instance.

Learning Path. Isolated activities do not make up a course. A motivating learning experience is achieved when the activities are linked with the others to built a learning path. Instead of sequential series of activities, a network of activities is proposed, so that every student can make up their own learning path performing the different activities (the nodes of the network) following the links between the activities. The combination of the activities in different ways allow the development of the following features:

- *Autonomy:* the students are owners of their own learning process. So, there should be some mechanism that allows them to make their own decisions to choose their own learning pace.
- *Challenge:* there must be an adequate level of challenge in the proposed activities, so that learners enter a state of *flow* [19], that is, they have a feeling of complete and energized focus in the activity, with a high level of enjoyment and fulfillment.
- *Rewards:* performing an activity should always have a reward. Usually, the reward is the resulting mark once the activity is assessed or, in other cases, some other rewards like additional benefits or social recognition.
- *Levels:* to maintain the sense of progression and challenge, there should be some levels of achievement and a system of blockage. This way, once a level is achieved, the rewards are obtained and the following levels are unblocked.
- *Trial and error:* people learn from their own mistakes, so error should not be penalized. Trial and error is a very natural and effective learning strategy that must be allowed and even promoted.

To illustrate the construction of a gamified learning system based on these principles, an example is set out in the next section. The use of a practical case can help to identify the key aspects and facilitate the understanding.

4 PLMan Learning System

The PLMan Learning System is a custom-made gamified, automated learning system that gives support to a first-year subject whose aim is to introduce students into Computational Logic. It will be used as an example to illustrate the design and construction of a gamified learning system.

The platform is structured around a gamified Website that manages all the information and elements of the system and allows the interaction of the actors (students and teachers). This is the entrance point for the students, who can download the learning activities, upload their solutions, obtain their marks and receive some predictions of the system about their learning progress. The teachers, on their behalf, enter the system to manage the students activity, introduce new activities, assign the initial stage and difficulty level of the activities and monitor the students progress. The gamified Website is the place that lodges the most superficial game elements, so that the students can have a game-like picture of their progress. To do so, elements like badges, leaderboards, and progression bars, among others, are introduced.

Nevertheless, the most interesting contribution is the internal redefinition of the learning process to achieve the desired deep gamification. The elements of the PLMan Learning System and how they are structured to make up the gamified experience are presented in the following sections. For each element, the strategies to fulfill the desired features are explained.

4.1 Learning Activities: PLMan Game

As it was stated before, learning activities are the blocks to build a gamified learning experience. PLMan game was designed to be used as the learning activity, bearing in mind that the objective of the course is learning Computational Logic. PLMan [21] is a game that challenges students to solve some *Pac-Man*-like mazes by means of logic programming in Prolog language. The fact of using a game as learning activity predispose students to accept it as a funny task. It has, definitely, an evident *game flavour*.

In PLMan students create automated controllers for Mr. PLMan, the main character. The goal is making these automated controllers able to eat all the dots of a given maze, dodging the perils. Automated controllers are developed in Prolog programming language, constructing sets of rules to reason about the maze and decide actions, so performing this activity will lead students to improve their level of logic thinking and develop their Prolog skills. Therefore, the activity has a *meaning* for the subject to be learned. An example maze along with an automated controller written in Prolog is shown in Fig. 2.

```
##################
#     .......    #
#   ............ #
#@......E......#
#   ............ #
#     .......    #
##################
```

```
:- use_module('pl-man-game/main').
plman :- see(normal, up, '.'), doAction(move(up)).
plman :- see(normal, down, '.'), doAction(move(down)).
plman :- see(normal, left, '.'), doAction(move(left)).
plman :- see(normal, right, '.'), doAction(move(right)).
plman :- see(normal, down-left, 'E'), doAction(move(left)).
plman :- see(normal, down-left, '.'), doAction(move(down)).
plman :- doAction(move(right)).
```

Fig. 2. Example maze along with the Prolog knowledge base that controls Mr. PLMan (@) to eat all the dots dodging the enemy (E)

PLMan is a turn-based game. Each turn, Mr. PLMan can perform one of these four generic actions in one of 4 orthogonal direction (`up`, `down`, `left`, `right`):

- `move(Direction)`: move one cell towards the direction.
- `get(Direction)`: get the object placed at the contiguous cell.
- `drop(Direction)`: drop the current object (reverse of `get`).
- `use(Direction)`: use the object towards one the direction.

The game ends when Mr. PLMan succeeds (all the dots in the maze are eaten) or fails (it comes across an enemy or bomb, the limit of turns is reached or there is a time-out during execution).

The combined effect of the sequence of actions will lead to a possible solution. It is important to highlight that the solution is not, in general, unique. Therefore, the student can obtain their own solution, introducing their own strategies. This way, along with the open possibilities offered by the game, the *experimentation* is encouraged and the *creativity* is favored.

An important feature for an activity is scoring its results. In this case, the *score* is the percentage of dots eaten, so there is a way of measuring the degree of correctness of the solution. Additionally, some punishments are also added to the score to enforce testing, code revision and detailed behaviour design. Punishments are applied in case of collision with a wall, invalid or erroneous action with the objects, or rule failure if no clause is successful in a given turn.

Each time students develop any new controller for a given maze, they are *automatically assessed*. The fact of using a programming language like Prolog makes available some automatic tools that can be incorporated to the system. This way the score is obtained immediately, as soon as the solution is uploaded to the system.

Mazes are designed to have an increasing difficulty, requiring progressively more programming abilities. In the first mazes, simple rules in the form "If you see an enemy to your left, move right" are enough to construct successful controllers. As the game progresses, more difficult mazes are delivered, requiring more complex controllers to succeed. This leads students to learn Prolog programming, as well as logic thinking and small bits of Artificial Intelligence. These features allows the introduction of the *progressiveness* in the activity, so that it allows training from very simple to quite complex contents and skills.

4.2 Learning Path

Once the activities are defined, a second important question is the way they are combined so that the reengineered learning process is complete. The learning experience is conceived as a network, so that the activities are considered as nodes of the network, and the links between the activities represent the conditions to pass from one activity to the other. The objective of this scheme is allowing the generation of different adapted learning paths and the implementation of the desired features described in Sect. 3.3.

The feature of progressiveness given to the activities, explained in the previous section, allows the definition of different *levels* of difficulty. More than 400 different mazes have been made for PLMan, with different layouts, objects to get and use, enemies and obstacles to avoid and even problems to solve. These mazes are organized into 4 main stages and up to 5 levels of difficulty per stage.

The stages are sorted by increasing difficulty, so that as one moves from one stage to the next one, new knowledge about the programming language is required to overcome it. Thus, for stage 1 it is only required the use of simple rules and the maze is deterministic (the maze remains unchanged between executions). Stage 2 maintains deterministic mazes but incorporates the use of multiple conditions in the rules. In stage 3 some indeterminacy is added and in stage 4 indeterminism and possible situations to control increase. To progress

from one stage to another, a minimum score is needed, so a block/unblock strategy can be implemented.

At each stage, students have to solve 1 to 5 different mazes. Although the required knowledge and skills to solve every maze in a stage are the same, there are different levels of difficulty for the different possible mazes. In fact, to get each new maze for solving, students start by pick up their desired difficulty level among valid levels for the stage in which they are. The greater the difficulty level, the more the contribution to the final grade. Then, the system presents them with a random maze from their selected level of difficulty.

The students can solve offline as many mazes as they want in every stage, so that they can decide upload the solution to advance to a new stage (if unblocked) when they feel confortable with their developed knowledge and skills. As a consequence, students have a feeling of progress and *challenge* that stimulates them and maintain them in the state of flow. Moreover, the fact of selecting their desired difficulty levels gives the student some control to their learning path, promoting their *autonomy* and decision making.

Students use PLMan software to develop and test their solutions to each maze they get assigned. Every time they have developed a solution they consider to be working, they submit the solution through the PLMan Website. The automated system runs the solution and evaluates their score and marks. The accumulated marks make up the system *rewards*. The system shows detailed evaluation to the students and, if they complete more than 75 % of the maze, they unlock the next maze and can continue. If not, they have to improve their solution and send it again until they achieve 75 % or more.

The system is designed in the aim of formative assessment, considering that students need to learn from their own mistakes without being penalized for it. Because of this, students do not have a limit of submissions for a given maze. The system always consider the best solution they have submitted to give them marks. Partially solved mazes also contribute to their final grade proportionally to the percentage solved of the maze. This is the way to perform a *trial and error* strategy.

5 Conclusions and Further Work

In this paper we have presented our experience designing and developing a gamified learning experience. Few years ago, reports foresaw that gamification was set to be a disruptive innovation in the field of education. Now, is the time for the gamification to take off. However, experiences in learning gamification are, by now, quite limited and usually stay on the surface, just offering a layer of standardized elements such as badges, leader boards and medals. A fun and efficient gamified learning experience is much more than a mix of game mechanics, dynamics and components. Mature gamification experiences must go further in their proposals. In this context, we propose a deeper transformation of the learning process, making up a true process reengineering.

Our proposal claims an active learning, promoting the intrinsic motivation of the students, who learn for their own satisfaction. Students have different

abilities and learn at different rates. A gamified strategy for learning must be closer to students interests and provide them with some autonomy getting their best. The key is moving towards an adaptive gamified student-centered learning model.

From our experience we have learned some important lessons about the gamification of the learning process: the importance of fun as a consequence of learning, the need of having an immediate feedback of our actions, the trial and error possibility as a major source of learning and progress, the relevance of experimentation and creativity as a means to develop the learners skills and the importance of autonomy to give the learners the control of their learning process, among others. All these features are propellants for learning and a way to improve the motivation of learners.

These lessons have guided the design of a gamified learning system to help students to develop their knowledge and skills in the context of a computational logic subject. The result is an operative platform that provides a gamified learning experience that fulfills the desired features.

Certainly there are aspects that are subject to discussion but we consider them as a starting point for teachers who want to approach the world of gamification. In the future, we plan to improve the system and enrich the experience with the students' feedback.

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