Exploring the Importance of "Making" in an Educational Game Design

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Abstract. Educational games have been employed in many settings as a means to engage young students. Different genres and applications of games have been used to improve learning experience. The design or making of games in learning activities has been linked to teaching of new skills. Within this paper we explore and discuss the differences of involving young students into the game design and development process compared to just playing an educational game. In particular, we designed an educational math-game and an activity that involves children in playing or modifying the game, and we performed a between groups experiment with sixty students of the second grade of middle school (12 to 13 years old). Students formed three equivalent groups of twenty. The first group played the game, the second engaged with re-designing and modifying the game and the third (control) group solved the same exercises (with the educational game) on paper. The results showed that the making group exhibits certain attitudinal benefits. Hence, our findings suggest that learning through games should include more than just playing a well-designed game, it should also consider the involvement of students with various "making" affordances.

Keywords: Interaction design; empirical evaluation; serious games; learning; design principles.

1 Introduction

Contemporary research on interaction design for learning has focused mainly on the usability of the technology enhanced learning systems. Our thesis is that any learning environment (formal or informal) requires a consideration also for qualitative aspects, such as engagement and enjoyment. Ongoing research on game-based learning has focused on the evaluation of a teacher-led pedagogy. In this work, we suggest that a learning environment would benefit by considering educational games as a new medium for creative pedagogy and not only as a teacher-led tool or tool for just practicing. For example, teenagers have been reported to engage highly with malleable virtual environments, such as Minecraft, Little Big Planet 2, Roblox, Disney Infinity, and others; all supporting game making/modification as a core play mechanic.

K. Chorianopoulos et al. (Eds.): ICEC 2015, LNCS 9353, pp. 367–374, 2015.
DOI: 10.1007/978-3-319-24589-8_28

In this work, we explore students experience with designing and developing an educational game. A fundamental principle of meaningful education is that all students can learn if the appropriate personalized conditions are given to them [12]. Research into multiple learning styles confirms that students learn in many different ways [14]. This perspective is crucial for all students and especially to those with fewer opportunities or lower performance to standard tests. Educational games have been proposed as a means to engage students. However, limited research has been conducted on the potential of students' involvement in the process of game making.

Our methodology is user-centered and considers the elaborate design and evaluation of an educational game. First, in collaboration with math and computer science teachers, we designed and developed a math game. Then, we investigated the impact of the making aspect on students' experience. The math-game is named "Gem-Game" and it is targeted to students that attend first and second class of middle school (12-13 years old).

After students' involvement with the respective process (playing, making, traditional learning), we used attitudinal surveys to measure their engagement. In addition, we performed some interviews in order to gather (qualitative) information on their motivation and their opinion regarding the respective instruction method and the content. We used quantitative method to analyze the results from the surveys and we triangulate our findings with the qualitative data extracted from the interviews.

2 Background and Research Questions

The use of educational games can be effective only if elements like goals, competition, challenges, fantasy and motivation are employed to facilitate learning. Young students are not always motivated to play an educational game. But certain design principles have been found to be extremely important on increasing students' motivation and interest to play an educational game [1].

A variety of environments have been developed by researchers to introduce game making concepts to children. Popular visual programming environments include Scratch [10] Alice and Storytelling Alice [8]. The idea of making games for learning instead of playing games to learn is one of the fundamentals of Constructionism. The design or making of games in learning activities has been linked to teaching of new STEM literacy skills [3, 4]. One common inspiration is the work of Papert and Harel [9] that stresses the importance of creating a 'felicitous' environment to facilitate learning. There are studies (e.g. [5]) supporting that learning by making is harder but it gives more substantial results.

As aforementioned, from a constructionist perspective, there are theoretical reasons for believing that making games can be educationally beneficial: Kafai, [6, 7] has argued that when making games, learners also construct knowledge and their relationship to it; "The learner is involved in all the design decisions and begins to develop technological fluency. Just as fluency in language means much more than knowing facts about the language, technological fluency involves not only knowing how to use new technological tools but also knowing how to make things of significance with those tools and most important, develop new ways of thinking based on use of those tools" ([6], p. 39). As technology has moved on opportunities have also arisen to develop new making pedagogies.

This work centers on investigating the impact of making pedagogy (e.g., modifying a serious game) on students engagement during the learning process.

3 Methodology

3.1 Gem-Game and Procedures

The main purpose of Gem-Game is to improve the mathematical skills of players/learners. The main character moves up or down dependent on the operation executed by the player (figure 1). So students also get a spatial idea of upwards movement when adding and downwards movement when subtracting. The final objective of the player is to retrieve his dog by collecting diamonds. To achieve this goal, the player must go through three different levels.

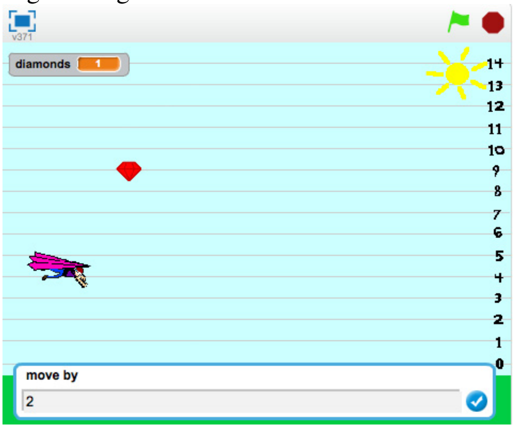

Fig. 1. Screenshot of the Gem-Game

In particular, the player must correctly add/subtract in order to reach each diamond that scrolls horizontally from right to left. For example, if the player is positioned on line 6, and the diamond is on line 1, the player must write -5 in order to reach the diamond. Notably, if the player makes a mistake, it is a constructive one, because the player can continue by typing a correction from the new position.

In addition to a group that played with Gem-Game serious game (experimental group 1), another group followed a more traditional paper-based pedagogy (control group). We also employed a third group (experimental group 2) in order to evaluate the effects of making pedagogy. Hence, students of the third group had the chance to get engaged with the game code by altering its scenario in the Scratch environment. In particular, students were involved with changing the fairy of the game, who helped the hero to achieve his goal. The participants changed the costume of the fairy and fit the dialogue properly and according their own preferences (e.g., see figure 2 next page).

Fig. 2. Example of how students altered the game scenario in the scratch environment

3.2 Sampling

The between groups experiment was consisted of sixty students, forty boys and twenty girls (12 to 13 years old). All the students who participated in the experiment attended the first grade of middle school. They formed three equivalent (age, gender, average grades) groups of twenty students; two of the groups were practiced with the math game (with a different way) and one (control) practiced traditionally by solving exercises on paper.

3.3 Measures

A wide range of data was collected to address our research question including surveys, short interviews and observations. During most of the sessions, one of the researchers/teachers was present to assist and observe the students. Regarding the quantitative data, we employed a questionnaire (5-point Likert scale from strongly disagree to strongly agree) that measures students' attitudes of immersion with the game and their intention to participate in the game. Table 1 lists the questionnaire items used to measure each factor and the source adapted from the literature.

We also conducted semi-structured interview with some students, these interviews focused on their motivations with the respective teaching practice and their opinion for mathematics and computing topics.

3.4 Statistical Analysis

First, we checked the validity of the questions used in the survey. Cronbach`s α was found to be greater than 0.7 on both constructs. Next, we evaluated the reliability of the questions. The reliability of a question was assessed by measuring its factor loading onto the underlying construct. The factor analysis identified two distinct constructs: 1) Immersion (IMM); and 2) Intention to Participate (ItP); with factor loadings of the questions/items being greater than 0.7.

Table 1. Constructs and questions used, adopted from [1, 2].

Constructs	Questions Used
Intention to Participate* (ItP)	• 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?
Immersion* (IMM)	• 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?

**mean values of the questions were used for the analysis*

To examine our research question regarding game making impact of students' experience, we conducted between groups t-test. We used three independent variables (playing, making, control) and two dependent variables (ItP, IMM). All statistical analyses reported were conducted with a significant level of 0.05.

4 Results

Based on the empirical results illustrated in Table 2, making pedagogy indicates a significant effect on students' intention to participate (ItP) in the learning activity. On the other hand, there is no significant effect on students' sense of immersion (IMM).

Table 2. Testing the effect of game play and game make on students' intention to participate and immersion with the process.

Con-structs	(I) Mean (S.D.)		(J) Control Group Mean (S.D.)	Mean Differ. (I-J)	Std. Error	Sig.
ItP	Playing Story Game Group	2.68 (1.22)	2.23 (1.10)	.450	.367	.615
	Making Game Group	3.35 (0.78)		**1.117**	**.301**	**.004***
IMM	Playing Story Game Group	2.58 (1.34)	2.32 (1.30)	.267	.417	.919
	Making Game Group	2.88 (1.26)		.567	.404	.507

***. The mean difference is significant at the 0.05 level.**

Although our findings are preliminary, and there is a clear need for more in-depth investigations; by observing figure 3 (next page), we notice that making pedagogy exhibits certain benefits compared to game based learning and traditional learning.

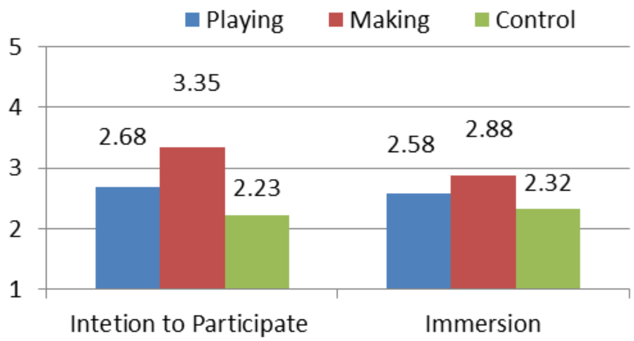

Fig. 3. Mean scores for intention to participate and immersion on each respective group

After the activity, students' participated in a semi-structured interview. Most of the students were familiar with playing an educational game; however students from the experimental groups were looking forward for the activity (since they were informed). At the end both experimental groups, found the activity amusing and easy.

During the semi-structured interviews with the students, the researcher guided the conversation in order to probe different aspects of students' motivation, attitudes and learning performance throughout the activity. In the conversations, students supported the idea of using video games at school. They were also positive on the possibility of introducing similar activities in other STEM courses (besides mathematics).

According to the informal data gathered from researcher's observations, students seemed enthusiastic with the game-play, particularly at the making group. Students' were experienced with many commercial games (e.g., Assassin's creed, league of legends) and they mentioned that although Gem-Game was simple, they found it very interesting with familiar game mechanics. As a result they did not get frustrated from the educational content, even at the very high and competitive levels (e.g., diamonds were moving faster). In particular, *the making group was more eager, with a very high intention to enroll on similar tasks in the future and plenty of ideas for further improvement of the game and the process*.

5 Conclusion and Discussion

In this work, we examined the importance of making affordances (e.g., modifying-extending a serious game) in students' engagement with an educational math-game. In addition to playing the math-game, students had the chance to get engaged with the game code by altering its scenario in the Scratch environment. Our findings suggest that students could benefit with the "making pedagogy" in gameplay. Thus, it is very important that we consider this issue and carefully examine how our educational game designs may address making affordances. From our early field studies we can support that the game making affordances could offer an enjoyable and engaging game-based learning process that requires further study.

Overall, it is important to use a variety of teaching tools and practices beyond the traditional (passive) 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; this will assist students to achieve learning in a meaningful and creative way.

Based on our observations and interviews, when students were informed that they would practice in mathematics with an educational game, they became very eager. In contrast, the students that solved exercises on paper appeared to be less excited. All students were concentrated and completed their activity quite fast. 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 and extending the game.

In summary our work in progress provides empirical evidence for the importance of the making aspect in an educational game design, however there are also certain limitations. First, the generalizability of the results must be carefully approached since the field study was conducted in a specific context (e.g., content, age). In addition, the introduction of other in-depth methods, such as video observations and log files analysis, will allow us to triangulate the results and have a complimentary picture of the findings. This will allow us to attain deeper understanding on how making affordances can be successfully employed in educational games design.

Further research should move across two paths: interaction design principles that transform curricula concepts into engaging serious games and pedagogy for interactive modification of serious games. The implications of this research concern the practice of both interaction designers and educators. Interaction design is needed in order to create engaging making mechanisms in games design and development, while educators need to consider pedagogies for employing serious games both as technological tool and a creative medium. Finally, in addition to interactions in learner-led pedagogy, further research should study the social interactions that happen between learners. Since education stands on a social science pillar, we suggest that the design of serious games should also consider their social embedding in everyday school and informal learning practices.

Acknowledgements. We would like to thank all the students and teachers for their participation during the game-design phase and the experiment.

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