Learning by Playing and Learning by Making

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Learning by Playing and Learning by Making

Barbara Garneli[1], Michail N. Giannakos[2], Konstantinos Chorianopoulos[1], and Letizia Jaccheri[2]

[1] Ionian University, Corfu, Greece
bgarnelisch@gmail.com, choko@ionio.gr
[2] Norwegian University of Science and Technology (NTNU), Trondheim, Norway
{michailg,letizia}@idi.ntnu.no

Abstract. Serious video games have been proposed as a means to engage students with the Science, Technology, Engineering, Mathematics (STEM) curriculum, but there is limited research on the required game elements and teaching practices. In particular, there is limited evidence on the effects of the storytelling element and of student involvement in making games on the learning performance and on the attitudes of the students. For this purpose, we designed a between groups experiment with eighty students (12 to 13 years old). They formed three equivalent groups of twenty students each who practiced with a serious game in three different ways. The first group played the storytelling game, the second played the same game but with no story, and the third was engaged with modifying the game code. Finally, the last (control) group practiced traditionally by solving exercises on paper. We found that girls with low grades benefited the most by playing the game and by engaging with the code and that the game making group wishes to repeat the exercise. Further research should perform similar studies with a focus on involving students in serious game modification, over longer periods of time and for additional curriculum topics.

Keywords: Serious game, programming environment, behaviorism, constructivism, storytelling element, code engagement, CS education.

1 Introduction

In this research, we are exploring the performance and preference of students for alternative learning styles. A fundamental principle of effective learning is that all students learn if the appropriate personalized conditions are given to them [14]. Research into multiple learning styles confirms that students learn with many different ways [11] [16]. This perspective is crucial for all students and especially to those with fewer opportunities or lower performance to standard tests. Serious games have been proposed as a means to engage students with Science, Technology, Engineering and Mathematics (STEM) curriculum. However, limited research has been conducted on effectiveness of serious game elements and teaching practices. Moreover, there is no evidence of the effect of students' involvement in the process of game making on their learning performance and attitudes.

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The purpose of this empirical investigation is to measure students' performance and attitudes and to *identify potential differences among the diverse ways of serious games usage*. Our work is expected to contribute to the understanding of how students' performance and attitudes are connected with the serious games application in the educational context.

2 Related Work and Research Hypothesis

Behaviorism is a basic theory in the research of educational media and especially video games. According this perspective, learning is a matter of reinforcing the relevant stimuli and response. Thorndike and Hagen [17] provided the behaviorism theoretical background: Repetition is important to learning especially for skills like writing, reading or arithmetic. Also it is possible to strengthen a response by providing a reward after it. In the past, Skinner [15] created a drill and practice machine according to these characteristics. Modern behaviorist software, especially video games use repetition and rewards widely. The critique of these titles refers to the automatic repetition and the extrinsic motivation [5]. Therefore, our first hypothesis is that *the involvement with a serious math game has a positive effect on students' performance* (H1).

The use of educational games can be effective only if elements like goals, competition, challenges, fantasy influence motivation and facilitate learning. Motivation refers to the initiation, the intensity and the persistence of behavior. Nevertheless, students are not always highly motivated. Previous research has claimed that a game's story can motivate students to use an educational game [3]. In order to achieve better results, the story must be interesting for both, boys and girls and according their age as well as the school context [4]. Hence, we hypothesize that math *game with story can significantly improve students' performance (H2).*

The idea of making games for learning instead of playing games for learning is one of the fundamentals of Constructivism. The design or making of digital games in learning activities has been linked to teaching of new STEM literacy skills [2]. One common inspiration is the work of Papert and Harel [12] that stresses the importance of creating a 'felicitous' environment to facilitate learning. The idea here is that students benefits from being happy and in a carefree and creative settings. There are studies [5] supporting that learning by making is harder but it gives more substantial results. From this perspective we assume that *students' engagement with the video game code improve their performance (H3).*

Moreover, introductory programming is supported by computer science educators in order to make programming easier and more interesting. The most popular approaches are based on Visual Programming Languages, such as Logo, Scratch, and Alice. Their aim is to provide accessible graphical interfaces for code construction and program display [13]. Thus, our fourth hypothesis is that *students' engagements with the game via* visual environments (e.g., Scratch) significantly motivate students to engage in programming (significantly influence their Behavioral Intention) (H4).

Finally, we explored potential differences between boys and girls to the above assumptions [9]. In the following section we will describe the methods we use in the reported research.

3 Methodology

3.1 Materials

In this research, we examine the effect of serious games elements on learning performance and attitudes. For this purpose, we used the Scratch programming environment[1]. We employed the math Gem Game[2], which consists of three levels that refer to the addition and subtraction of positive and negative numbers. The first level includes addition and subtraction of positive numbers; the second is concerned with the addition and subtraction of negative numbers and the third with both operations with integers. The main character (Peter) moves up or down dependent on the number entered by the player in the text box. In addition to the three platform-like video-game levels, there is also a story (Fig. 1), which assigns a mission to the hero. Additionally, we made another version without the story (Fig. 2).

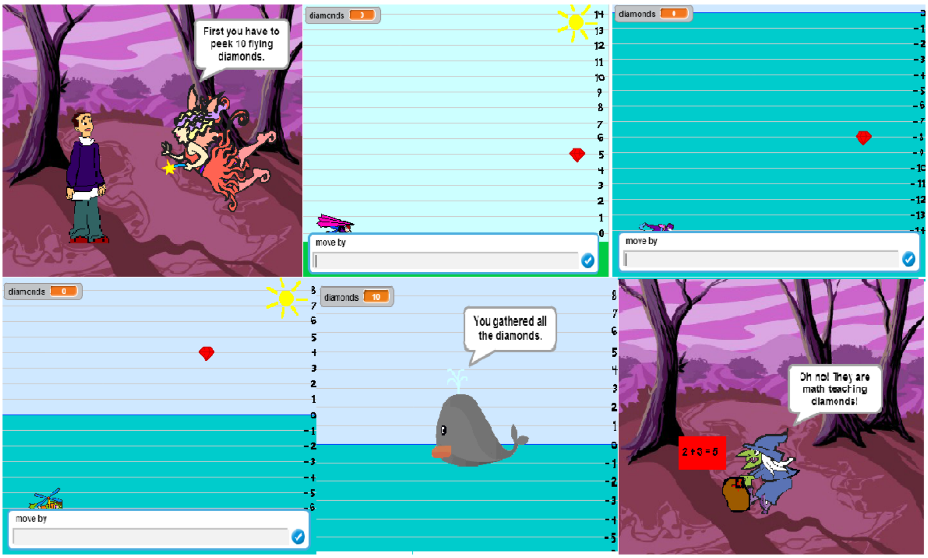

Fig. 1. Story and Practice with the Gem Game

[1] http://scratch.mit.edu/

[2] We employed the most recent version of the game http://scratch.mit.edu/projects/10181336/

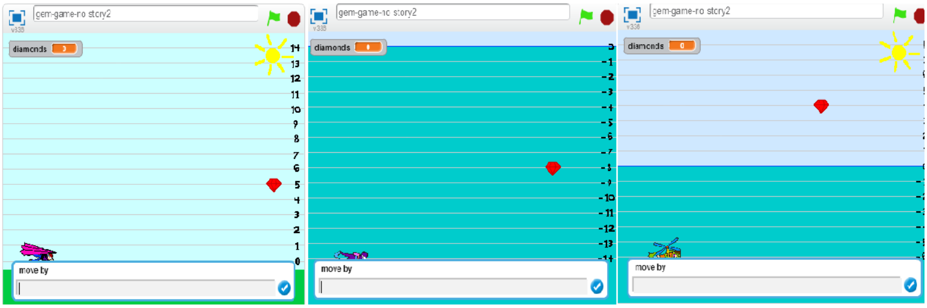

Fig. 2. Gem Game without story

3.2 Subjects and Experiment Design

We performed a between groups experiment with eighty students, fifty-three boys and twenty-seven girls (12 to 13 years old). All the students who participated in the experiment attended the first grade of junior high school. They formed four equivalent (age, gender, average grades) groups of twenty students each who practiced with the math game in three different ways. The first group played the storytelling game, the second played the same game but without the story, and the third was engaged with changing the game code. The last group (control) practiced traditionally by solving exercises on paper.

Fig. 3. Altering the avatar of the fairy in the Gem Game

The empirical study was conducted in the context of secondary education. The school curriculum consisted of the respective math unit and the use of a programming environment, which are part of the first grade's curriculum. The research conducted two weeks after students had finished the relevant math unit at school. Additionally, they used the scratch environment to play games for one hour in order to be familiarized with it as well as with the use of video games. The research lasted a week period in January 2013 and was conducted at school as a part of the normal teaching procedure.

3.3 Measuring Instruments

We employed a pre-test to examine the students' performance and a post-test to assess their improvement. We also prepared thirty exercises on paper for the practice of the control group. Instructions for altering the game code were used for the last group. Moreover, we employed a questionnaire (5-point Likert scale from strongly disagree to strongly agree) that measures students' attitudes such as expectation of improvement, concentration, immersion, intention to re-attend in the future and intention to study programming (Table 1).

Table 1. Attitude towards ICT education questionnaire

Factors	Questions	Source
Expected Performance Improvement	Was the activity useful for your math? Do you believe that this activity improved your math skills? Did you become more effective in math? Do you believe that your performance is better?	[8]
Behavioral Intention	Do you intend to repeat this activity? Do you think that this activity must be part of the normal teaching procedure? Do you wish that this practice will be continued in the future?	[8]
Immersion	Do you forget the time as long as you are practicing? Do you bother for what is happening around as long as you are practicing? Do you forget the problems you have during your practice?	[6]
Concentration	There is nothing that can disturb you from finishing this activity Generally, you were concentrated during this practice You‘ve skipped some activities of this practice	[6]
Programming Intention	Are you interesting in learning programming? Do you intend to keep learning programming? Do you intend to study programming regularly?	[7]

In the end, we prepared questions for a semi-structured interview by some students regarding their motivations with the respective teaching practice and their opinion on STEM topics. These data provided a vehicle in order to interpret and validate the results in the Discussion and Conclusions section.

3.4 Procedure

Firstly, the students were informed that they'll practice in the certain unit of mathematics and they completed the pre-test. Afterwards, they practiced according to the treatment groups they belonged to (story, no-story, make game, control). At the end of the practice, the control team was informed about the correct answers of the test in order to make the procedure similar to the rest of the treatments who received immediate feedback due to the interactive nature of the game. Additionally, the team that was engaged with the code altering received instructions about the changes to the heroes of the story and the dialogue between them. The proposed activities children involved with concerned the fairy of the game that gave instructions to the hero in order to achieve his goal. The participants changed the costume of the fairy and of the dialogue according to their own preferences, so it had nothing to do with the actual math unit. After the end of the practice, all the teams completed the post test and the questionnaire. Finally, a semi-structured interview was conducted.

3.5 Results

We used quantitative method to analyze the results from the surveys and the performance tests. First an analysis was made in order to check the equivalence of the four groups using data from the pre test. The one way Analysis of Variances (ANOVA) ($F(76) = 0.742$ and $p = 0.530$) test was applied on them and the results show that there is no statistical significant difference in the performance of the four groups.

In order to measure the performance's improvement, a paired samples t – test was applied using data from the pre and the post-tests (table 2).

Table 2. Performance's improvement (paired samples t – test)

Team [Hypothesis]	T(19)	P	Average (pre test)	S.D. (pre test)	Average (post test)	S.D. (post test)
Practice with the gem game (story) [H1]	-0.815	0.425	10.20	2.218	10.45	2.012
Practice with gem game (no story) [H2]	-0.261	0.797	9.15	2.231	9.25	2.314
Practice with the gem game (code engaged) [H3]	2.604	**0.017***	9.80	2.546	9.25	2.403
Traditional practice	-1.553	0.137	9.9	2.269	10.55	1.820

* at 0.05 level of significance

According the table 2, there is no improvement in the performance of the four groups. The students who not only played the gem game but were engaged with the game code had worse results in the post test.

Additionally, the ANOVA test was applied to compare the performance's improvement between the four groups ($F(76) = 4.907$ and $p = 0.038$). The results showed evidence for difference in the performance improvement. In order to detect the students' characteristics who had this attitude the ANOVA test was applied again on the four groups with different ways: for those kids who had made more than two mistakes in their pre test's answers and separately for boys and girls. After the analysis of the results, we found out that the girls with lower performance in the pre test had better results by traditional practicing (Table 3).

Table 3. Performance's improvement between groups (ANOVA test)

Factor	Teams	F	Significance
Performance between teams for girls with lower performance	Traditional practice > Practice with the gem game (with story)	4.91	• **0.041***
	Practice with the gem game (engaged with the code)	4.91	• **0.049***

* at 0.05 level of significance

Afterwards, we carried out an analysis of the reliability of the scales used in the survey. Regarding the reliability of the scales, Cronbach`s α indicators was applied and the results of the Cronbach's test were Expected Performance Improvement (0.906), Intention Behavior (0.755), Immersion (0.867), Concentration (0.594) and Intention for Programming (0.941). After removing the 3rd question for the concentration, the Cronbach's α indicator changed to (0.720). So, all the factors show acceptable indices of internal consistency.

Finally, ANOVA ($F(76) = 4.352$; $p = 0.007$) test was applied to the scale's medians of the questionnaire. The intention to repeat the practice (Behavioral Intention) exhibits significant difference among the traditional group and the engaged with the code one and insignificant difference among the traditional group and Learning by Playing one. The activities that included engagement with the code, or playing without story had better results than the practice on paper (Table 4).

Table 4. Intention to repeat the practice

Factor	Teams [Hypothesis]	F	Significance
Behavioral Intention	Traditional practice < Practice with the gem game (engaged with the code) [H4]	4.352	**0.005****

** at 0.005 level of significance

The intention to learn programming by the team that changed the game code was very big (73%) and there was no significant difference between boys and girls.

According our findings, low performance girls improved more by the traditional way than by playing the game with any way. The use of a serious game seems to be useful for those boys who do not really like the usual instruction processes. The storytelling element in an educational game does not seem to affect the improvement of students' performance and it might be negative in their intention to repeat the practice. Finally, students who changed the game code did not improve their performance in the math post-test. But they would strongly prefer the repetition of this learning process in the future instead of practicing on paper. Also their intention to learn programming in the future was increased. The most important dependent variable in the serious game context seems to be the attitude of the students and in particular, their feelings of engagement and fun with the activity.

Most of the students who answered the Semi structured interview were familiar to the video games use and they were very anxious to participate to this activity which was amusing and ease. Additionally, this activity made mathematics as well as the educational software use in the learning process more interesting to them. Finally, we triangulate our findings with a content analysis of the qualitative data extracted from the interviews.

4 Discussion

Our findings might facilitate teachers in the preparation of interesting learning tools and activities that are personalized to individual learning styles. Firstly, we found that low performance girls improved more by the traditional way than by playing the game. On the other hand we found no significant difference in boys' improvement that used the different practice modes. This may be observed due to the less time girls spend playing video games and their different preferences [9]. The use of a serious game seems to be useful for those boys who do not really like the usual instruction processes.

Findings also indicate that the storytelling element in an educational game does not seem to affect the improvement of students' performance. Moreover, students who practiced themselves without storytelling prefer to replay the game rather than working in the traditional way. One explanation is that the plot and the story can be effective only if it keeps evolving [3]. Otherwise the storytelling element might have negative influence on the repetition of the practice.

We found that students who changed the game code did not improve their performance in the math post-test. Nevertheless, the students would strongly prefer the repetition of this learning activity instead of practicing on paper. Indeed, teaching programming by making an action game is more effective in comparison to the traditional teaching [1]. Also their intention to learn programming in the future was increased. The lower performance results of this group might be explained by the fact that the making activity did not have any connection with the math unit. Therefore, further research should engage the students with code that is closely connected to the respective curriculum topic.

Moreover, it appears that the forty-five minutes teaching period is inadequate in order to improve pupils' performance in whatever way they practice. This confirms the importance of duration and repetition in the learning process [15]. Reliability could improve if the children's practice had been repeated several times. Thus, the most important dependent variable in the serious game context is the attitude of the students and in particular, their feelings of engagement and fun with the activity.

Based on our observations and interviews, when students were informed that they would practice in mathematics with an educational game, they became very excited. In contrast, the students that solved exercises on paper appeared to be less relaxed. All students were concentrated and they completed their practice quite quickly. Students who played the game liked the activity but some of them did not want to repeat it. They even asked if they could play another game. On the other hand the students that engaged with the game code wanted to keep refining the code.

It is also necessary to consider some limitations to the above findings. We have evaluated the performance of the alternative learning styles by employing a paper-based test, which is biased towards the students who employed paper-based training. Therefore, we suggest that the lack of differences in the learning performance of students might be more an effect of the assessment medium than an effect of the learning treatment. For example, students who trained with the math video game should have been also post-tested with the same math video game.

5 Conclusion and Further Research

In this work, we studied the effect of a math-game during the learning process. In addition of playing the serious game in two different versions (with and without story), students' had the chance to get engaged with the game code by altering its scenario in the Scratch environment. Our findings suggest that some types of students could benefit by alternative pedagogic techniques such as serious games. We found that serious games are beneficial for those who are not motivated by the traditional teaching practice. Moreover, the game making activity could be an effective and amusing learning style that requires further study. Testing different teaching techniques is very useful in order to motivate students and especial those with lower performance. Overall, it is important to use a variety of teaching tools and practices beyond the traditional teaching in order to facilitate the full spectrum of learning styles. Further research should perform similar studies over longer periods of time and for additional curriculum topics in order to be able to provide the overall picture of the effect of students' involvement in the process of making games and guide educators to use more teaching tools in a more effective way in order to assist students to achieve learning in a meaningful and creative way.

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