Gamification in Computer Programming: Effects on learning, engagement, self-efficacy and intrinsic motivation

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Abstract: Worldwide, the workforce requires professionals to master programming skills, regardless of their knowledge domain. This demand has led higher education institutions to strengthen their programming courses, which currently experience high dropout rates and low academic performance. Some institutions have even faced the need to offer new programming courses for those students whose field is not computer related, which adds more challenges due to their background. Given this setting, gamification, the use of game elements in non-game contexts, is put forward as a solution to redesign related courses. Thus, the purpose of this study was to analyse the impact of gamification, using badges, on learning performance, intrinsic motivation, self-efficacy and engagement in engineering students taking a basic programming course. It also analysed the effects of student background variables such as gender, grade point average and previous gaming experience. One hundred sophomore undergraduates participated in a quasi-experiment, lasting 6 weeks. A pretest-posttest design with control (N=50) and experimental group (N = 50) was setup. Students carried out mandatory (e.g. chapter reading quizzes) and optional tasks (completing activities in Code Academy or Pyschools), and were awarded with badges and meta-badges, through a web based application called Credly. The university learning management system was used as a platform to inform students of the activities that would be rewarded with and to keep track of the students' assignments. Data collection methods included self-reported questionnaires about intrinsic motivation, self-efficacy and personality; and a programming test. Results show a statistically significant improvement in engagement in gamification students, compared to the control group. However, no significant impact on learning performance, intrinsic motivation, self-efficacy and any of the student background variables was observed. The higher engagement is promising, showing that gamification might push programming courses. However, further research is needed to understand the lack of connection between the aforementioned variables.

Keywords: gamification, programming, intrinsic motivation, learning, self-efficacy

1. Introduction

The workforce increasingly demands that employees master programming skills (Burning Glass Tecnologies, 2016). By using mathematics, logic and algorithms in coding, individuals develop computational thinking, meaning that people are able to solve problems like a computer scientist (Selby, 2014). The importance of coding, started by Papert (1980), is currently supported by recent research (Soloway & Spohrer, 2013; Lye & Koh, 2014). This workforce demand has led higher education institutions to improve and strengthen their current offer of programming courses, which currently face high dropout and failing rates (Yadin, 2011; Watson & Li, 2014). Other institutions have even opened programming courses for non-computer science students (Muller & Kidd, 2014; Noor, Harum & Aris, 2014).

Among the different methodological strategies to enhance programming skills, such as using robots (Major, Kyriacou & Brereton, 2012), video (Sharp & Schultz, 2013) or virtual worlds (Esteves et al, 2011), gamification is put forward as an alternative solution to the aforementioned issues. It offers the possibility to engage and motivate students in a fun way (Beltrán, Sánchez & Rico, 2016; Khaleel, et al, 2015). Although in terms of learning performance(LP) , the current literature is scarce and points out at a mix of several gamified elements, making it difficult to know which gamified elements are the key for success or failure in the learning setting (Ortiz, Chiluiza & Valcke, 2016).

Thus, in the current study, we implemented and evaluated a gamification approach, based solely on badges, to boost students' LP. Furthermore, we also considered a series of variables that might mediate the differential impact of gamification such as intrinsic motivation (IM), self-efficacy (SE) and engagement.

This paper is structured as follows: first, a conceptual and theoretical base, followed by the research hypothesis is presented. Then, the methodology and corresponding results are detailed. Finally, a discussion section along with reflections about further research is proposed.

2. Conceptual and Theoretical Base

2.1 Gamification and Digital Badges

Gamification is usually defined as the use of game design elements in non-game contexts (Deterding et al, 2011). These game elements refer to characteristics that are found in most games, such as awarding points, leaderboards and badges. In non-gaming contexts, the review of Hamari, Koivisto & Sarsa (2014) lists the use of gamification in, for instance, health, commerce and work settings. In the context of the present study, badges were selected as the key gamification element. This decision was driven by the literature review of Ortiz et al (2016), stressing the need to study the single impact of gamification design elements, instead of an undefined mixture of gamification elements.

A digital badge is “a representation of an accomplishment, interest or affiliation that is visual, available online, and contains metadata including links that help explain the context, meaning, process and result of an activity” (Gibson et al, 2015: p. 404). Its main purpose is to engage in positive learning behaviour, and to identify progress in learning and credential engagement, learning and achievement (Gibson et al, 2015). The focus on learning impact also balances the too strong focus on motivational variables in most gamification studies (Dicheva et al, 2015). When it comes to engagement, the focus is more on online learning environments showing a positive effect (Looyestyn et al, 2017).

2.2 Gamification and Student variables

Although learning performance, being able to see how students demonstrate their knowledge and skills (Marzano, Pickering & McTighe, 1993), is a key variable in education, the number of studies focusing on it is scarce. When available, studies show mixed results. For instance, De-Marcos et al. (2014), stress that students in the gamified condition carried out the tasks better than the control group, but mastery of theoretical knowledge was better in the control group. In terms of research in relation to programming courses, the results are positive (Ibañez, Di-serio & Delgado-Kloos, 2014). To explain these results, we can build on the gamification theory of Lander who links performance to gamified instructional design (2014). The theory stresses how gamified elements in the instructional design affect learning via mediation or moderation.

Another variable influencing the positive impact of gamification is an increase in Intrinsic Motivation (Chou, 2015). IM refers to doing something because it is interesting or enjoyable (Ryan and Deci, 2000)a. The Self-Determination Theory (SDT) of Ryan and Deci (2000)b helps explaining three psychological needs that are satisfied by intrinsically motivated behaviours: Autonomy, Belonging and Competence. When combined with gamification, autonomy is boosted by giving the freedom to choose optional activities (Werbach & Hunter, 2012). Competence is pushed by badges, since they give a sense of status recognition, evidencing the accomplishment of tasks (Gibson et al, 2015). Finally, relatedness is promoted when students can share and see each other’s accomplishment and/or awards such as badges (Grant, 2016). Research also shows how IM is highly correlated with LP (Taylor et al, 2014).

Finally, self-Efficacy and engagement also play a direct or mediating role when studying the impact of gamification on LP. Self-Efficacy is the belief that a person can successfully carry out a specific tasks (Bandura, 1977) and engagement refers to a student’s psychological, cognitive, emotional and behavioural reaction to academic and social activities in and out of class, in a quantitative and qualitative way, to achieve successful learning outcomes (Gunuc & Kuzu, 2015). In both cases, studies show a positive relationship between SE and engagement with LP (Shkullaku, 2013; Heng, 2014). Table 1 summarizes the main research variables to be studied.

Table 1. Summary of dependent and independent variables

Variables	Definition
Learning Performance	Being able to see how students demonstrate their knowledge and skills (Marzano, Pickering & McTighe, 1993)
Intrinsic Motivation	Doing something because it is interesting or enjoyable (Ryan & Deci, 2000)
Self-Efficacy	Is the belief that a person can successfully carry out specific tasks (Bandura, 1977)
Engagement	Student's psychological, cognitive, emotional and behavioural reaction to academic and social activities in and out of class, in a quantitative and qualitative way, to achieve successful learning outcomes (Gunuc & Kuzu, 2015).

2.3 Gamification and background variables

Other variables – studied in the literature - affecting the learning process through gamification are gender, age, previous gaming experience and personality (Pedro et al, 2015; Koivisto & Hamari, 2014; Landers & Armstrong, 2014; and Karanam et al, 2014). Due to the nature of the computer programming courses, also domain specific variables, not connected directly to gamification, can affect LP: career progress, number of times taking a subject, high school major and career, previous experience on the topic and general grade point average (GPA) (Owusu et al, 2013; Hoskey & Maurino, 2011; Byrne & Lyons, 2011; Wilson & Shrock, 2001).

3. Research Hypothesis

Building on the available conceptual and theoretical base, we present the following research hypotheses:

H1 - Students involved in a gamified Computer programming course will attain higher intrinsic motivation, self-efficacy and engagement as compared to students in a control condition.
H2 - Students involved in a gamified course will attain higher learning gains as compared to students in a control condition, considering the changes in mediating variables (intrinsic motivation, self-efficacy and engagement) and the interaction with co-variables (age, gender, personality, gaming experience, programming experience, number of times taking the subject, GPA, high school major, career and career progress).

4. Methodology

4.1 Sample

The study involved 132 undergraduate first-year students from different engineering programs of an Ecuadorian public university. These students self-enrolled in an introductory computer-programming course, divided into four parallel sections, taught by four different teachers. These teachers shared similar characteristics in terms of years of experience, and positive students' evaluation grade. Due to individual circumstances not related to this subject (absences, illnesses, dropping out of subject), a final sample of 100 students was considered in the complete intervention study. A quasi-experimental design was set up using two parallel sections for the control condition (N =50) and two for the gamified experimental condition (N=50). Informed consent was obtained from all students, and approval to proceed with the study, was obtained from the university authorities.

4.2 Research Instruments

All instruments were piloted involving 50 students prior to the intervention, in order to check language problems, translation inconsistencies and calculate initial reliability scores to develop the final version of the scales. To get demographics, students filled out a background questionnaire about their age, gender, faculty, career, high school major, digital gaming experience, programming experience and number of times taking the subject. Further information, such as their GPA and curriculum progress, was collected through the university's academic system. We measured learning gain through an 18-item knowledge test. Two versions were designed to avoid students remembering the items. In terms of IM, we adapted the interest/enjoyment sub-scale of the Intrinsic Motivation Inventory (IMI) to a programming context (Ryan and Deci, 2017). For instance, instead of "I would describe this activity as very interesting"; students would read, "I would describe programming as very interesting". Regarding, SE, we built on Bandura's guidelines (2006), to develop a 20-item scale adapting the four problem solving techniques proposed by Pólya (2014) to a programming context: understand the problem, design a strategy to solve the problem, write the program, and verify the program. We also designed the items based on Pennington & Grabowski (1990) and Ramalingam & Wiedenbeck (1998). See Table 2 for a sample of the items used. The full version is available upon request to the authors.

Table 2: Self-Efficacy sample items

Dimensions	Sample Items
Understand the problem	Identify the input/output variables
Design a strategy to solve the problem	Select or create algorithms that are needed to solve the problem
Write the program	Write code lines syntactically correct.
Verify the program	Think of an alternative way besides the one already used, to write the program, using fewer lines.

To determine engagement, we counted the amount of optional activities (10 in total) carried out and turned in on time through the learning management system (LMS). Finally, the Spanish Version of the Big 5 Inventory by Benet-Martinez & John (1998) was used to measure personality.

4.3 Design of the gamified experience

The gamified intervention was set up following three course units; taking four weeks. During class, students were asked to sign up in Credly, a web-based system to award and store digital badges. To raise engagement, they were awarded with their first badge for collaborating in this activity. Online, through the LMS, students received the instructions to earn badges at the beginning of each unit. They were presented with five activities (one or two mandatory and the others optional), from which students could choose three to carry out. If students finished three successfully, they earned a unit badge. In addition, if they received all the unit badges, they additionally obtained a final badge (a meta-badge) that would recognize them as a programming expert. To visualize the activities they had carried out and still needed to complete, they also received a tracking badge. The mandatory activities comprised of achieving the highest grade in a reading quiz based on the unit chapter or any quiz, and the optional activities included completion of the programming exercises in two web-based platforms: Code Academy and Pyschools. They had to upload a screen capture in the LMS as evidence. The badge design was made in Credly and the names were related to the course units in the study. Finally, a week before finishing the intervention, students had the chance to award a "good pal" badge for helping others throughout the course. Figure 1 depicts an example of the tracking badges, leading to earning the unit badge and the final (meta) badge.

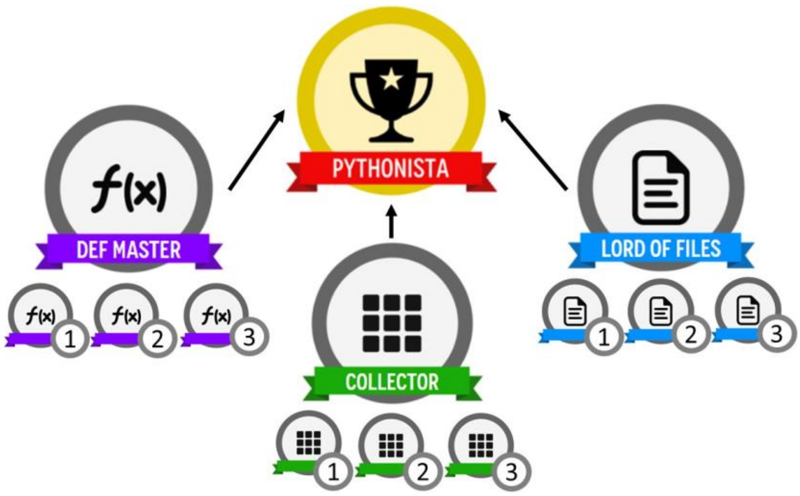

Figure 1: Badge System

4.4. Procedure

The intervention was set up during the second half of the first semester of the academic year 2016-2017. Before the intervention, in a pre-test phase, students filled out the Big 5, SE, IM and background questionnaires, via Google forms. The knowledge test was filled out during class time as a paper and pencil test. During the six weeks of the experiment (including 1 week for pre and 1 for post-test), the gamified and control condition turned in the optional and mandatory assignments. However, in the gamified condition students got badges for carrying out the assignments successfully. At the end of the intervention, students filled out for a second time the SE and IM instruments via Google forms and the post- test in-class during the last lesson.

4.5. Data analysis

All analyses were carried out with SPSS (version 20) with a significance level of p <.05. Descriptive statistics were calculated to develop an overview of the research variable values. Preliminary analysis discarded all co-variables since none of them were significantly related to learning gains. Prior to the analysis, assumptions were tested (homogeneity of variance, normal distribution). For testing the hypotheses, analysis of variance (ANOVA) and covariance (ANCOVA) were carried out. To counter the impact of multiple comparisons, Bonferroni correction was applied. Interpretation of the effect sizes was based on Baguley (2009), who puts forward the following benchmarks: small effect size (from d=0.2), medium effect size (from d=0.5), large effect size (from d=0.8).

5. Results

Descriptive statistics about the background variables show how both experimental and control group share similar characteristics. .

H1 - Students involved in a gamified Computer programming course will attain higher IM, SE and engagement as compared to students in a control condition.

Concerning hypothesis 1, the ANOVA analysis results showed a significant differential impact of studying in the gamified condition in terms of Engagement [F (1, 98) = 11,06 , p = < .001]. Cohen's effect size value (d=.67) points at a medium size effect. No significant effects were observed in relation to the other variables: IM [F (1, 98) = 1.99, p = .16] and SE[F (1, 98) = 2.67, p = .11].

H2 - Students involved in a gamified course will attain higher learning gains as compared to students in a control condition, considering the changes in mediating variables (IM, SE and engagement) and the interaction with co-variables (age, gender, personality, gaming experience, programming experience, number of times taking the subject, GPA, high school major and career and career progress).

Regarding hypothesis 2, the analysis results showed no significant effect in neither LP nor the mediating variables: Research Condition [F (1, 95) = 2,31, P = .13], [F (1, 98) = ,02 P= .90], SE [F (1, 98) = .90, P = .35], and engagement [F (1,98 = 2,60, P = .11].

Table 3 summarizes the mean (M) and standard deviation (SD) in relation to all research variables.

Table 3. Mean (M) and Standard Deviation (SD) of Variables (N = 100)

Variable	***Condition***	**Pre-test M(SD) MIN/MAX**	**Post-test M(SD) MIN/MAX**	**Difference pre/post M(SD) MIN/MAX**
Learning Performance	Experimental	4,74 (2.41) 1/14	9.64 (2.95) 2/15	4.89 (3.11) -1.33/10,67
	Control	1.64 (1.51) 0/7	7.28 (2.75) 2/14	5.64 (2.97) -1.50/11
Intrinsic Motivation	Experimental	5.13 (1.43) 1/7	5.27 (1.18) 1.57 (7)	.13 (.60) -1/1.86
	Control	1.70 (1.37) 1/7	5.05 (1,21) 1.86/7	.35 (.90) -1.43/4.43
Self-Efficacy	Experimental	66,76 (20,18) 19.50/100	74.39 (14.93) 43.50/106.50	7.63 (13.47) -12/50.50
	Control	57.38 (22.14) 8.50/88	69.72 (14.75) 29/93.50	12.34 (15.30) -17.50/52.50

In terms of Engagement, the control group performed an average of 5 (SD = 3.81) activities whereas the experimental group performed a mean of 8 (SD = 2.86). In both cases, with a minimum of 0 and a maximum of 10

6. Discussion

The present study analyzed the potential impact of badges on LP in the context of a quasi-experimental study. When it comes to our first hypothesis, the results showed that gamification lead to a significantly higher level of engagement. This finding is in line with the related education literature in the computer programming domain (Akpolat & Slany, 2014). This result also aligns with Landers's theory (2014), explaining how game characteristics influence changes in behaviour or attitude. In the specific case of badges, studies also support this hypothesis (Denny, 2013). However, it is necessary to point out the lack of available studies focusing exclusively on badges and their effects on engagement.

In terms of the second hypothesis, following Landers's theory (2014), we would expect that the positive effect on engagement, would mediate a positive effect on learning, but as the results reflect, this did not happen. Neither the impact on LP, nor the mediating or co-variables could be confirmed. Possible explanations could be related to students´ exhaustion and lack of cooperation when filling out the research instruments. In terms of IM and SE, the use of self-reported questionnaires and the online administration could have also had an effect (Fernandez-Ballesteros, 2004). Other reasons could be linked to the nature of the course. At the start of an introductory programming course, SE and motivation tend to be high, but when more demanding tasks are being put forward, they decrease (Chilana et al, 2015; Zainal et al, 2012; Teague et al, 2011). The present target group of students were involved in this study in the second half of the term, when the already demanding tasks become even more and more complex. Finally, the role of teachers could also play a role. For instance, their actual attitude towards gamification could have a positive or negative impact on the overall learning experience (Marí-Parreño, Seguí-Mas & Seguí-Más, 2016).

7. Limitations and Directions for Further Research

We have to acknowledge some limitations of the present study. First, teachers' feedback procedures, reinforcement practices, among others, might have interfered with the basics of gamification as an instructional tool. Second, we have to consider side effects of the online administration of the research instruments. Third - though the intervention already showed some promising results - the length of the intervention was short compared to studies taking a semester. Hence, the importance of defining some directions for future research: opt for a longer duration of the gamification experience, set a more controlled environment by also focusing on additional teacher variables and on students when filling out research instruments. Additionally, collect qualitative data to complement the quantitative information. In terms of technical requirements, include the badge system in the LMS to avoid a possible flow interruption while navigating in the system.

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