A Comparative Study of Gamification in Progamming Education in a Croatian High School

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***Abstract*— During the European Code Week event in 2019. a comparative study on using a gamification platform (namely CodeCombat) for programming education was conducted in 4 distinct 1st and 2nd grade classes (8 groups of students). The groups were from three distinct study programmes: computer technician, economist and car mechanic. With each group two surveys have been conducted one on self-assessment (before using a gamification platform) and one on self-evaluation (after using the gamification platform) in order to answer three simple questions: (1) what is the perception of students on the importance of programming knowledge and skills in everyday life (before and after using the platform), (2) did the students perceive that their knowledge and skills have been improved during the lesson (if yes, how much), and (3) did their motivation to learn programming increase due to using gamification? A total of 79 responses has been collected and the analysis of the results show that there is an increase in motivation for learning programming for the economist study programme, a decrease of motivation for the car mechanic study programme and an indifference in motivation for the computer technician study programme.**

Keywords*— *gamification, codeweek, code combat, survey, motivation, high school, programming, education

I. Introduction

The term gamfication, which has raised major interest from both academia and industry is usually defined as "*the use of game design elements in nongame contexts*" [6], [5]. Gamification in the most broadest sense is often a successful method for fostering motivation among people, supporting user engagement and enhancing positive behavioral patterns on various services like increase of activity, quality of work, socialization and hence productivity [4].

One of the most interesting applicative fields of gamification, often with promising results is of course education as numerous studies have shown [1], [2], [7], [3]. Due to the nature of gamification, especially from a videogaming perspective, computer science educators on all levels of formal education were often the first to adopt gamification processes into their lectures and the field of programming education has been very fruitful as shown in various studies (i.e. [8], [9], [10] and others).

Fig. 1: Screenshot of the CodeCombat gamification platform (student's view)

The European CodeWeek which is "*a grassroots initiative which aims to bring coding and digital literacy to everybody in a fun and engaging way*" [11] which has been held from October 6th to 20th 2019 and had 4.2 million participants and more than 72,000 activities from 80 countries from all over the world. One of these activities has been held in a Croatian high school with the objective to use gamification as a facilitator to educate various levels of high school students in programming. The event was organizied due to a previous success of using gamification (see [12] for details). In particular the gamification platform CodeCombat (available at https://codecombat.com/) shown on figure 1 was used.

From a game genre perspective CodeCombat is a dungeon crawler game in which a player has to navigate through a dungeon by avoiding enemies and traps, collecting items like keys and similar in order to advance through the game. The twist to education is that the player character has to be navigated using programming code as can be seen on figure 2. In the current version the Python and JavaScript programming languages are supported. We have chosen to use Python since it is a common choice for teaching programming in Croatian schools. Each level usually introduces some core programming concepts like basic syntax, function arguments,

strings, understanding of documentation, loops etc.

Due to the fact that CodeWeek has been targeted towards all kinds of students regardless of age, educational background or even learning programme, we have chosen to conduct the activity in four distinct 1st and 2nd grade high school classes in which 8 groups of students have participated. We have conducted two surveys and have analyzed the results achieved by the students during this activity.

In this paper we would like to report on this activity by firstly introducing the methodology in section II. Afterwards we shall present the obtained results and provide a brief discussion on findings in section III. In the end we draw our conclusions in section IV.

II. Methodology

The coding activity was devided into three disting parts: (1) a survey on self-assessment (before using a gamification platform), (2) using the gamification platform to solve as much levels as possible, (3) a survey on self-evaluation (after using the gamification platform). The two surveys were quite similar in order to allow us to compare the results before and after using the gamification platform. Students had to answer three simple questions: (1) what is their perception on the importance of programming knowledge and skills in everyday life, (2) did they perceive that their knowledge and skills have been improved during the lesson (if yes, how much), and (3) did their motivation to learn programming increase due to using gamification? The questions had to be answered on a scale of 1 (not at all) to 5 (a lot). Additionally, in the second survey an open-ended question was added: Name one useful thing you have learned during the lecture. The surveys were anonymous and were conducted using an on-line surveying tool.

The activity has been conducted with 8 groups of students: two groups of first grade car mechanics, two groups of first grade economists, two groups of secon grade economists and two groups of second grade computer technicians. For each group the students were instructed to firstly fill out the first survey. Afterwards they were instructed to open the CodeCombat platform (a special class inside CodeCombat has been created for each group) and try to solve as many levels as possible with and additional motivation that students who score best shall be awarded. The students had a total of 30 minutes to solve levels after which they were instructed to fill out the second survey.

III. Results & Discussion

A total of 79 responses for each survey as well as 79 playing results have been acquired during the activity. In the following we will present a short analysis of results. In table I a comparison of answers to the question regarding motivation to learn programming before using the gamification platform and after using it. The abbreviations are defined as follows: 1CM - first grade car mechanic, 1EC - first grade economist, 2EC - second grade economist, 2CT - second grade computer technician, 1 - first grade student, 2 - second grade student and EC - economist student.

TABLE I: Statistical analysis of motivation to learn programming

		Before		After		
	n	$\overline{x}_B$	σ_B	$\overline{x}_A$	σ_A	$\overline{x}_B - \overline{x}_A$
1CM	21	3.29	1.19	2.90	1.67	-0.38
1EC	19	3.05	1.31	3.11	1.45	0.05
2EC	16	2.88	1.36	3.13	1.26	0.25
2CT	23	4.04	1.07	4.09	1.12	0.04
1	40	3.18	1.24	3.00	1.55	-0.18
2	39	3.56	1.31	3.69	1.26	0.13
EC	35	2.97	1.32	3.11	1.35	0.14

If we compare the results one can see that there is an increase in motivation for learning programming for the economist study programme (the first grade students show an indifference, whilst the second grade students show an increase in motivation), a decrease of motivation for the car mechanic study programme and an indifference in motivation for the computer technician study programme.

These results are intriguing since as it comes out, just by using a (very interesting) gamification platform, perceived motivation to learn programming does not increase automatically, but seems to depend on age and previous knowledge. First grade students seem to have a lower motivation in learning then their older peers, but this assumption has to be tested with comparable groups. Car mechanic student, which have the least previous knowledge in programming and computer science in general lost their motivation after using the gamification platform. This might be the case due to frustration since additional knowledge would be required to actually start understanding the concepts and techniques covered in the platforms tasks.

On the other hand, while first grade economist students have shown indifference in regard to motivation, their second grade peers have shown an increase in motivation after using the platform. This might be since they have a bit more knowledge about programming, having covered some programming fundamentals in the first grade, but still not enough to do something useful. The gamification platform seemed to provide an application domain for their knowledge and motivated them to learn further.

The hypothesis of usefulness might also explain the indifference of computer technician students - the knowledge provided by the gamification platform is something they have already, more or less, internalized in their previous studies, so even if the platform is interesting and funny, it isn't useful enough to motivate them to study further.

In table II the perceived knowledge of programming before and after using the gamification platform is analyzed. As one can see from the table, all groups of students perceive that their knowledge has increased after using the gamification platform.

It is interesting to note, however, that first grade students have a very similar level of perceived knowledge increase regardless of study programme, whilst their second grade peers have quite a different perspective. The second grade economist

Fig. 2: Example task in CodeCombat

TABLE II: Statistical analysis of perceived knowledge in programming

	Before		After		
	$\overline{x}_B$	σ_B	$\overline{x}_A$	σ_A	$\overline{x}_B - \overline{x}_A$
1CM	2.19	1.08	2.81	1.44	0.62
1EC	2.53	1.12	3.16	1.07	0.63
2EC	2.00	1.21	2.88	1.20	0.88
2CT	2.83	0.83	3.13	0.97	0.30

students perceived that they have learned more then the computer technician students. This might be since second grade computer technician students have already learned some of the basic concepts used in CodeCombat's initial lessons, whilst economist students have not. Also, it is worth mentioning that second grade computer technician students perceived they have learned the least of all other groups of students.

TABLE III: Keyword analysis in open-ended question

Keyword	Comments
programming	23
algorithms	11
nothing	9
playing games	9
logic thinking	2

It might be useful to review what students have perceived to have learned during the lesson. In table III a summary of keywords used by students in the open-ended question, dealing with useful things learned is provided. As one can see from the table, most students have answered that they

TABLE IV: Statistical analysis of performance

	Levels		Concepts	
	$\overline{x}_L$	σ_L	$\overline{x}_C$	σ_C
1CM	5.55	2.06	3.09	1.11
1EC	5.58	1.87	3.05	1.13
2EC	7.00	2.14	3.80	0.77
2CT	8.61	2.98	4.26	0.92

have learned some aspects of programming (programming, algorithms, logic thinking), but, on the other hand, there were quite a number of students which answered that they have not learned anything (a total of 9 students). This indicates that gamification does not always provide the necessary motivation for any student. Additionally, also 9 students have answered that they had learned to play games, not perceiving that the game was only a method of delivering programming knowledge. This can be interpreted twofold: (1) from a negativist perspective, students do not perceive a gamified programming environment as serious enough to learn anything useful, or (2) from a positivist perspective, students are not aware that they have learned very useful knowledge since it was as simple as a game for them.

In the following the performance of students during their use of the platform is analyzed. Table IV shows a comparison of student groups in regard to numbers of levels solved and numbers of programming concepts internalized.

As one can see from the table, the computer technician student had performed best, as one would expect. It is interesting to observe that both groups of first grade students,

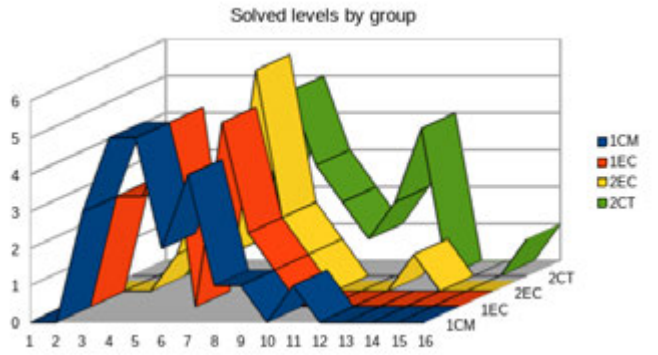

Fig. 3: Solved levels by student group and number of students which have solved the given level

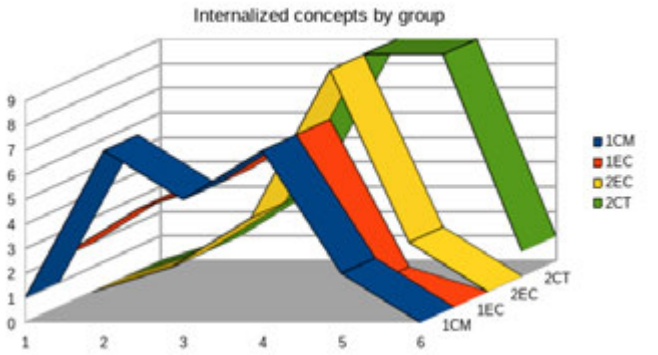

Fig. 4: Internalized concepts by student group and number of students which have internalized the given number of concepts

regardless of study programme performed equally well – there is almost no difference in their results in both number of solved levels and number of covered concepts. Since the study was conducted during the start of the school year it seems that both groups of students had on average a similarly well preexisting knowledge in computer science and programming coming from their primary education. It would be beneficial to repeat the study with first grade computer technician students and compare the results to see if there would be any significant difference.

It is also interesting to note that second grade economist student outperformed their first grade peers significantly, almost as mush as computer technician students outperformed them.

Figure 3 gives a side-by-side comparison of student groups in regard to solved levels. The best of all students (a computer technician) was able to solve 16 levels. The best of all second grade economist students was able to solve 13 levels. A first grade car mechanic student was able to solve 11 levels whilst the best first grade economist student was able to solve 9 levels. One can observe visually that most students in all study programmes have solved between 3 and 7 levels. What differentiates computer technician students from the other groups is that they have a number of above average students which has shifted their distribution to the right.

Figure 4 shows a similar side-by-side comparison, but this time in regard to internalized concepts. As one can see from the figure, only one student (again a computer technician) was able to internalize 6 concepts. The distribution of car mechanic students is shifted to the left since quite a number of students internalized only 2 or 3 concepts. On the contrary the distribution of computer technician students is shifted to the right due to a number of more advanced students. The distributions of both first and second grade economic students are very similar, but the distribution of first grade students is flatter indicating on average worse results.

IV. Conclusion

In this paper we have reported on a comparative study in programming education which was conducted as an activity of the European Code Week 2019. in a Croatian high-school. We have conduced two surveys and a gamification platform activity for four distinct groups of first and second grade students in which 79 students have participated. The surveys were aimed upon studying the impact of gamification on the motivation of students to learn programming.

The results have shown that gamification is not a "*silver bullet*" and just by introducing it into the classroom does not necessarily increase students motivation to learn a complicated topic like programming. As we have discussed, the benefits of gamification come only to light if the lessons are being perceived useful by the students and if the students have adequate preexisting knowledge to understand the topics being covered. Namely, car mechanic students, which had the least background in computer science perceived a loss of motivation to learn programming. Economist students had a slight increase in motivation, especially second grade students. Computer technician students have shown an indifference in motivation before and after using the gamification platform, which might be due to the fact that they are already motivated to learn programming since they chose the study programme but also due to the fact that the lessons did not provide them with much additional knowledge in regard to their existing skills.

An interesting observation was that first grade students had very similar results when using the gamification platform regardless of their particular study programme. Since only car mechanic and economist students in the first grade participated in the activity, a future study should be conducted that shall also include first grade computer technicians to see if there will be any significant difference in results.

Nevertheless, all groups of students perceived that their knowledge in programming has increased, and we believe that by tailoring the lessons and activities to be aligned with the particular study programmes that the results would have been even better.

Our future research will be aimed towards more profound studies of gamification effects over longer periods of time.

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