COMPUTER-ASSISTED GAMIFICATION IN A COMPUTER PROGRAMMING COURSE: AN EXPERIENCE REPORT

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Abstract

Gamification refers to the use of elements related to game design in non-game contexts. The use of gamification in teaching-learning processes has several benefits that promote the educational process of students. Gamification seeks to increase the level of motivation, participation and commitment of learners, generating a positive impact on learning, through the use of mechanisms of interest, emotion and fun. In the area of computer programming, studies have been conducted that highlight the use of gamification to promote motivation, participation and support the learning of topics related to the area. However, more empirical studies are needed to understand the impact of gamification on several educational aspects. For this reason, the objective of this paper is to present an experience in which a gamification tool was selected and integrated into an introductory computer programming course. From a literature review and a comparative analysis using criteria matrices, the CodeGym tool was selected. This tool supports the learning process of basic computer programming concepts using the Java programming language. This gamified tool integrates elements related to the game such as points, badges, progress bars, levels, leaderboards, unlimited attempts, among others. The participants were 17 students from the undergraduate program in Systems Engineering, who were given the opportunity to spend part of their class time developing the modules included in the gamified tool.

The data collected in this learning experience with CodeGym is related to two aspects: participation and students' perception. The participation was characterized by the number of interventions made by the students in the gamified environment, extracting quantitative data of the number of attempts in the solution of the exercises, levels completed, achievements reached, badges obtained, among others. Secondly, a survey was carried out to find out the students' perceptions and the results were analysed using both quantitative and qualitative methods. Results show that the experience using gamification promotes students' level of participation and confidence in learning. As for the participation that the students showed, a high level of persistence could be observed during the development of the exercises; when the level of difficulty of the exercise increased, generally the students continued trying until the objective was achieved. The students expressed in the survey that they perceived a more playful and recreational learning environment, which generated a greater interest in the topics of the course. Also, CodeGym was rated by the students as a good complement to the traditional classes. Results of this experience contribute to a better understanding of the benefits and challenges that exist using computer-assisted gamified environments to support the teaching-learning processes of computer programming.

Keywords: Learning computer programming, computer-assisted gamified environments, participation of learners, and commitment of learners.

1 INTRODUCTION

Computer programming is a fundamental discipline today. It is necessary for professionals in this area to acquire skills that allow them to face the challenges of contemporary technological progress [1], [2]. Given the complexity of the teaching and learning process of computer programming [3]–[5], it is essential to have motivating and innovative teaching methodologies that facilitate learning [6]. In Borges et al. [7], the use of game-related methodologies is highlighted, due to the benefits it generates in the participation, motivation and commitment of students. Gamification is immersed in game-related methodologies and has generated great interest due to the adoption of characteristics and elements of the game in academic contexts [8]. The use of gamification in teaching-learning processes seeks to increase the level of participation, commitment and motivation through the use of interesting, exciting, fun and playful mechanisms [9].

In the area of computer programming, gamified approaches have been developed, highlighting the increase in levels of motivation and participation of students in the learning process. Such is the case

of [10], where it is observed an improvement in the capacity to solve algorithms, in addition to a more pleasant learning environment; favoring the realization of activities that generally are difficult for the students. The studies carried out in [11], [12], where gamification approaches are implemented in computer programming courses, conclude that the use of gamification provides an increase in motivation and participation in the educational process of students. On the other hand, there are studies like [13] where the impact of gamification is analyzed, and they conclude that there is no effect on the learning and motivation of the participants. Thus, as suggested in [14]–[16], more empirical studies are needed to understand the impact of gamification on several aspects such as student participation and their perceptions regarding this type of approach.

In this context, this paper aims to answer the following research question: What is the effect of a computer-assisted gamified learning environment on the participation and perceptions of computer programming students? This paper presents an experience in which a gamification tool was selected and integrated into the classroom methodology of an introductory course in computer programming. CodeGym © [17] was the selected environment to support the learning process of basic concepts of computer programming using the Java programming language. The study involved 17 students from the faculty of systems engineering at the Universidad Santo Tomás in Tunja (Colombia), who devoted 50% of the weekly classes to interact with the selected modules of the gamification tool.

The data collected in this study allowed us to analyze aspects related to student participation and perception based on the learning experience using CodeGym. The analysis of participation was characterized by the number of interactions carried out by students in the gamified environment, considering the number of attempts in the solution of the exercises, levels completed, achievements reached and badges obtained. In addition, a survey was conducted to analyze the perceptions that students had in the development of the class using CodeGym. This survey addressed open-ended and multiple choice questions. Results show that the experience with gamification promotes the level of participation and confidence of students in learning computer programming. In terms of participation, a high level of persistence was observed in the development of the practical exercises; when the level of difficulty of the exercise increased, students generally continued trying until the objective was achieved. The students perceived a more playful and fun learning environment, which generated a greater interest in the topics of the course. CodeGym was rated by the students as a good complement to the traditional classes. This study presents interesting conclusions that contribute to a better understanding of the benefits and challenges that exist when using computer-assisted gamified environments to support the teaching-learning processes of computer programming.

This document is structured as follows. The following section presents the proposed methodology, describing the selected gamified environment, the participants and the instruments used for data collection. The third section presents the results of the study related to the participation and perceptions of the students. Finally, the fourth section presents the conclusions of this work.

2 METHODOLOGY

2.1 CodeGym ©

CodeGym is a platform that integrates the concept of gamification for teaching computer programming through the Java language. This tool aims to make the students' educational process more interactive and exciting through the incorporation of game-related elements such as points, badges, progress bars, social interaction, levels, leaderboards, unlimited attempts, narrative scenarios, player performance statistics and access to blocked content. The 80% of the activities proposed by CodeGym are practical in nature, because it bases the learning on the concept of training. The student can advance in the levels proposed by CodeGym by validating the activities performed and receiving instant feedback. At the end of the proposed tasks, the user visualizes the number of attempts made and the “dark matter” obtained, as shown in Fig. 1. The dark matter can be understood as the points that the student acquires when solving the practical exercises. This dark matter is used to unlock the lessons and levels.

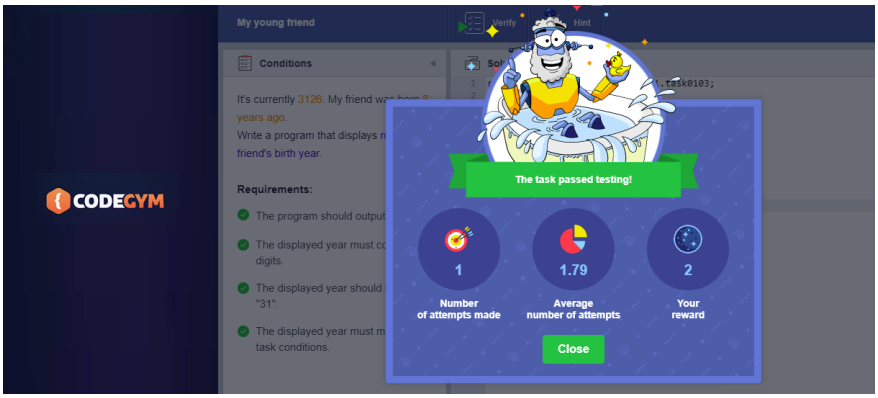

Figure 1. Screenshot of a problem solved in CodeGym.

The platform allows the user to obtain achievements when he meets the conditions established to acquire them. CodeGym categorizes the achievements as objectives or goals that encourage students in the development of the exercises or practical tasks. For example, students can achieve achievements by completing 50 tasks, develop all level 1 activities, perform 10 tasks in series without mistake, achieve the development of 100 practical activities, among others.

It is also interesting the use of out-of-classroom activities proposed by CodeGym, among which there are forums and spaces for users to interact and contribute to the community in a collaborative way. Another remarkable aspect of CodeGym is the relationship that the modules of the tool have with the topics proposed in the curriculum of the chosen course; in addition to the availability and online access from the web that the tool offers. Furthermore, the gamified features of the platform, the programming language used and the availability of different didactic techniques for learning are remarkable. Due to these characteristics it was decided to integrate CodeGym within the methodology of the introduction to computer programming course.

2.2 Design of the educational intervention

The learning experience was designed for students of the subject "Introduction to Computer Programming", which has a theoretical and practical nature of three academic credits. Four sessions of two hours each were given weekly, and 50% of the sessions were integrated into the CodeGym methodology. This experience lasted 8 weeks and provided the student with knowledge about computer programming fundamentals, understanding of data types, functions and their application in problem solving, assignment of variables, combination of conditional structures, basic and complex loops. Table 1 shows the relation of the proposed topics in the course curriculum and the selected CodeGym modules that were integrated in the course.

Table 1. Relationship between the course and the CodeGym modules.

Competence	Content	CodeGym module
Fundamentals of computer programming	Approach to computer programming	Level 0: Introduction (7 exercises)
		Level 1: Introduction to Java: output, int and string data types. (21 exercises)
Understanding of the concept of function, use and application in problem solving	Data types	Level 2: Introduction to Java, variables, methods (19 exercises)
	Functions and procedures in software programming	
Fundamentals of computer programming	Setting up the IDE	Level 3: Your First Program: keyboard input, working in the IDE (26 exercises)

Understanding a structure that allows you to set multiple conditions	Simple and complex conditional structures (IF statement)	Level 4: Introduction to Cycles (43 exercises)
Combination of basic cycle structures, complex loops and assignment of variables	Application of loops in problem solving	
	Use of conditional structures and combination with cycles	

2.3 Participants and data collection

The study involved 17 first semester students from the systems engineering faculty of the Universidad Santo Tomás in Tunja (Colombia). The ages of the participants ranged from 17 to 20 years old. 100% of them are male, 8 students are graduates of private schools, 8 of public schools and one student graduated from a validation institute.

The experience carried out in this study, allowed the collection of data related to two aspects: participation and perception of the students. To measure participation in the experience, a table was constructed with the data that CodeGym provided at the end of each practical exercise and when new achievements and badges were obtained. The table contained data related to the current level of the student, dark matter obtained, medals achieved, number of attempts for each practical exercise resolved, and achievements awarded according to each student's performance.

The data related to the students' perceptions were collected through a survey in Google Forms. This survey was applied the week after the last session in which CodeGym was used. Table 2 presents the survey questions on perceptions about the use of CodeGym.

Table 2. Survey of students' perceptions.

#	Question	Type of question
Q1	What elements integrated in CodeGym did you like the most?	Multiple
Q2	What drove you to advance in the development of the levels and lessons proposed in CodeGym?	Multiple
Q3	What is your general perception about the use of CodeGym in the methodology of the Introduction to Computer Programming course?	Open
Q4	Regarding gamification in learning, what is your perception about the use of game elements such as badges, points, levels, rewards, leaderboards, among others, within the methodology of the computer programming introduction course?	Open

3 RESULTS

3.1 Student Participation

Student participation was analyzed through the table where data was collected regarding the number of achievements, medals, and attempts made by students.

3.1.1 Achievements

As described in section 2.1, CodeGym awards different achievements for the fulfillment of different goals and objectives established by the tool. These objectives refer to the persistence and continuity that the student evidenced in the platform. Generally the achievements are granted for reaching a certain number of tasks in a certain time limit, with the aim of engaging the student to use the tool periodically and continuously.

At the end of each level, the student captures the data provided by the platform and it is collected in the built table. Fig. 2 presents a bar chart with the information of the achievements obtained by each student.

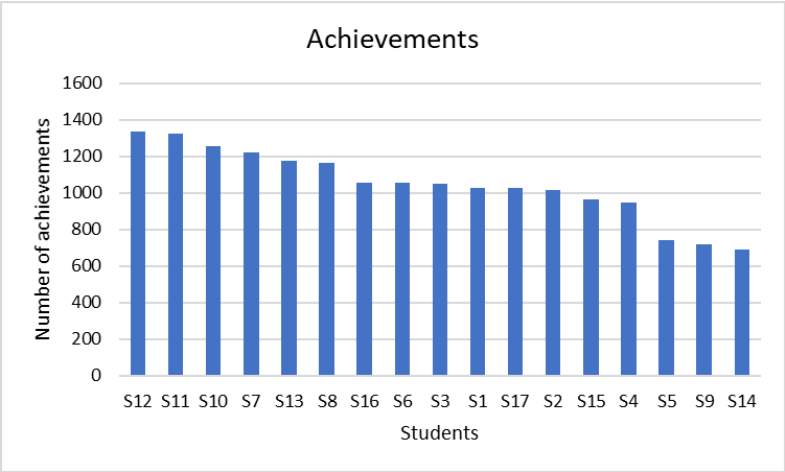

Figure 2. Achievements per student.

The figure shows the ranking of students where it can be seen that some of them obtained a much higher amount of achievements than other participants. The student with 1338 achievements surpassed by 49% the one with the lowest amount of achievements in the class. 53% of the students had a higher achievement than the average of the class. These students achieved high levels of achievement due to persistence and consistency of activities up to the last level. The students who had low achievements had a low participation behavior in the last levels, since they did not interact and did not fully solve the proposed practical activities.

3.1.2 Medals

At CodeGym, medals are awarded according to the student's achievements. Each achievement represents one or several medals that the user accumulates. As the student reaches the different achievements described in section 2.1, the number of medals increases. Two examples of achievements are shown in Fig. 3.

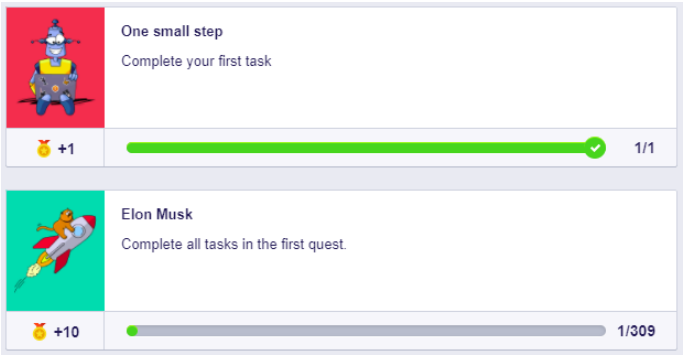

Figure 3. Medals awarded for achievements.

The first achievement displayed is awarded for completing the first practical task, providing the student with a medal. The second is awarded for completing all the tasks in the first level, which gives the student 10 medals. As the level of difficulty to achieve increases, the number of medals awarded increases too. Each student may earn a different number of medals, because the persistence and achievement level may not be the same among participants. Fig. 4 shows the average number of medals achieved per level developed in CodeGym.

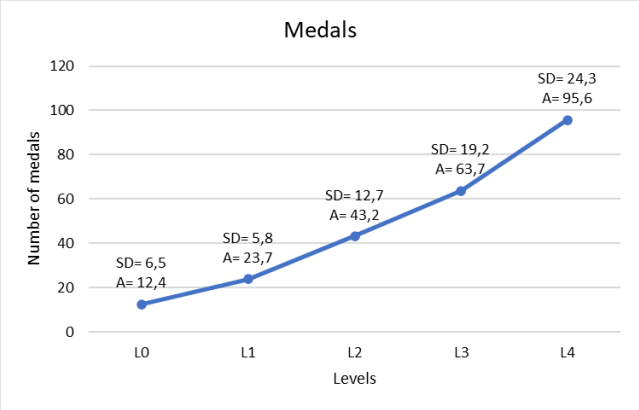

Figure 4. Average (A) medals achieved per level.

It is evident that as the development of the activities proposed in each level advanced, some students acquired a greater number of achievements, which translates into a greater number of medals. In the first two levels there was less dispersion of data (standard deviation - SD), in other words, students achieved a similar number of medals. On the other hand, in the higher levels, a higher standard deviation is appreciated, because in the formative process using CodeGym, some students were more persistent and constant, which allowed them to obtain a greater difference in the number of achievements and, consequently, a much higher number of medals than other students.

3.1.3 Attempts

When the student finishes each proposed exercise, CodeGym presents the number of attempts made (see Fig. 1). This data was collected in each of the levels developed by the students, during the time the experience lasted. The number of attempts made represents the continuous execution of exercises that CodeGym allowed the students to do. The tool facilitated the constant practice and sending of unlimited attempts. In Fig. 5 you can see the box diagram corresponding to distributions of the attempts made in level 3 exercises.

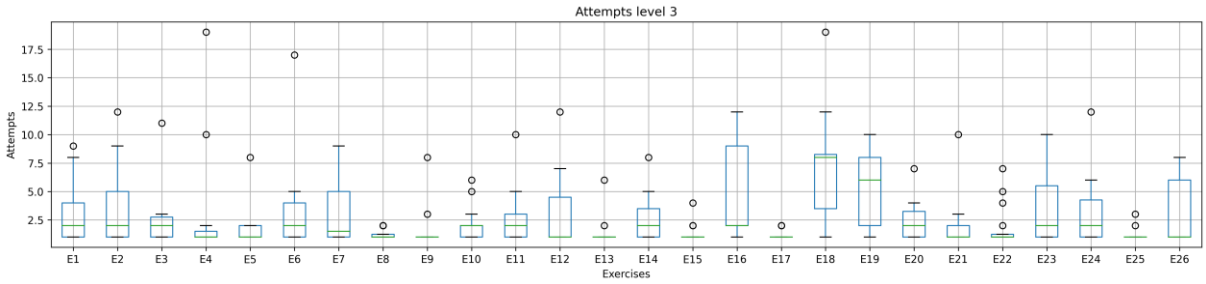

Figure 5. Box plots of attempts in level 3 exercises.

The behavior of the other levels is very similar to the level 3 presented in Fig. 5. This figure shows the concentration of the number of attempts made per exercise and the outliers or number of attempts outside the usual range. As the level of difficulty in the topics proposed by the platform increased, there was an increase in the number of attempts sent.

3.2 Students' perceptions using CodeGym

The information related to the perceptions generated with the use of CodeGym, was collected with the instrument built in Google Forms (see Table 2). Question 1 is related to the elements integrated in CodeGym that generated the most satisfaction in the students. In the answers given by the participants, it was identified that 82% of the respondents liked having immediate feedback, which indicated to the student if the answer sent was correct or not, in addition to providing guidance or clues as to why the solution sent was wrong. 76% of the students were attracted to the integration of elements such as collaborative forums where students could share their doubts and concerns and receive input from other community participants, and the presentation of content by levels allowing them to advance in a staggered manner. On the other hand, gamified elements such as the clues to

solve the exercises, the obtaining of points and the groups to share information, did not generate great acceptance or influence in the interest of the students.

Question 2 of the survey refers to the factors that drove the students to advance in the development of the levels and lessons proposed in CodeGym. 88% of the students mentioned that wanting to complement the themes seen in class was one of the factors that generally pushed them to continue with the development and progress in the practical activities. Additionally, 70% of the students referred to the desire to learn new topics before seeing them in class, and 65% related the challenge generated by the tool to the desire to continue with the development of the activities.

The questions with open answers are related to the perceptions that the students acquired with the use of CodeGym and with the integration of elements related to the game in the methodology of the introduction to computer programming course. The answers obtained allowed to extract data that were organized into categories, concepts and indicators. In Fig. 6 the diagram presents the concepts related to gamification in learning and establishes the indicators that group the answers given by the students.

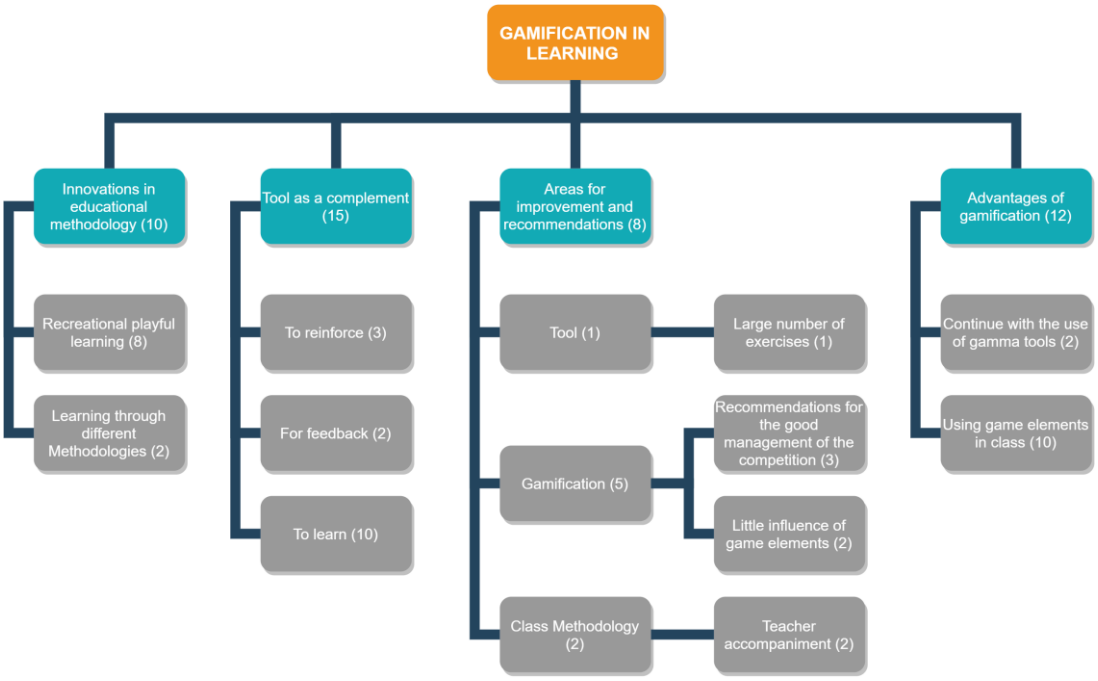

Figure 6. Students' perceptions using CodeGym.

The categorization shown in Fig. 6 presents 4 fundamental concepts extracted from the answers given by the students. The concept innovations in the educational methodology is related to the perceptions that assimilate the use of CodeGym as an innovative methodology that allows learning in a playful and recreational way, where students can assimilate the proposed topics through different ways than the commonly used traditional methodology. The concept associated with the use of the tool as a complement refers to the perceptions that associate the use of CodeGym as an addition to the classic teaching methodology. In this concept the students perceive the tool as a complement to reinforce what they have learned, to give feedback to what they have seen in class and to learn new topics. In the concept related to the aspects to improve and recommendations, we classified the perceptions linked to the suggestions that the students presented in relation to the great amount of exercises proposed by CodeGym, the recommendations of the good handling that should be given to the competition and in some cases the little influence that the elements of the game presented in the interest of the student. In this concept it was also evident how important it is for some students to be accompanied by the teacher in the training process. Finally, in the advantages of gamification, it was presented the opinions about the continuation of the use of gamified tools and the interest that presented the use of game elements in class.

The use of CodeGym as a complement, was one of the concepts to which the students referred more. The 33% of the answers are related to the perception that the tool allowed them to reinforce, feedback and improve the learning of different topics seen in class. It is worth mentioning that 4% of the

perceptions show the importance that students perceive in relation to the teacher's accompaniment; for them, the tool does not replace traditional classes.

The 22% of the obtained answers associate the use of CodeGym as an innovative methodology in the classroom. The students assimilated the tool as a good initiative that allowed to awaken a greater interest in the proposed topics. In addition, another 22% mentioned that integrating elements of the game in class captured the attention of the students, who referred to the increase in attention and motivation during their learning process.

The 6% of the perceptions related to the good management of competitiveness. For them it is essential to take into account a healthy competition, which does not generate demotivation or discomfort for not achieving the objectives to the same extent as other students.

On the other hand, it is worth mentioning that 2% of the opinions refer to the abundant amount of practical exercises proposed by the tool, generating an accumulation of activities. This could give an indication of why only 29% completed level 4 in its totality, taking into account that by this date the students were in their final exams.

4 CONCLUSIONS

The objective of this study was to report an experience in which CodeGym was integrated as a gamified environment, with the purpose of analyzing aspects related to student participation and perception. The use of CodeGym in the traditional classroom methodology shows a good acceptance by the students taking into account the information collected with the perceptions questionnaire and the information collection table related to participation.

In order to analyze the students' participation, the medals achieved, the number of attempts per exercise and the achievements were taken into account. In the first levels there was a smaller difference related to the number of medals obtained per student. As the level of difficulty in the topics increased, a greater dispersion in the obtaining of medals was observed. This phenomenon was also seen in the number of attempts made per practical activity. In the initial levels the students developed the exercises in a smaller number of attempts, but as the level of difficulty increased, the number of attempts submitted increased as well. It should be noted that CodeGym allowed constant practice, without limiting the number of submissions so that the student was free to make mistakes and try again. On the other hand, in terms of achievements, there is evidence of a more participatory activity in some students than in others. 53% of the students developed and made the sending of the progress made in the five levels, evidencing a greater number of achievements.

In relation to the perceptions of the participants, it is shown that 82% of the opinions using CodeGym were favorable, for the students was attractive the use of elements of the game in class, generating in them a greater participation and dedication in the resolution of the proposed exercises. Most of the respondents report a favorable perception related to the learning experience, because CodeGym allowed them to increase their interest in the proposed themes, increasing the practice and challenging the student in the solution of exercises with increasing levels of difficulty. The 22% of the opinions refer to the use of CodeGym as an innovation in the educational methodology due to the integration of recreational and playful learning techniques that allow the understanding of the proposed themes through methods different from the traditional ones. For 33% of them, the tool used performs well as a complement to reinforce the themes seen, to give feedback to the classes and to learn new related concepts. Additionally, 26% of the perceptions report a great acceptance with respect to the use of gamification within the classroom, they perceive the use of elements of the game in the formative process as beneficial, since it increases the interest and motivation to learn, they even suggest to continue with the use of gamified tools in later semesters.

The main contribution of this study is to provide new experiences of the use of gamification in the traditional classroom methodology. The result of this study presents interesting benefits and conclusions of the use of elements of the game in class. The students' perceptions were favorable to continue implementing computer assisted gamification in the teaching-learning process of computer programming. There are still challenges and aspects to be evaluated related to the effects generated by gammatization. It is proposed as future work to replicate this experience in longitudinal studies that allow us to analyze different aspects in the long term.

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