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Quest-based Gamification in a software development lab course: a case study

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Abstract

Motivation and engagement play a crucial role in student success in a course. Students may lose interest or underestimate courses that tackle non-core learning outcomes to their specific curriculum or program. Gamification, using game elements (e.g., rewards, challenges) in non-game contexts, is one way to motivate and engage students. Some educational courses use project-based learning, where students tackle problems, overcome obstacles, and gain knowledge. Quest-based games are designed as systems of challenges that players must complete to advance and win the game. They were linked with education by applying specific game mechanics to a computing course unit. This paper case studies the application of a quest-based gamification approach in a mandatory software engineering course to boost engagement among higher education students. Results were collected through observational methods and surveying the students, indicating a tendency for higher grades in course years implementing gamification while maintaining satisfactory levels of motivation and engagement.

Keywords: *Gamification; education; quest-based games; software Engineering.*

1. Introduction

Motivation and engagement are crucial factors in determining a student's success in a course. However, students often disengage or undervalue courses they perceive as not central to their curriculum or program. This can negatively impact the achievement and quality of desired learning outcomes. One way of increasing the levels of engagement is through gamification (Alsawaier, 2018).

Gamification involves incorporating elements of games into non-game contexts, as explained by Deterding, Khaled, Nacke, and Dixon (2007), such as education (Tsai, 2016). This can include using rewards and challenges to promote intrinsic and extrinsic motivation, as Surendeleg, Murwa, Yun, and Kim (2014) pointed out.

Based on their contents, specific educational courses adopt a project-based learning strategy. Students engage in problem-solving activities: a series of actions to move from an initial state to a desired end state while overcoming obstacles and building knowledge (Jonassen & Rohrer-Murphy, 1999) (Ward, 2012).

Quest-based games are intentionally built as systems of problem-solving tasks that players must accomplish to progress and ultimately win the game (Howard, 2008). Gameplay activities (completion of specific objectives related to quests) provide a logical narrative structure, determining the story and progression within the game, as stated by Smith, Anderson, Kopleck, Lindblad, Scott, Wardell, and Mateas (2011). Fabricatore and López (2014) linked quest-based games and educational courses by identifying and implementing five patterns of game mechanics in a computing course.

This paper presents a case study where gamification was used to increase the engagement of higher education students in a mandatory informatics engineering-based course unit not perceived as central to the overall curriculum. While revising the syllabus, a quest-based system was applied, entitled “World of LPRO”, following the game mechanics stated by Fabricatore and López (2014)). Results were collected through observational methods and surveying the students. Research aimed at answering the following research questions:

- RQ1. Regarding student engagement, what was the impact of a Quest-based Gamification on student grades?
- RQ2. Regarding student motivation and interest, how do students perceive the Quest-based Gamification approach?

The paper is organised into four additional sections. Section 2 provides context on Quest-based Gamification and outlines the core gameplay patterns. Section 3 showcases the case study, a programming lab course taught in an Electrical and Computer Engineering master's program. Section 4 details the student data collection methodology and presents the results obtained. Finally, Section 5 concludes the paper with final remarks on the study.

2. Adopting Quest-based Gamification

Game mechanics are crucial in determining the player experience, as they are central to the gameplay and must be mastered for success (Fabricatore, 2007). These mechanics make the gameplay appealing and motivating for players (Polaine, 2005). According to Fabricatore and López (2014), quest-based games' core mechanics are divided into five gameplay patterns, as described in Table 1.

Table 1. Quest-based games' patterns of gameplay.

Pattern of Gameplay
Quest structure (QS): Quests consist of: (I) A goal that requires completing specific tasks to meet the victory conditions, together with optional conditions for additional challenges and rewards; (II) The resources or tools needed to achieve the objective and (III) The significance of the quest in terms of progressing in the game. Quests are conveniently described (usually through a thematic narrative) so the player knows the expected outcomes.
Strategic open-endedness (SOE): Quest objectives can be accomplished through multiple strategies, giving players the freedom to "do more" or "do things differently." This enables players to try different methods of play and encourages them to attempt increasingly complex strategies as their skills improve.
Non-linear progression (NLP): Players are usually free to choose when they want to complete a quest. When this is impossible, it is usually because of the quest's narrative or how it connects to other quests. The quest's briefing and debriefing stages provide information about its availability and how it is related to other quests.
Orientation (O): The game provides briefing information through resources such as maps, accessible to the player at any time to aid in decisions about when, how, and what to engage.
Challenge-based reward (CBR): Rewards are typically given according to the principle of "the more you achieve, the more you receive." Meeting the primary victory conditions earns a standard reward. Accomplishing more difficult tasks earns additional rewards, such as extra resources and recognition of increased skill (such as a promotion in the game). In quests involving teamwork, rewards are based on each player's contributions.

Source: adapted from Fabricatore and López (2014).

When applying the gamification approach to the course, although not restricted to these, there was an attempt to enforce all five gameplay patterns. For clarity, when describing a specific gamification element in the next section, the pattern(s) acronym will be annexed between italic box brackets [] (e.g. if an element incorporated the “Challenge-based reward” pattern, the *[CRB]* notation would appear next to it), whenever relevant.

3. Programming Lab: A Case-Study

The presented approach was applied to a programming lab course (LPRO) in the 1st semester of the 4th year of a 5-year Electrical and Computer Engineering integrated master programme (Faculty of Engineering of the University of Porto [FEUP], 2013). Although not central to its core syllabus, LPRO was a mandatory course, and students had basic programming skills from a couple of courses in the 1st year. Its purpose was to endow the students with sufficient software development aptitudes to seamlessly integrate a professional development team.

LPRO's contents encompassed three main topics, namely i) JAVA: Object-Oriented Programming (OOP), using Java as a supporting programming language and JUnit testing; ii) UML: Unified Modeling Language (Kaur & Singh, 2011) for documenting the artefacts of software systems; and iii) PROCESS: Scrum (Rising & Janoff, 2000) for software project management and development. Lectures briefly overviewed the main topics, engaging students in autonomous, self-paced learning. At the lab, teams of students developed a software project (80% of the final grade) and hands-on exercises to consolidate the learning outcomes. 20% of the final grade came from two individual tests.

The World of LPRO setting used a role-playing game-like medieval fantasy narrative where the player character (student) starts as an inexperienced adventurer, clueless about the fine arts of Software Development, and thrives to become a skilful master.

3.1. Main plot

The main plot (Figure 1a) that drives the adventurers comprises three challenges: a main quest, side-quests and trials of passage. To be successful, the student must finish the main quest, complete 3000 XPs (eXperience Points) worth of side-quests and overcome the two trials of passage.

Figure 1. Main Plot elements (on the left); XP Levels (on the right).

Grouped in pairs or triads, adventurers prepare for the main quest by completing side quests. **Side quests** *[QS]* are small-scale hands-on exercises to develop, improve and enhance student skills, covering the three main topics (five per topic). Some are mandatory (assuring

minimum topic coverage), while others are optional (Figure 2) *[O]*. Growing in complexity, each side-quest awards the adventurers with XPs *[CBR]*, allowing promotion up a series of levels (Figure 1b) until attaining "Developer" (3000 XPs).

Adventurers can tackle the side-quests in any order they choose *[NLP]*. However, following the "Path of Enlightenment" *[O, CBR]* by completing certain side-quests until a specific deadline awards enough extra XP for reaching the final level without needing an extra side-quest.

Trials of passage are two individual tests. The first consists of a mid-course 2-hour unit-test-driven *JAVA* programming challenge, and the second consists of a final course one-hour-long multiple-choice questionnaire covering *UML* and *PROCESS*. Failing one means failing the course.

The **main quest** *[QS]* is the course-long software development project, where adventurers apply all their attained skills, grouped in a party (team) of four or five. Although having some required outcomes, adventurers are free to tackle the intrinsic challenges as they see fit *[SOE]*.

	Topic			
Level	JAVA	UML	PROCESS	
I	***"Here Be Dragons"*** *Basics* **100XP**	***"Here Be Objects"*** *Modelling Basics* **100XP**	***"Pitch the topic"*** *Concepts, Methodologies* **100XP**	Mandatory
II	***"Dragon's Bane"*** *Classes, Collections, Generics* **300XP**	***"Here Be Classes"*** *Class Diagrams* **300XP**	***"The Vision, The Story and The Enforcer"*** *Phases & Practices* **300XP**	
III	***"The Quest for WYSIWYG"*** *SWING* **500XP**	***"Rules of Conduct"*** *State Diagrams* **500XP**	***"Scrolls of Foresight and Achievement"*** *Artefacts* **500XP**	
IV	***"Row, row, row your boat..."*** *I/O Streams* **100XP**	***"Rules of Trade"*** *Sequence Diagrams* **100XP**	***"The Olde Shop"*** *Supporting Tools* **100XP**	Bonus
V	***"Divide & Conquer!"*** *Concurrency, Threads* **100XP**	***"Rules of Engagement"*** *Other Diagrams* **100XP**	***"The Herald's Tale"*** *Emerging Techonologies* **100XP**	

Figure 2. Side-quests schema.

3.2. Rewards and Special Items

As motivators for completing more side-quests (thus further consolidating their skills), adventurers are rewarded with special items *[CBR]* that will allow for grading bonuses. Here is where "Magic" enters the narrative.

A *Wand* is rewarded if an adventurer completes all five side-quests regarding a specific topic. *Wands* cast magical spells and can be used to compensate for faults or failures on the trials

of passage (Figure 3a). Moreover, adventurers can combine *Wands* into *Staffs* (Figure 3b) for more potent spells, even allowing extra credits on the main quest.

Figure 3. Rewards and Special Items: Wands (on the left); Staffs (on the right).

4. Results

Although starting in 2007, the course had the gamification approach introduced in 2017/2018, lasting for four more occurrences (as of 2021/22, the course's contents were redefined and adapted to a new Master Programme).

Students' final grades data was collected and compared with the equal period before adopting gamification to assess the impact on overall success. To answer RQ1., we considered the quantitative data collected, represented in Figure 4. Final grades tend to improve in gamified course instances (2017/2018 and beyond) compared to non-gamified instances (before 2017/2018).

	No Gamification				**Gamification**				
Academic Year	13/14	14/15	15/16	16/17	17/18	18/19	19/20	20/21	**Histogram**
Mean Grade	16,3	15,41	14,65	15,51	**16,04**	**17,03**	**16,25**	**16,40**	

Figure 4. LPRO final grade average before and after introducing gamification.

Also, students' feedback was surveyed to measure the perceived gamification's effects. The survey (Figure 5) was about the new gamification-like learning experience, where students had to rate statements using a five-point Likert scale: (1) Strongly disagree; (2) Disagree; (3) Neither agree nor disagree; (4) Agree; (5) Strongly agree. They also had room to provide further comments on the course.

Question	1	2	3	4	5	Histogram
Gamification was a good idea.	8,7%	0,0%	8,7%	30,4%	52,2%	
Side-quests were self-paced and tackled non-linearly.	0,0%	4,3%	8,7%	43,5%	43,5%	
Students grouping (parties and packs) was effective.	0,0%	0,0%	13,0%	43,5%	43,5%	
Special Items were good motivators.	0,0%	0,0%	8,7%	13,0%	78,3%	
Side-quests complexity was adequate.	0,0%	0,0%	13,6%	31,8%	54,5%	
Path of Enlightenment fostered on-time deliveries.	8,7%	0,0%	13,0%	26,1%	52,2%	

Figure 5. LPRO student feedback survey results.

Analysing the survey results and answering RQ2., students considered that introducing gamification and following the "Path of Enlightenment" performed well. Also, they considered the system of rewards and special items highly motivating.

However, despite stating that side-quest complexity levels were adequate, they felt the "Path of Enlightenment" was time-consuming and required extra work, thus preferring a more self-paced approach. One critique focused on the lack of direct connection between the reward system and actual weight in the student grade.

Overall, special items were valuable to help low-grade students not to fail the course while enabling high-grade students to improve their final grades further. The fewer Wands needed to pass the trials of passage (in case of borderline failure), the more one could improve the final grade (by combining them into Staffs). One of the most popular (and coveted) items used by students was the *Staff of Divine Development* since it increased by 1 point the main-quest grade (on a grading scale between 0-20), translating into a 0.8-point increase in the final grade (a plausible explanation for the increase in the average grade in gamified instances).

5. Conclusion

This paper applied a quest-based gamification strategy to a non-core mandatory software engineering course. We discussed how gamification can improve student engagement and motivation by linking different quest-based games' core mechanics to the teaching and learning component. Results indicate a tendency for higher grades in course years implementing gamification. Student feedback suggests that the gamified-based course is motivating and gripping while suitable for the assessment components.

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