Gamification for Engaging Computer Science Students in Learning Activities: A Case Study

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Abstract—Gamification is the use of game design elements in non-game settings to engage participants and encourage desired behaviors. It has been identified as a promising technique to improve students' engagement which could have a positive impact on learning. This study evaluated the learning effectiveness and engagement appeal of a gamified learning activity targeted at the learning of C-programming language. Furthermore, the study inquired into which gamified learning activities were more appealing to students. The study was conducted using the mixed-method sequential explanatory protocol. The data collected and analysed included logs, questionnaires, and pre- and post-tests. The results of the evaluation show positive effects on the engagement of students toward the gamified learning activities and a moderate improvement in learning outcomes. Students reported different motivations for continuing and stopping activities once they completed the mandatory assignment. The preferences for different gamified activities were also conditioned by academic milestones.

Index Terms—E-learning, engagement, game mechanics, game dynamics, gamification

1 Introduction

In education, engagement has been identified as a valuable indicator of students' academic achievements [1], [2], [3], [4]. Students who are engaged are attracted to their work, persist in their academic activities despite challenges and obstacles, and take visible delight in accomplishing them [5]. Consequently, different approaches have been developed and evaluated to foster students' engagement. Among the most successful approaches are digital games because they can potentially create engaging learning experiences for students when coupled with effective pedagogy [6], [7], [8]. However, in practical terms, the design and deployment of digital games is costly in terms of time, effort, and money, mainly due to the graphical interface that they require and the narrative that is needed to support them. In this sense, gamification introduces a new approach which uses elements and dynamics of games with no ambition to deploy complex narratives or visual settings. Gamification has been successfully applied by commercial brands as a means of supporting user engagement and fostering user activity, social interaction, or quality and productivity of actions [9]. The commercial success of gamification along with its simplicity of deployment makes gamification a popular subject for academic inquiry [10]. Thus, understanding whether gamification can be effective to engage students and to improve their academic learning outcomes is a pertinent, practical issue [11].

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The research described in this paper was designed as a case study to investigate the use of gamification to teach basic concepts of C-programming language to undergraduate engineering students. There were three research objectives for this case study:

1) To explore the impact of gamification on students' engagement.
2) To gain understanding about students' engagement through students' reports and interactions with the gamified platform.
3) To measure the impact of gamification on student academic performance.

This article starts with a review of the main concepts involved in gamification (Section 2). Then it shows the design of the gamified learning activity (Section 3). Section 4 presents and discusses the quantitative and qualitative results of the evaluation of the study. Finally, conclusions are outlined in Section 5.

2 Background

2.1 From Games to Gamification

Salen and Zimmerman [12] define games as "a system in which players engage in artificial conflict, defined by rules that result in a quantifiable outcome" (p. 80). Creating an engagement game is a significant challenge that involves the conception and design of rules to immerse players in fun activities [12], [13]. Game design balances the use of a set of elements and rules that when brought into practice provoke emotional responses in players [13], [14]. Elements and rules are known as the mechanics of the game. The former include points, tokens, and badges whereas the latter prescribe how to gain reputation, reach achievements, and collect elements. Players are driven to run-time behaviours through designed rules known as the dynamics of the game. Dynamics should guarantee activity loops that comprise three components, namely action, feedback, and emotion [15]. Players perform tasks that are rewarded by the system; this recognition of players' success generates positive emotions and increases engagement. Conversely, failures generate some level of anxiety that encourages players to continue performing their tasks. Dynamics of the game intend to drive players into a flow state which results in engagement [16]. Finally, the mechanics and dynamics of the game are designed to trigger emotions that players find pleasant or fun; this is called the aesthetics of the game [13].

Games are just artefacts that are worthless unless people play them [14], consequently game designers should structure their designs to create emotions through the mechanics and dynamics of the game, emotions that encourage players to continue playing the game. In the game design arena, Lazzaro identifies four keys to unlocking players' emotions: 1) providing opportunities for challenge, strategy, and problem solving (hard fun); 2) introducing elements that foster mystery, intrigue, and curiosity (easy fun); 3) leading players to excitement or relief moods (altered states); and 4) promoting competition and teamwork (people fun) [17]. On the other hand, LeBlanc organises the types of player pleasure into eight categories: sensation, fantasy, narrative, challenge, fellowship, discovery, expression, and submission [18] as cited by Schell [13]. Successful games use balanced combinations of some of these keys or categories.

Recently, gamification has emerged as a means of supporting customer engagement and enhancing positive patterns in user service by using game mechanics in serious contexts [10]. Indeed, frequent flyer programs offered by major airlines; Starbucks, in conjunction with location-based social network Foursquare; and Nike+ are examples of how gamification can be successfully used in business [19]. Research in education is beginning to integrate game principles into instructional design aiming to benefit from gaming capabilities to improve students' outcomes.

2.2 Gamification of Education

In the education arena, there have been several attempts to gamify learning activities with two main purposes: the first to encourage desired learning behaviours, such as following software engineering best practices, fostering the participation of students into learning communities, or promoting active participation in peer assessment [20], [21], [22], [23], [24]; the latter to engage students in learning, for instance by the use of learning materials such as tutorials or digital tools [25], [26].

Most of the gamified frameworks, for example Khan Academy, use points and badges to reward progress and levels of expertise acquired by learners whereas the most extensive game dynamic used is competitiveness through leaderboards [22], [26], [27], [28]. However, there has been controversy in reference to the use of rewards in learning environments. Whereas some authors argue that extrinsic rewards have negative effects on students' self-motivation to learn [29], others claim that the risks are minimised once users understand the relevance of the activity for themselves [30], [31]. Further studies are necessary to explore the impact of these reward elements in gamified learning activities. This study is an attempt to gain knowledge in this direction.

Despite gamification being relatively new as an academic topic of study [10] some studies report evidence of academic cheating behaviours [26], [32]. These studies revealed that students were likely to cheat when they perceived tasks as irrelevant. Consequently, gamification processes should be carefully designed not only to promote engagement toward gamified learning activities but also to prevent, detect, and discourage dishonest student behaviour. This work focuses on the former issue, reward elements, neglecting the academic dishonesty problem, despite its importance.

2.3 Guidelines for Gamification of Education

Besides avoiding the aforementioned risks, the big challenge in gamified learning environments is to achieve learner engagement. From the perspective of a video game designer who is now devoted to making engaging e-learning software, Raymer [33] states that the setting of goals and objectives, feedback, and rewards are the key components for developing gamified learning environments. Goals and objectives need to be split into achievable steps that learners could accomplish by using their skills; designers should keep students within their flow channel [16]. Feedback is included to avoid students getting lost or confused about what to do and how to do it within the learning environment; it is also important to inform students about the progress they have made. Finally, Raymer [33] recommends the use of rewards to acknowledge students for their work and effort, and highlights the relevance of broadcasting this information throughout the learning community to foster peer motivation. Similarly, the taxonomy of satisfaction metrics for gamified e-learning [34] includes the need to provide manageable tasks (context) for learners, trying to keep them working within the flow channel through mechanics. The taxonomy also states the need to provide feedback and information about progress as well as the social and competitive elements necessary to promote learners' engagement. In every gamification design approach there is a tacit recognition of the need to implement meaningful gamification for the user [13], [15], [35]. To this end, Nicholson [35] presents a user-centred theoretical framework which recommends: 1) designing considering the benefits for the user; 2) focusing on introducing fun elements instead of elements of scoring; 3) offering the possibility of choosing different ways to achieve users' goals; and 4) integrating game mechanics into the non-game setting. We will base the design of our gamified environment on Nicholson's framework.

2.4 Gamification in Education for Engagement

The success of gamification on education is tied to its potential to engage students in learning activities because engagement has been proved as positively correlated with outcomes of student success, including satisfaction, persistence, and academic achievements [36], [37], [38], [39]. There are diverse conceptualisations of engagement that reflect the multifaceted nature of the concept [1], [40], [41]. However, engagement is typically described as having three components [1]:

- *Behavioural engagement.* Related to participation and can be understood as positive conduct, absence of disruptive behaviour, participation in school-related

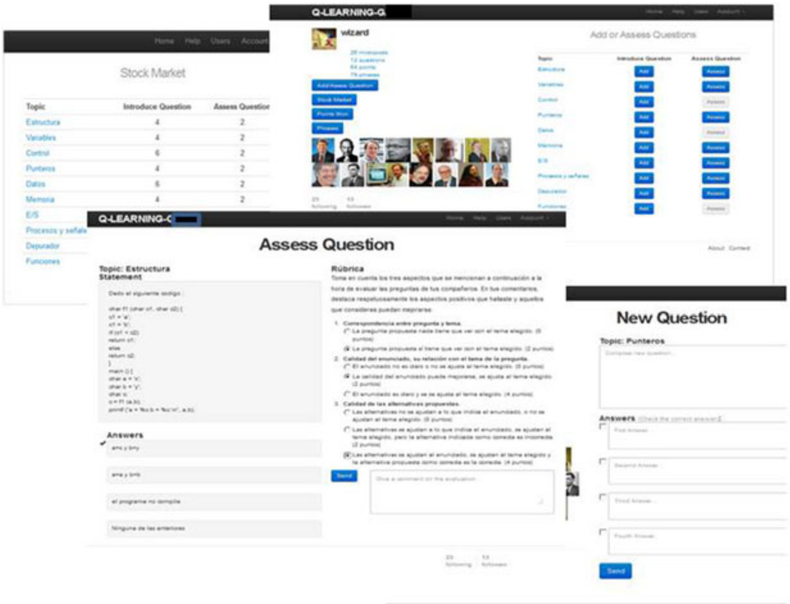

Fig. 1. Work and planning activities.

activities, and involvement in learning and academic tasks expressed as effort, persistence, and attention [40], [41], [42].

- *Affective engagement.* Focuses on the willingness to do the work and includes interest in learning activities, enjoyment, and positive attitudes about learning [40].
- *Cognitive engagement.* Refers to students' investment in learning to achieve deep understanding and expertise. This implies a desire to go beyond the requirements and to relish challenges [41]. It has been suggested that deep approaches to learning are associated with higher levels of learning outcomes [43]. Cognitive engagement is also closely related to strategies students use in order to solve a problem or understand a concept [43], [44].

For the purpose of this study, we will focus on cognitive engagement and explore to what extent students aimed to go beyond learning requirements, which gamified activities they decided to perform along the learning experience, and how successful their efforts and strategies were in terms of learning outcomes.

3 Description of Experiment

The primary purpose of the research study was to explore the impact of gamification techniques on students' cognitive engagement and learning about C-programming language. To this end, and based on the overview of the research literature, the Q-Learning-G platform was designed. The platform includes basic elements of game mechanics where students increase their levels of expertise by introducing and assessing questions related to C-programming language. The experiment was conducted to address the following hypotheses:

- *H1.* Students will work beyond the learning requirements of the course.
- *H2.* Students will change their learning strategy once they achieve the learning requirements of the course.
- *H3.* Students will gain knowledge of C-programming language by using the Q-Learning-G platform.

The secondary purposes of the study were: 1) to understand students' reasons for continuing or stopping work once the learning requirements were achieved, and 2) to identify students' preferences for gamified learning activities.

3.1 Materials

The Q-Learning-G is intended to be a gamified learning platform where students should achieve a learning goal and be recognised for their achievements. The students' academic goal was to earn 100 grade points in the gamified platform where they were allowed to carry out three kinds of activities:

1) *Work activities.* These were activities that allowed students to earn points through direct or indirect work. Direct work consisted of introducing multiple-choice questions or evaluating peers' questions following a rubric (see Fig. 1). Indirect work consisted in getting a qualitative grade through the questions introduced. While winning points, students showed their level of expertise in 10 relevant topics of C-programming language. To show mastery in a topic it was necessary to get at least 10 points in that topic. Furthermore, the work activities allowed students to collect phrases and badges for fun.

2) *Planning activities.* The platform provided a Stock Market Questions area that students could visit to know how the course behaviour had affected the direct work valuation (see left corner of Fig. 1). For each topic there was one value for introducing and another for assessing a question. These values were translated into grading points for students' work and followed the laws of supply and demand. For instance, when the amount of questions for a topic introduced but not evaluated exceeded the median

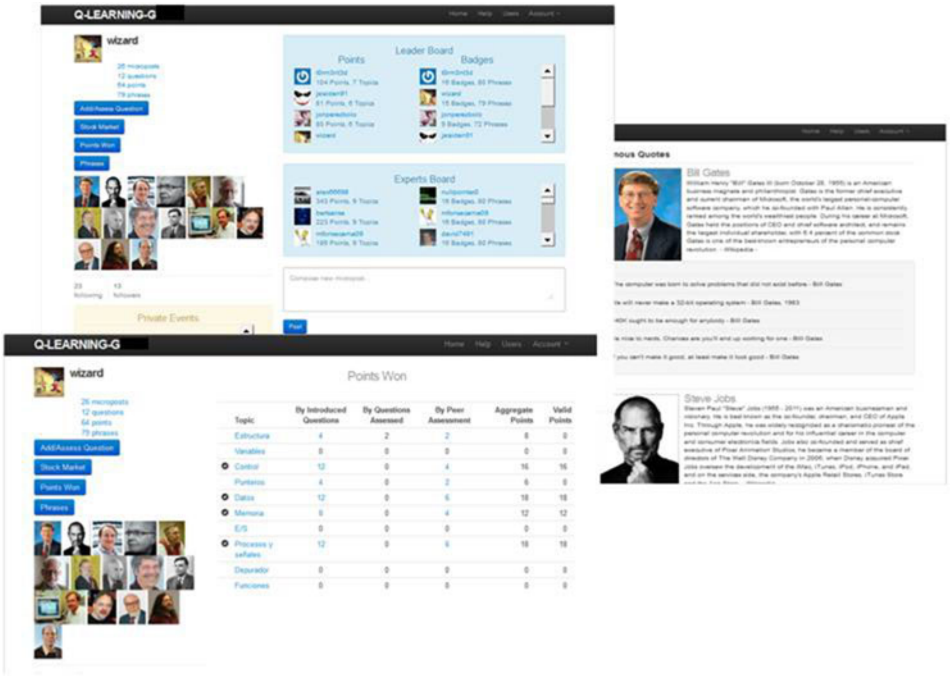

Fig. 2. Badges Showcase, Leaderboard, and Phrases Showcase areas supporting rewarding activities.

of the rest of the topics, the value of introducing a question about that topic decreased whereas the value of evaluating them increased. Each student could also visit the Grade Report area where there was a survey of the points earned by the student in each activity.

3) *Social activities*. The platform provides a Micro-blogging area that students could use to exchange messages with the instructor and their peers. A Public Event area reported the learning events in real time.

Work activities were intended to help students to master the main concepts of C-programming language. They were split into 10 manageable steps and students could plan the way and time to acquire mastery in each one of them. Three types of academic feedback were provided: 1) through the rubric, students had the criteria to follow in the peer evaluation; 2) peers assessed the quality of questions introduced; 3) academic rewards (grade points) could be consulted at any moment. Through microblogging students could interact with the rest of the learning community.

The Q-learning gamified platform recognised students' achievements and displayed them in three different areas (see Fig. 2):

1) *Leaderboard area*. The Leaderboard was used to display the ranking of the leaders in the gamified learning activity. Students appeared in this area ordered lexicographically by points and by sub-goals achieved.
2) *Phrases showcase area*. The Phrases Showcase had phrases from leaders in computer science. The work activities allowed students to not only earn points but also to win these phrases. The phrases were distributed randomly as students earned points and became experts in C-programming language topics.
3) *Badges Showcase area*. The Badges Showcase displayed images of the leaders collected. Once a student had collected all the phrases of a leader, a photo of the leader appeared in the student's Badges Showcase.

3.2 Participants

The study was conducted on two sections of an operating systems undergraduate level course taught at the *Universidad Carlos III de Madrid* (Spain) in autumn 2012. The sample comprised 22 students (aged 20-25, $M = 22.18$, $SD = 1.33$). Among the respondents, 17 out of 22 were male and five out of 22 were female.

Students had no previous experience with gamified applications but they had some experience with video games. Seven participants declared that they played less than two hours per day, 10 participants said they played between 2 and 4 hours per day, and five participants declared that they played more than 4 hours daily.

3.3 Instruments and Data Collection Procedure

For the purposes of the investigation, five questionnaires were designed by the researchers: a demographic questionnaire to get students' profiles; pre-test and post-test questionnaires to measure students' knowledge of C-programming language before and after the gamified learning activity; and two post-test questionnaires with open-ended questions to estimate students' reasons for getting involved in different activities and to identify their main focus during the learning activity.

The demographic questionnaire elicited information about students' sex and age, and through a close-ended question they were also asked to specify how often they played games.

The pre-test and post-test questionnaires aimed to assess students' knowledge of C-programming language before and after the completion of the learning activity, respectively.

Each questionnaire consisted of 10 multiple-choice questions, one for each C-programming language topic to be mastered: 1) how to structure a C program—functions; 2) simple variables—life and scope of variables; 3) control structures; 4) pointers and arrays; 5) structs; 6) memory allocation and memory management; 7) input/output; 8) processes and signals; 9) use of the debugger; and 10) how to compile, link, and execute programs. They were constructed and validated by four experienced computer science teachers (each teacher produced a subset of the questions that was validated by the other three).

The post-test questionnaires had two open-ended questions to estimate students' reasons for getting involved in different activities:

- *Q1.* Did you continue working after earning 100 points? And if so, tell us, why you did so.
- *Q2.* Did you stop working after earning 100 points? And if so, tell us what made you stop working.

Another two open-ended questions identified the students' main focus during the learning activity:

- *Q3.* Which activities did you prefer?
- *Q4.* Which activities did not appeal to you?

The interactions of students with the Q-learning gamified platform were logged for statistical analysis. For each student, the logged events were classified in two phases: prior to and after achieving the learning goal—i.e., earning 100 points through direct work. The logged events were: number of questions introduced; number of questions assessed; number of topics mastered; number of badges collected; and also the number of planning, work, social, and fun activities performed.

3.4 Procedure

The students had been given the same subject matter relevant to C-programming language in three lecture sessions in the autumn of 2012 at the *Universidad Carlos III de Madrid* (Spain).

The study started in the subsequent week. A text document was given to students outlining the purpose of the research and their right to withdraw at any moment. Informed consent was obtained for every participant. Then students filled out the demographic questionnaire and answered the pre-test questionnaire to measure the knowledge acquired in the lectures.

During the week that followed the three lecture sessions, students used the Q-learning gamified platform. At the end of the week, students answered the post-test questionnaire in order to explore the effects of the use of the gamified platform on their achievements. In addition, students were asked to fill out open-ended questions to analyse their preferences and motivations to interact with the application.

3.5 Data Analysis

This study adopted a mixed research method approach known as the sequential explanatory design method [45], [46]. The mixed research method is considered a legitimate, stand-alone research design in engineering education that combines the strengths of both qualitative and quantitative research [45], [47], [48]. The sequential explanatory design method comprises a quantitative phase followed by a qualitative phase [43]. For the quantitative phase, data about the activity of students using the platform was collected, and then the data was analysed statistically using parametric and non-parametric techniques. For the qualitative phase, open-ended surveys were administered and then analysed to shed light on the numerical results.

3.5.1 Quantitative Phase

For students' cognitive engagement, we evaluated their desire to go beyond requirements by measuring the amount of work performed after the accomplishment of the learning goal. The indicator used to measured work was the number of points achieved and the number of work activities performed. Any extra work was understood as the effort invested due to gamification. A more specific analysis of students' work was undertaken to measure their investment in achieving a thorough understanding and expertise of C-programming language. In this regard, the indicator used was the number of topics students mastered after achieving the learning goal. We also analysed the learning strategies used by students by comparing how they distributed their efforts among the activities provided by the platform. We measured the amount of attempts to do learning activities, namely working, planning, and exchanging information with peers, and compared this with the amount of attempts to do leisure activities, namely collecting items and checking performance in relation to their fellows.

Exploratory data analysis was used to examine the distribution of the quantitative data to find a tentative value of the extra work performed by students. The Shapiro-Wilk test of normality distribution was also used to verify the distribution of the data. For data that did not follow a normal distribution, the Wilcoxon signed-rank test was used. For the data that followed the normal distribution, a t-test was used.

Finally, in order to evaluate the impact of the gamified platform on learning outcomes, we used pre- and post-tests. Each questionnaire had 10 multiple-choice questions, one for each C-programming language topic to be mastered. The grades were used as indicators of learning performance. The statistical process included the use of a Shapiro-Wilk test of normality distribution to verify the distribution of the data. Since the data came from a normally distributed population, a t-test was used to determine whether there was a difference between the scores of the pre- and post-tests.

Table 1 provides a detailed description of evaluation criteria, indicators used, data gathering, and statistical process.

3.5.2 Qualitative Phase

Based on statistical results, students were asked to explain their reasons for continuing and stopping work once their learning goal was achieved. The data collected was examined using an open coding scheme [47], [48]. Students' reasons where grouped into categories to gain a better understanding of their behaviour.

To have a better understanding of students' activity preferences, they were asked to answer two open-ended questions. Answers were classified according to the students'

TABLE 1
Qualitative Criteria and Quantitative Indicators Related to Students' Engagement

Qualitative evaluation criteria	Quantitative indicators	Data gathering	Statistical data process
Students' effort using the Q-learning gamified platform.	Amount of direct work students did after achieving the learning goal.	Log files.	Non-parametric Wilcoxon signed-rank test.
Students' investment in learning using the Q-learning gamified platform.	Number of topics students mastered after achieving the learning goal.	Log files.	Non-parametric Wilcoxon signed-rank test.
Students' focus on achieving their academic goal.	Amount of attempts to do working activities before (WB) and after (WA) achieving their academic goal.	Log files.	Parametric t-test.
Students' interest in planning their activities.	Amount of attempts to do planning activities before (PB) and after (PA) achieving their academic goal.	Log files.	Parametric t-test.
Students' interest in social activities.	Amount of attempts to communicate with their peers before (SB) and after (SA) achieving their academic goal.	Log files.	Non-parametric Wilcoxon signed-rank.
Students' interest in doing fun activities.	Amount of attempts to do fun activities before (FB) and after (FA) achieving their academic goal.	Log files.	Parametric t-test.
Students' performance.	Marks in exam.	Pre- and post-tests questionnaires.	Parametric t-test.

work efforts during the learning activity. Instances where data from these questionnaires provide additional insights are presented in Section 4, below.

4 Results and Discussion

4.1 Impact on Participations Rates

In order to investigate whether the Q-Learning-G platform had a positive impact on students' participation rates, the amount of work done by students after achieving the learning goal was measured. For the purposes of this study, any work a student did after achieving the learning goal was considered extra work because that work did not count toward his/her final mark. Extra work could, thus, be attributed to the gamification factor.

Fig. 3 shows the box plot with the distribution of the extra work done by students after achieving the learning goal. The extra work was measured as the number of work activities performed after the learning goal relative to the number of work activities done before (WA/WB). The middle bar in the box plot shows that the median of the extra work percentage is equal to 29. Therefore, 50 percent of the participants performed additional work of more than 29 percent. A group corresponding to 25 percent of all participants dedicated more than 60 percent of additional work and another group of 25 percent made an effort below 17 percent.

A Shapiro-Wilk test of normality distribution was performed to examine the distribution of extra work. The test results indicate that the data were not from a normally distributed population ($W = 0.7932$, p-value < 0.001). Therefore, a one-sample Wilcoxon signed-rank non-parametric test was conducted on the extra work to evaluate whether their median was significantly different from 0 ($V = 210$, p-value < 0.001). All tests were conducted using an alpha level of 0.05. The results indicate that, in general, students continued their work even after reaching the learning goal, so their participation in the activity was beyond the course requirements.

For those students who wanted to continue using the gamified platform after achieving the mandatory academic goal, two main working options were available: 1) continuing work on the C-programming topics that allowed them to earn 100 points, or 2) trying to master unexplored C-programming topics. The second option seemed the most unlikely to be followed by students because it required the highest intellectual effort. Therefore, it was identified as an indicator of learning engagement.

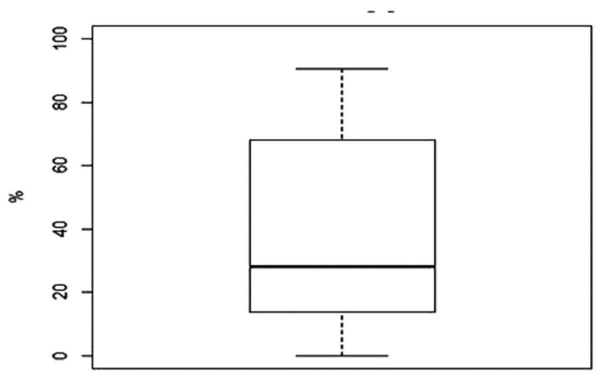

Fig. 3. Percentage of extra work done by students after achieving 100 grade points.

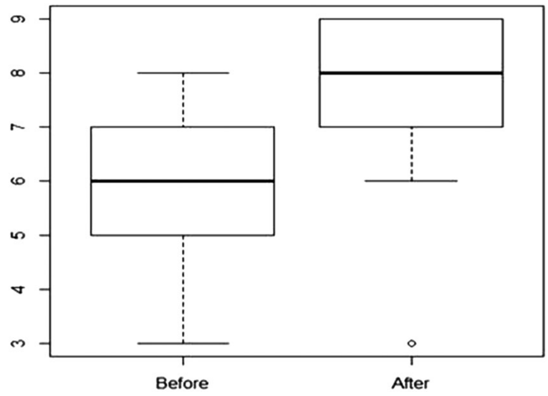

Fig. 4. Number of topics mastered before and after achieving the learning goal.

A Shapiro-Wilk test of normality distribution was performed to examine the distribution of the number of topics mastered by the students before and after achieving the goal. The test results indicate that the data are not from a normally distributed population ($W = 0.9073$, p-value $= 0.041$; $W = 0.8972$, p-value $= 0.026$, respectively). Thus, a non-parametric Wilcoxon signed-rank (paired-sample) test was used to compare the number of topics mastered. The results indicate that there is a statistically significant difference between the number of topics mastered after ($Mdn = 8$) and before ($Mdn = 6$, $V = 245.5$, p-value < 0.001) (see Fig. 4). Thus, the engagement in the gamified activity encouraged students to master unexplored topics in the C-programming language, work that required more intellectual effort and potentially improved students' knowledge about the C-programming language.

Consequently, hypothesis H1 was proved, i.e., students showed cognitive engagement by working beyond the learning requirements of the course and by mastering unexplored topics in the C-programming language.

4.2 Reasons for Continuing and for Stopping Work

From the 22 students who participated in the study only two of them stopped their work once they achieved the necessary 100 points. A post-test questionnaire included two open-ended questions to identify students' reasons for continuing work (Q1) or for stopping work (Q2) after reaching the academic goal. The data gathered (38 responses) was examined using an open coding scheme [48]. There were 20 responses for the question Q1 and 18 responses for the Question Q2. Comments gathered where classified into three major categories: fun, professional, and social.

The information collected from Q1 was classified into six codes that were identified and grouped into the three aforementioned categories. The fun category was grouped into two codes: badges (9) and leaderboard (2). The professional category had the associated codes: basic (1), proficient (3), and expert (2). Finally, the social category included the altruism (3) code.

Some of the reasons given by students for continuing work after earning the maximum amount of points were:

- "I continued because I wanted to get all the badges."
- "I continued to try to reach a better position on the Leaderboard."
- "I assessed more questions to gain more knowledge about C-programming language."
- "I kept assessing questions because I wanted to better learn how to use pointers in C."
- "I continued assessing questions because some of them were really challenging."
- "I continued assessing questions to help my peers reach at least 100 points."
- "I continued working because I supposed that my peers would appreciate receiving feedback, as I did, before reaching the first 100 points."

The information collected from Q2 was classified into five codes that were identified and grouped into the three aforementioned categories. The fun category was grouped into two codes: badges (5) and novelty (1). The professional category had the associated codes: points (3) and time (6). Finally, the social category included the code: activity (3).

Examples of reasons given by students for stopping work after earning the maximum amount of points were:

- "I had all the badges."
- "There were no new things to explore."
- "I already had the 100 points."
- "I also had to study for other courses."
- "There was not enough activity on the platform."

For students who signalled the fun aspect as the most important reason for continuing work, collecting badges was certainly a factor. They continued working because they wanted to earn all the badges. Furthermore, the relevance of this extrinsic reward was enhanced by the comments of some students who decided to stop working because there were no more badges to collect. Therefore, badges had a significant impact on engaging students with the learning tasks. On the other hand, the competitive aspect introduced by the Leaderboard was identified as a factor for continuing work for only a few students. The impact of the Leaderboard would probably be greater in a course with more enrolled students or in a learning activity lasting a shorter amount of time, with more opportunities to notice significant changes in the students' ranking.

There were some students who signalled the professional aspect as the most relevant for continuing work. These students expected to receive a learning benefit from the activity and found that assessing the questions introduced by their peers fit well with their personal learning goals. Some of them combined this professional benefit with the feeling of challenge, a pleasant emotion [48]. The lack of time was the students' main reason for stopping work.

Regarding the social aspect, we were surprised to notice that we had a considerable number of altruistic students in the course. These students continued working to help others win points and to provide their peers with feedback, which they found useful for learning.

4.3 Students' Investment in Gamified Learning Activities

Within the Q-Learning-G platform, students might invest their time and efforts according to their needs and preferences in four kinds of activities: work, planning, social, and fun. The number of interactions in each one of these activities was registered during the experiment and used as an

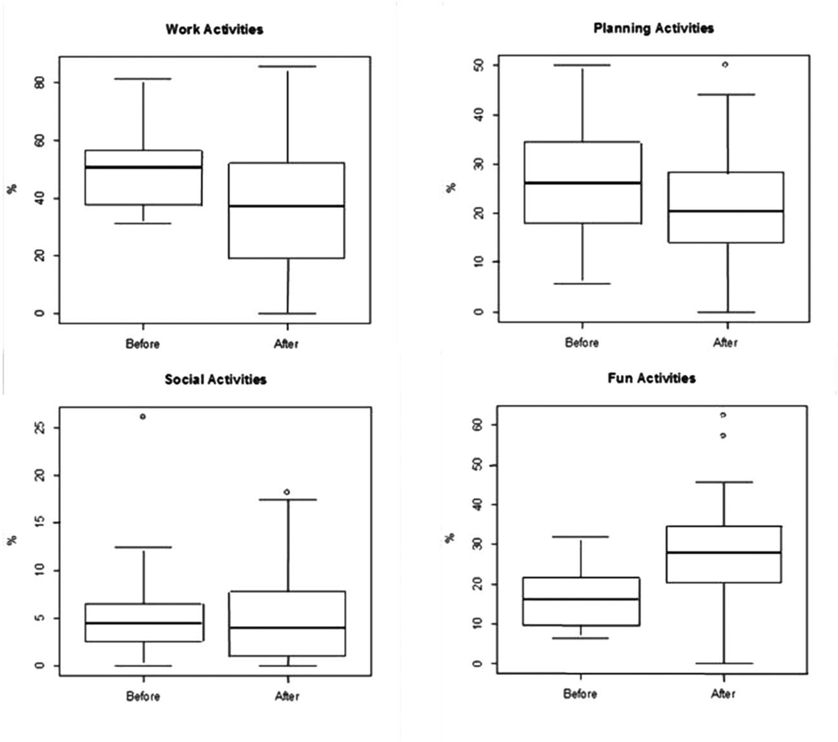

Fig. 5. Box plots of students' interactions with the gamified learning environment before and after achieving the learning goal.

indicator of students' cognitive engagement. The analysis was based on comparing the relative percentage of the activities performed in order to find students' preferred activities before and after reaching the learning goals (see Fig. 5).

A Shapiro-Wilk test of normality distribution was performed to examine the distribution of the relative percentage of the different interactions made by students on the gamified platform before and after reaching the learning goal. Table 2 shows that the percentage for all interactive activities apart from social (SB and SA indicators) may come from a normal distribution. Consequently, parametric tests can be used to compare the difference in students' preferences for performing work, planning, and fun activities. All parametric tests were conducted using a two-tailed alpha level of 0.05. The equality of population variances was tested for each action and assumed to be equal for social and planning activities, and not equal for fun activities.

TABLE 2
Results of a Shapiro-Wilk Test of Normality Distribution of the Relative Percentage of Interactions in the Q-Learning-G Platform

Indicators	Shapiro-Wilk test	
	W	p-value
WB	0.9381	0.1807
WA	0.9796	0.9095
PB	0.986	0.9823
PA	0.9695	0.6984
SB	0.771	0.000
SA	0.869	0.000
FB	0.9464	0.2674
FA	0.974	0.8016

A paired-sample t-test was conducted to compare the number of working activities performed before and after reaching the goal. The results indicate a statistically significant difference before reaching the goal ($\mathrm{M} = 51.70$, $SD = 14.53$) compared to the percentage found after the goal ($\mathrm{M} = 38.60$, $SD = 22.20$), $t(21) = 2.3392$, $p = 0.029$. This result shows us that although students continued introducing and assessing questions after earning 100 points, their interest in working activities decreased moderately.

In relation to fun activities, a paired-sample t-test was conducted to compare the amount of fun activities before and after achieving the goal. The results also indicate a statistically significant difference after reaching the goal ($\mathrm{M} = 28.00$, $SD = 15.51$) compared to before the goal ($\mathrm{M} = 16.84$, $SD = 7.57$) $t(21) = 3.9662$, $p < 0.001$. Thus, students showed more interest in fun activities after earning 100 points. They consulted the platform areas related to fun activities more often, namely the Leaderboard area and Phrases Showcase and Badges Showcase areas, once the mandatory academic goal was achieved.

Statistical analysis of planning and social activities does not allow us to draw any conclusions on them. Indeed, it was found that the social activities may not come from a normal distribution, and a Wilcoxon signed-rank test stated that the difference of the social activities before and after was statistically non-significant, $V = 122$, p-value $= 0.834$. Regarding planning activities, although they may come from a normal distribution the difference between the activities before and after achieving the learning goal was found to be statistically non-significant, $t(21) = 1.6246$, p-value $= 0.119$.

Summarising, results show that academic pressure caused students to concentrate their efforts on introducing and assessing questions while doing the mandatory assignment. Once the assignment was completed, students

TABLE 3
Students' Preferences for Activities

Group	Name	Points earned	Comment
G1	Fran	54	"I did not feel engaged by the activity in general... I did not find it fun to collect badges or to be among the first places on the Leaderboard... I could not achieve the minimum amount of points due to the lack of time."
	Peter	100	"I felt bored introducing new questions but I enjoyed collecting badges... I felt ashamed of my position on the Leaderboard."
G2	David	127	"It was an easy activity... I did not use the Stock Market to plan my activities... I felt satisfied by winning all the phrases and badges."
	Alice	130	"It was an entertaining way to practise the C-programming language and my main interest was to learn... I was not focused on collecting either phrases or badges."
G3	Mike	225	"I felt curiosity towards the badges and I wanted to collect them all... I took advantage of the Stock Market to win more points with less effort but I would prefer to take more risks. For instance, the possibility of facing more difficult challenges according to the level of mastery achieved."
	Paul	325	"It was an enjoyable and gratifying task... I was intrigued at the beginning of the activity but after two or three days of using the platform it was not a great challenge anymore... What made me feel better was being the leader of the competition."

continued working on these tasks but to a lesser extent. In contrast, fun interactions increased after achieving the learning goal. Thus, hypothesis H2 was proved, i.e., students changed their learning strategy once they achieved the learning goal.

4.4 Students' Preferences for Gamified Learning Activities

To portray a qualitative perception of engagement in the different activities, students were asked about activities they preferred and those that were not appealing for them. Students were clustered into three groups: G1 had the students that made less than a 20 percent effort after achieving the learning goal, G2 had those that made an effort greater than 20 percent but less than 60 percent, and G3 had the students that did more than 60 percent extra work after earning 100 points. The 22 students were distributed as follows: 36.4 percent were in G1, 31.8 percent in G2, and 31.8 percent in G3. Two students from each group were chosen to represent the perception of the emotional engagement of the group. Table 3 presents some of the students' typical answers.

Fran, for example, started the activity late and did not even achieve the learning goal, whereas Peter abandoned the activity when he had earned 100 points. Thus, it can be inferred that they were not engaged in the learning gamified activity. They were not interested either in the academic or fun activities. However, at least for Peter, collecting badges seemed to be an attractive activity. Thus, unfortunately some students did not find the gamified learning activity appealing and they made the minimum effort necessary to get a reasonable grade for the course.

Students from groups G2 and G3 found it more appealing in general to spend their time and efforts on fun rather than on work activities. This corroborates the statistical analysis over quantitative data. However, students from group G3 claimed that more challenging activities encouraged them to work more. Finally, a student from group G3 mentioned that his interest in using the platform decreased after two or three days. The previous comment indicates that there is a limit to the amount of time students might be engaged in this gamified activity.

4.5 Impact on Learning Outcomes

The analysis of the students' learning outcomes was done through the qualitative measure of students' comprehension of C-programming language through a pre-test and a post-test taken by students before and after the use of the gamified platform respectively.

A Shapiro-Wilk test of normality distribution was performed to examine the distribution of the pre-test and post-test scores achieved by students. The test results indicated that the data may come from a normally distributed population ($W = 0.9442$, p-value $= 0.242$; $W = 0.9433$, p-value $= 0.232$, respectively). For this reason, a t-test was used to compare the scores before and after using the Q-Learning-G platform. The results indicated that there is a statistically significant difference between the scores after ($M = 4.73$, $SD = 1.68$) and before ($M = 3.45$, $SD = 1.18$), $t(21) = 4.96$, p-value < 0.001. Thus, the hypothesis H3 was proved. It can be concluded that students improved their comprehension of C-programming language as a result of the use of the gamified platform.

5 Conclusions and Future Work

In this study we attempted to investigate the learning effectiveness and engagement appeal of a gamified activity targeted at the learning of C-programming language. To this end, we created the Q-Learning-G platform where students introduced and assessed questions related to C-programming language using basic elements of game mechanics. The design of the Q-Learning-G platform followed the principles stated in Nicholson's user-centred theoretical framework [35].

Results showed that most students continued working even after earning the maximum amount of grade points which is considered as evidence of cognitive engagement [41]. Furthermore, they continued mastering unexplored C-programming topics which also showed that students were committed to learning. Among the most common reasons for continuing work after achieving 100 points were to collect all the badges and to keep learning. Collecting badges was the most effective driver of participation and lack of badges discouraged students from continuing work. Other mechanic elements included in the Q-Learning-G platform, namely the Leaderboard, Stock Market, and Microblogging areas, were not reported as appealing in this environment. The second most relevant reason for students to keep working after achieving 100 points was professional, specifically their desire to gain more knowledge about C-programming language. The evidence in our study is not conclusive regarding whether the additional work done by students can be attributed to intrinsic motivation, to gamification or to a complex interplay of motivational states. The use of rewards in gamified applications has been questioned by authors who claim that rewards can reduce internal motivation [18], [35], [49], whereas others, on the contrary claim that rewards might help students to internalize the desire to do the learning activities [30]. Therefore, further research would help to clarify this point.

Whereas cooperative mechanisms of working also fostered some altruistic students to work beyond the initial requirements, there were also some students that did not continue working after achieving 100 points. These findings match the outcomes of a recent study on gamification of a learning experience in tertiary education [26] which found that motivation was not the same for everyone. We therefore intend to determine what learner (or player) profile traits will benefit the most from gamified learning activities.

Quantitative results showed that there were differences in the amount of effort invested in different activities before and after earning the maximum amount of grade points. The amount of work and planning activities decreased slightly after achieving the academic goal whereas the fun activities increased. These findings reinforce the idea that a learning activity combining game elements in a gamified learning environment can engage students in achieving their main goal: to learn [35].

From an academic point of view, gamification was successful. According to the comparison between the pre- and post-test results, students improved their knowledge of the C-programming language. Therefore, our results corroborate findings from studies which claim that engagement is a valuable indicator of students' academic achievements [1], [2], [3], [4].

The present study had some limitations. First, the study involved students who had never been exposed to a gamified learning activity before. It would be interesting to investigate the learning effect and engaging impact of gamified activities when these activities are conducted regularly and, thus, become less of a novelty for students. Second, the gamified learning environment was designed and evaluated to take advantage of the limited amount of time for a mandatory activity in an engineering course. Further studies are necessary to determine parameters such as the amount of time, the number of students, and also the optimal number of badges that could maintain effective engagement levels. Finally, the study investigated short-term retention of C-programming language knowledge. It is likely that a long-term evaluation would promote a better understanding of the effect of the learning environment on students' learning outcomes.

Finally, the specific gamified learning activity employed in this study had positive effects on knowledge acquisition and was effective in promoting cognitive engagement of undergraduate students learning the C-programming language. Collecting badges arose among other game mechanics elements as the most successful mechanism to foster engagement; thus it can be used as an effective game mechanics element in similar learning environments.

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