Effort analysis of computational thinking process over a gamified and non-gamified environments

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Abstract. In recent years, the computational thinking has been established as a formative priority from primary school onwards, both internationally and nationally level, which has led to initiatives of recreational strategies and curricular integration. The initial training processes in programming are mainly focused on workshops about teaching methodologies, therefore, the assessment instruments are artifacts that measure the quality of the solution elaborated by the teacher, relegating the evaluation of the process due to the difficulty to obtain elements that allow the characterization. Thus, this article characterizes through analytics and statistical tests the process of solving computer problems by primary school students based on the effort involved in each challenge. Hence, experimental tests were conducted with a group of K-12 students, who solved a series of drills using a block-based tool, both gamified and non-gamified with the purpose of corroborating that gamification generates higher levels of global effort. In the end, the results show that a group of students exhibits a higher level of engagement and effectiveness in the gamified version while in the non-gamified version they are more reflective. Not only do these results provide crucial information for the creation of assessment instruments of the computer solving problems process, but also provide to the behavioral differences in gamified environments.

Keywords: Computational Thinking, Learning Analytics, Learning Assessment.

1 Introduction

Computational thinking, in particular, the ability to program computers has in recent years become a training priority since primary education [20]. This is due to its influence on other skills, such as: analyzing problems, holistically and strategically, designing solutions in an iterative and planned manner, testing the quality of the solutions developed to seek improvements and greater adjustments to the problem analyzed [13], as well as, the influence on mathematical skills [5].

However, achieving high levels of problem-solving, particularly computational ones, requires high levels of motivation, effort, and abstraction, both at the problem and solution level and therefore generates difficulties in training and evaluation. The foregoing lies in the difficulty of establishing educational methodologies that establish a training process that considers the problem-solving characteristics of the group of students [8]. Until now, most assessment tools in the context of computational thinking training focus on evaluating the solutions developed [23,19], discarding the study of the process of elaboration of each solution where the student selects the solutions. strategies to use and, therefore, manifests the indicators of skill acquisition. However, there are initiatives that seek to describe computational problem-solving strategies by means of educational traces captured from autonomous learning platforms and guided by challenges [12,7].

On the other hand, gamification is presented as a dynamic alternative that contributes to the increase of levels of motivation and effort on the part of students in learning processes. In this context, they have developed frameworks such as LEGA [4], which includes gamification techniques designed based on Bloom's taxonomy [1], on an educational platform, applications like Knowma+[2] , have also been designed, which has allowed researchers to evaluate what elements of gamification contribute to improving the interaction of students with the platform, a gEchoLu gamified online discussion tool has also been designed, which has allowed us to analyze the influence of gamification on the behavior, participation, and motivation of the students [9]. The variables that are analyzed to measure the behavior of students affect emotional controlled motivation [10]. A study conducted on an intelligent tutorial system, examined the different mitigation, cognitive commitment, self-motivation and groups, totally gamified, partially gamified and non-gamified. This study has characterized the positive and negative effects of each group, concluding that the gamification elements increased the students' commitment rate, but it is not evident if these of gamification elements, these elements were assigned in 3 fully gamified group presents better results than the partially gamified group, however, these groups they present a greater effort than the non-gamified group [3]. Consequently, to measure the effect of gamification, surveys are usually carried out, which allow qualitative data to be obtained, while the records in these platforms allow obtaining quantitative data about the students' objective behavior.

Therefore, in this article, we study the level of effort of a group of primary education students in two computational problem-solving environments: Gamified and Non-Gamified. Specifically, the behavior is analyzed in terms of overcoming the different levels proposed in the game, overcoming the obstacles, as a function of time, attempts and other variables that describe the effort invested by the students. The main objective of this study is to obtain, from the captured traces, a characterization of the students in the two environments and, therefore, seeks to answer the following research question:

RQ: Do students invest more effort in the face of computational challenges in a gamified environment?

It is expected to observe, in the students, lower levels of effort to learn to programme in a resolution interface of computational challenges without gamification as opposed to the interface with gamified components.

2 Related works

Computational thinking is a metaphor about the reasoning used by people and machines [15], it is a problem-solving ability in such a way that a computer is capable of carrying it out. Currently, this skill is not limited to computer science professionals but requires its acquisition in an increasingly wide range of disciplinary areas due to rapid penetration. Technology in every phase of our lives. That is why a wide variety of initiatives have emerged that seek to promote computational thinking at different educational levels. Among the main initiatives aimed at promoting computational thinking are: 1) Code time, 2) Scratch Day, 3) Alice, 4) Blockly, 5) CodeWeek and 6) "Informática Desenchufada". The main feature of these proposals is the simplification of computational concepts and the gamification of interfaces or activities, always with the purpose of reducing the complexity of programming languages using blocks of instructions and increase the motivation of the participants through the game, respectively.

There are indications that the development of computational thinking promotes the motivation in learning processes and improves skills such as those associated with mathematics in primary and secondary school students [5]. This is achieved through the strengthening and contextualized application of the abstraction, the algorithms, and the problem-solving process. Mathematics and computational thinking are closely related, mainly in the capacity to construct models of reality through conceptual representations that allow to reduce the complexity of the problem and solve it through algorithms that can be processed by a machine.

Fan Yang and Frederick W.B. Li used neural networks to analyze how students performed, what factors would affect their performance, how students can progress, and whether students have potential for better performance. . The main conclusion is that the student's performance can be estimated [22]. On the other hand, the study carried out by Basogainet al. on computational thinking in mixed-learning pre-university classrooms, present a description of the concepts integrated under the term Computational Thinking and analyze the benefits of learning environments [6]. One of the main works in this area corresponds to the studies of García-Peñaalvo et al., Who in his article that describes the effects of computational thinking in pre-university education, where they emphasize that it is very important to explore the effect to carry out activities with a programming focus, since these experiences have both primary and secondary education, with a special sense in computational thinking as one of the components within the toolbox to develop an education It is a reflexive and critical way to help children solve problems using the technology with which they will live daily [14].

It has been determined that the incorporation of gamification elements increases the commitment and effort rate by students [3]. In the formation of computational thinking, frameworks have been developed that allow the incorporation of gamification into the educational process in order to encourage effort on the part of students [18].]. In this same line, an educational mobile application has been designed that seeks to develop computational thinking in a mathematics course in primary education, however, only the results of the group of students are reported. students that solve the challenges in the gamified environment [17].Similarly, the formation of computational thinking in the field of social sciences has been integrated using the Scratch block programming interface [21] it is seen that the contextualization of social sciences in an environment Auditory increases motivation and commitment on the part of students [16]. Finally, a study analyzes the behavior of students, through observation, in a formation of computational thinking based on games for elementary students and in an unplugged environment, where a high level of commitment and interest is appreciated. participate in activities [18].

As reviewed in the literature, gamification encourages the extrinsic motivation of students and, with this, increases in their commitment and effort in problem solving are expected. However, in the study of computational thinking there are no studies that describe, by means of the analysis of their interactions, the differences in effort of the same group of students in both gamified and non-gamified environments.

3 Methods

For the validation of the hypothesis, an experimental study was carried out in three primary schools. As a tool for the formation of computational thinking, traditional Kodetu [1] and its gamified version [2] have been used. This platform corresponds to a block-based programming game where students must solve 15 challenges, which go from less to more complex. In Kodetu students must design an algorithm that allows the astronaut (Figura 1) to reach its destination without falling into a vacuum. To reach the solution in each level, the tool provides a series of blocks that correspond to actions that the astronaut can execute: forward, turn to the right, turn to the left, among others. Therefore, the student must construct the sequential solution that takes the astronaut, step by step, from the point of origin to the destination marked by a red symbol. This tool, in both versions, seeks to promote computational thinking among primary and secondary school students. In addition, it allows to collect data of the resolution traces of each one of the proposed challenges or levels. Kodetu has a gamified version, in which users are faced with the same challenges but with some additional features such as limit times for each level, lives, number of maximum blocks to use and a ranking where you can compare with other users [11].

[1] http://kodetu.org
[2] http://gami.kodetu.org

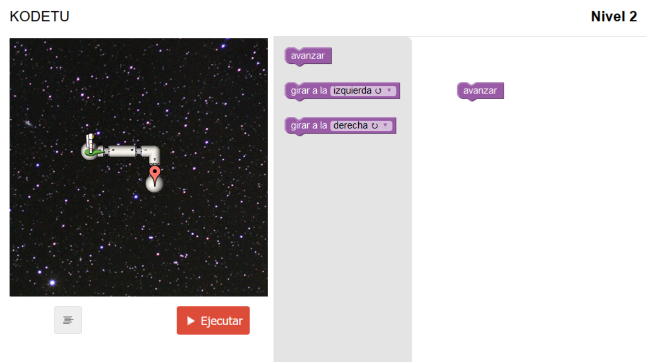


Fig. 1: Kodetu environment.

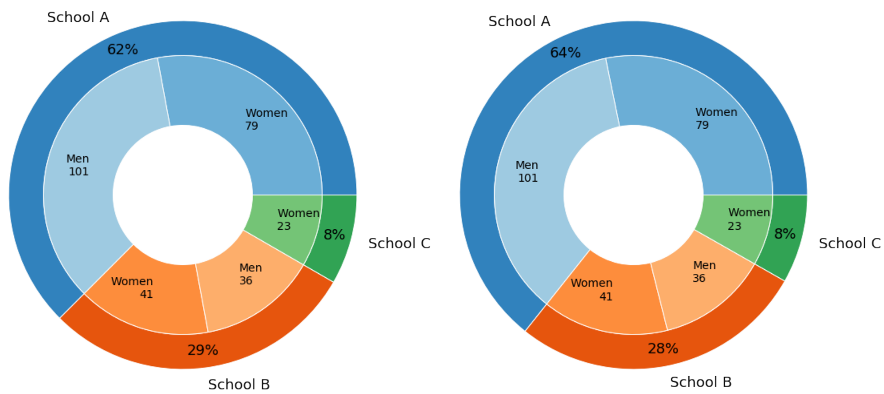
3.1 Participants

The stored information of each of the students is anonymous, safe and is not considered any sensitive data. However, for each participant, the informed consent was requested from the legal tutors, indicating the purpose of the study and the feasibility of withdrawing their students at any time during the experiment.

The distribution of participants / gender for each school is shown in Figures 2a y 2b.The number of participants can be observed and their distribution by gender is similar in both versions of Kodetu, gamified and non-gamified. Likewise, the greatest number and diversity of participants come from School A (gamified n = 150, non-gamified n = 180), with students from third (n = 42, n = 49), fourth (n = 34, n = 41) , fifth (n = 34, n = 41) and sixth (n = 40, n = 49) basic and where the average age is 10 years (SD: 1.43). While in school B (n = 70, n = 77) participations students from third (n = 36, n = 37) and fifth (n = 34, n = 40) basic and where the average age is 10 years (SD: 1.34). Meanwhile, in school C Individual participation of students of sex (n = 20, n = 23) basic and where the average age is 11 years (SD: 0.52). For each school, two groups participated by level, that is, by School A, two third, fourth, fifth and sixth grade participated.

3.2 Procedure

For the collection of data, two workshops were held in each of the courses, in which the students had to play, freely, with the tool for 45 minutes. In order to analyze the impact on students' computational thinking, it was decided to start experimenting with the non-gamified version of Kodetu. Therefore, all the courses held two 45-minute sessions, where each session comprised: 1) Describe the objective of the session, give access to the corresponding platform and monitor the free activities of the students.



(a) Gamified. (b) No gamified.

Fig. 2: Distribution of participants by gender in both platforms.

3.3 Construction of the Dataset

To build the Dataset, the data captured in the Kodetu database was used, both for its traditional and gamified versions. Once the data were obtained, they were processed in a Python script, from which different demographic and effort attributes were generated for each level. Thus, the elaborated dataset contains the following attributes: Course, Age, School, Parallel, Genre, Level, Success, Gamified, Time between actions, Total Time, Total Blocks and Ratio blocks/time.

4 Results

The main results obtained from the experimental study carried out in the three schools are presented below. The effort variables are analyzed according to the type of interface with which the students interacted to reveal the differences in commitment. Due to the fact that the data do not meet the normality conditions, it has been decided to apply the non-parametric Kruskal-Wallis test.

It can be seen in 3 that the participation of gamified and non-gamified students remains regular until the seventh level, which marks the decline in the participation of gamified students. Non-gamified students maintain a greater participation up to level 9. At level 10, gamified students duplicate non-gamified students, although at low numbers, they manage to finish the last level of the game. According to this, the extrinsic motivation (gamification) would have a positive impact, although in a small number of students, on the level of achievement in the game.

Figure 4 shows that gamified students have a higher ratio in the game in general, except in levels 10 and 11. That is, students manage to perform a greater

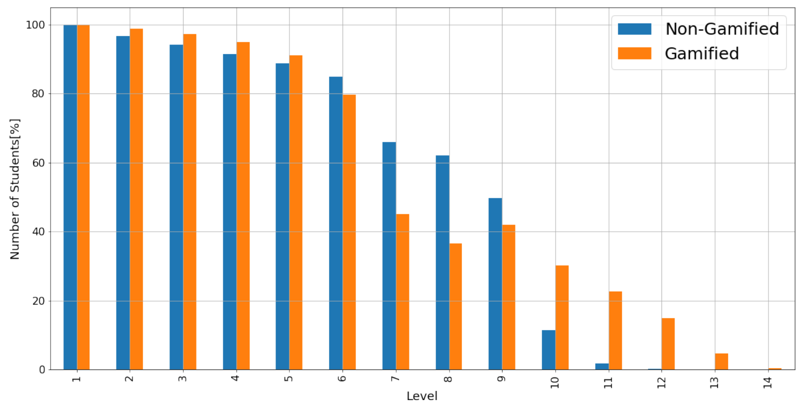


Fig. 3: Distribution of participants by level in both platforms.

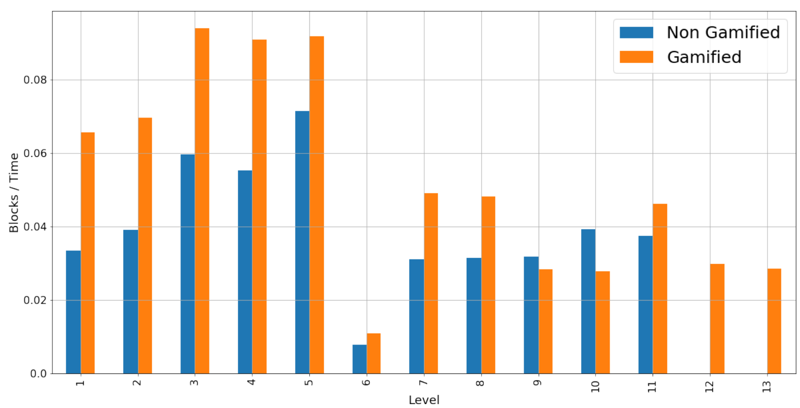


Fig. 4: Ratio between blocks/time by level.

number of actions in less time. Between the levels s 1^{***}, 2^{***}, $3^{\cdot}$, $4^{\cdot}$, $5^{\cdot}$, $6^{\cdot}$, $8^{\cdot}$, $9^{\cdot}$, $11^{\cdot}$ and $12^{\cdot}$ the difference is statistically significant (Kruskal-Wallis test).

It Figure 5 that gamified students used less time to solve the game in general. Except for levels 6 and 11 in which they were surpassed by non-gamified students. For levels 1^{***}, 2^{***}, 3^{***}, 4^{***}, 5^{***}, $6^{\cdot}$, 7^{***} and $9^{\cdot}$ the difference turns out to be statistically significant (test Kruskal-Wallis).

Figure 6 shows that non-gamified students perform a greater number of attempts at all levels involved, however, they leave the game at the two last levels. The difference in the number of attempts per level is statistically significant for levels $1^{\cdot}$, 2^{***}, 3^{***}, 4^{***}, 5^{*}, 6^{***}, 7^{***}, 8^{*}, 9^{***} and $10^{\cdot}$ (test Kruskal-Wallis)

Finally, Figure 7 shows that non-gamified students use more time between actions in the game in general, except at level 10 in which they slightly exceed the time compared to gamified. For levels 1^{***}, 2^{***}, 3^{***}, 4^{***}, 5^{***}, 6^{***}, 7^{***},

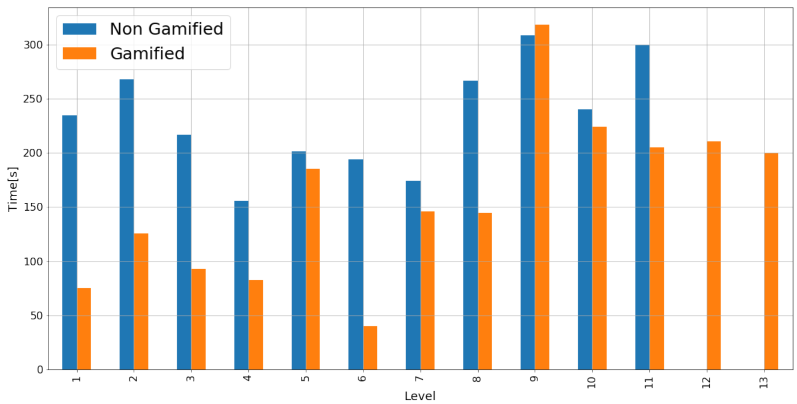


Fig. 5: Time for each level.

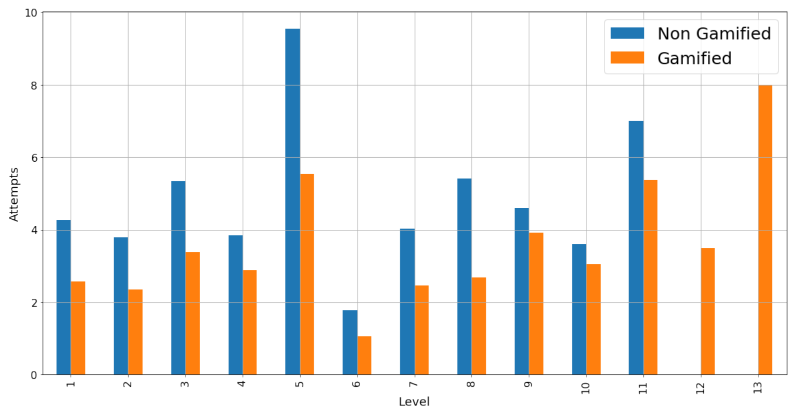


Fig. 6: Attempts for each level.

8^{*}, 9^{***}, $10^{\cdot}$ and $11^{\cdot}$ the difference turns out to be statistically significant (test Kruskal-Wallis).

5 Discussion

As shown in the results, the students during their participation in the non-gamified Kodetu version turn out to be more analytical, they take more time in each attempt for each level and, also, they realize a greater number of attempts, this would produce greater exhaustion and increase the probability of abandonment. This would explain why in this version the students did not solve the higher levels of the game. In contrast, the same students during the gamified version of Kodetu turn out to be more impulsive when facing each level, using a shorter time between each attempt. Likewise, their level of competitiveness

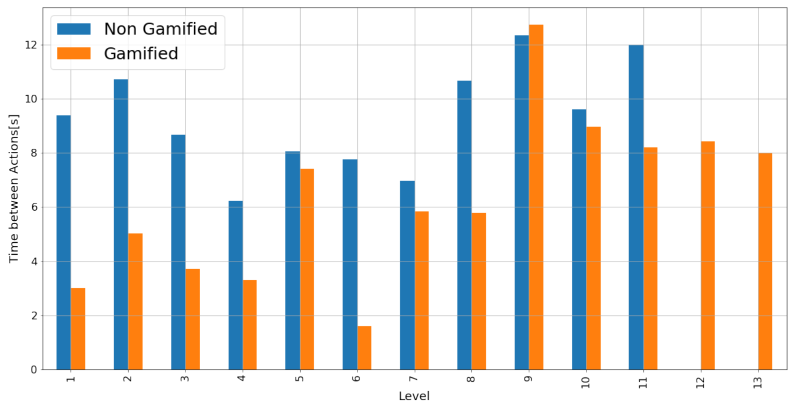


Fig. 7: Time between actions for each level.

increases as evidenced by the fact that more students reach the more complex levels of Kodetu. According to this, the gamification of the game would act as an extrinsic motivation that would facilitate the permanence of the students until reaching the higher levels of the game.

After having used the non-gamified version, the students acquired the computational thinking skills since they were more effective in solving the challenges even when the gamification components generate high levels of stress.

6 Conclusions

Computational thinking is a problem-solving skill that is currently not limited to computer science professionals, but requires its acquisition in an increasingly broad range of disciplinary areas and has been shown to promote the learning of other skills, such as mathematics and social sciences. This relevance has fostered the emergence of initiatives that seek to promote autonomous self-learning of computational thinking from the first educational levels. The main feature of these proposals is the simplification of computational concepts and the gamification of interfaces or activities. However, there is a lack of characterization of the commitment and effort on the part of the students towards gamified and non-gamified environments. This study has shown that the same group of students exhibit significantly different behaviors when confronted with computer problem-solving interfaces through block programming, depending on the inclusion/exclusion of gamification. In particular, a greater level of commitment among the students has been appreciated when solving the challenges in the gamified interface and, in addition, higher levels of effectiveness. While in the non-gamified interface higher levels of reflection were observed. Consequently, the design of teaching practices that combine gamified and non-gamified environments could contribute to an acquisition with higher levels of computational thinking produce.

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