Gamified Digital Math Lessons for Lower Primary School Students

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***Abstract*— This paper presents experiences in introducing gamification to digital lessons for students' mathematics learning in lower primary school. The study was conducted in a second and third grade primary school in Croatia where students (N=59) used tablet computers for a variety of gamified learning activities. Gamification algorithms and extensions were designed and integrated in digital lessons to improve young learners' motivation and engagement in math learning. This paper presents preliminary experiences in applying gamification in lower-primary school mathematics learning and further explores how the gamification strategy influenced the level of student learning interest. The results show that gamification allows students to sustain more interest compared to the non-gamified approach to learning with digital resources.**

Keywords*— *gamification, technology enhanced learning, primary school, mobile learning, interest

I. Introduction

In the broadest sense, gamification refer to "the use of game elements and game-design techniques in a non-game context" [1]. Another definition states that "gamification is using game-based mechanics, aesthetics, and game-thinking to engage people, motivate action, promote learning, and solve problems" [2]. Some examples of gamification include competitions and giveaways of consumer goods (e.g. collecting prize coupons or pictures from chocolates), frequent flyer and member benefit programs, and points and badges through social applications (e.g. Foursquare Swarm and Google Maps Local Guides).

Although gamification can be used in a variety of contexts, the focus of this paper is on the use of games and game elements to motivate and engage students in the learning process. In the field of education, gamification is used to create or improve interactivity, to foster engagement, to positively influence behavior, and to encourage learners to investigate and expand their knowledge [3]. Generally, researchers agree that gamification, if done appropriately, could be a powerful educational tool [4]. Prior research has shown that when compared to traditional educational methods, gamification can increase students' motivation and engagement [5].

This study is part of a mobile learning project called SCOLLAm, where a multiplatform scalable mobile learning platform has been designed and used in lower primary school context. The main aim of this study is to explore which gamified learning designs can be used to improve learning and encourage students to engage in a variety of mathematics tasks. As part of the project, self-contained customizable interactive web applications (referred to in the remainder of this paper as widgets), to be used in the existing school lessons deployed on tablet devices [6]. These widgets contain digital educational contents and are tailored for second and third grade primary school students, and implemented and tested in cooperation with elementary school from Zagreb, Croatia. A number of experiments were conducted, and usage data was logged and analyzed.

This paper is structured as follows: Section 2 provides an overview of research and recent advances in the field of gamification in education. Section 3 describes the study methodology, introduces the research context and participants, presents a short overview of the way digital lessons with gamification were implemented in the classroom and describes the gamification system design. Section 4 reports on the results of the gamified learning approach. Finally, Section 5 presents conclusions and gives an outlook of possible future work.

II. State of the Art

According to Werbach and Hunter[1], there are three main structural parts of the gamification process: game elements, game-design techniques, and a non-game context. When implementing game elements, most of the gamification setups include one or more common elements: points, badges and leaderboards (also known as "PBLs"). Points are used to keep player scores, give rewards, mutually compare two players or as a measure of distance a player has to surmount to reach a next game level. On the other hand, badges usually denote a particular achievement and are awarded when players achieves a certain goal, which is not necessarily linked to the number of points. Badges can be showcased to other players (e.g. via player homepage or published on a social networks). Leaderboards show a rank or position of a player, relative to other players in a game. Since they can have positive or negative motivational effects on players, leaderboards are often implemented and shown in a way that minimizes demotivation, e.g. showing only a part of a global list with 2-3 players who are ranked just above and below the user.

In recent years, a number of researchers used game elements in a variety of educational scenarios in order to improve student engagement and motivation, typically with a goal of increasing students' cognitive test performance. While some researchers

focused on experiments and implementation of gamification elements, like awarding points [7] or badges [8], the others explored if and in which conditions gamification becomes effective [4], [9], [10]. In a study that explores the attitudes of future primary school teachers about gamification [11], it found mostly positive reactions to the use of educational videogames in the classroom.

In accordance with these results, the research that conducted the experiment with badges on a group of 8th grade students in Brazil [10] showed that students who received more rewards (badges) improved engagement and performed better on tests. Buckley and Doyle [4] went a step further, and analyzed the nature of motivation the students had, concluding that the final results of gamification depend on whether students were intrinsically or extrinsically motivated. Similarly, Botički et al. [8] identified four groups of students according to their behavior in acquiring badges: Explorers, Badge Hunters, Sharers and Dodgers. Their study researched a general conclusion that badges are a good motivational tool, but only if the context in which they are applied is meaningful. In a blended learning experiment conducted by Tan and Hew [12], a group of postgraduate students attended a gamified course (including points, badges and leader board). The study showed that the gamified experimental group produced results of higher quality, and in the same time, all of the experimental students agreed that the course was highly motivating.

III. Methodology

A. Participants

The study participants were second and third grade elementary school students (7-8 years old). There were in total 3 classes (two second grade classes and one third grade class) with a total of 59 pupils, with each class having their own dedicated teacher for all subjects. Since these pupils were participated in prior experiments as part of the SCOLLAm mobile learning research project, they were familiar with the researchers, tablet computers and mobile applications (Figure 1).

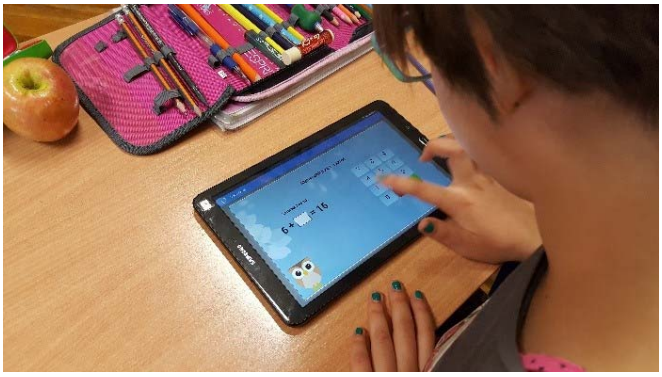

Figure 1 A student using a mathematics widgets as part of an in-school lesson

Members of the research team participated in class activities on a regular basis and conducted professional development sessions with the teachers. Prior to the implementation of the digital gamified lessons, researchers were observing and analyzing activities in the classroom, and came to the informed ideas on the digitalization of traditional lessons and later the introduction of gamification. Teachers were often found to propose their own ideas on how to improve the existing lessons with the use of simple mobile games or quizzes.

B. Tools and systems used

As a part of a SCOLLAm (Seamless and COLLAborative Mobile learning on tablet computers) project, a multiplatform mobile learning system for seamless and collaborative learning - SCOLLAm [in]Form [6] was developed. As a part of this system, a web-based lesson designer [in]Form Author, and a digital lesson player [in]Form Player applications were designed, allowing an easy creation of interactive multimedia-rich digital learning lessons, and their execution through the [in]Form system (Figure 2).

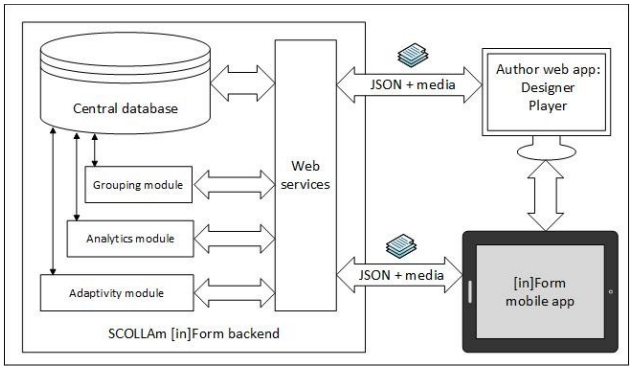

Figure 2 High-level overview of the SCOLLAm system architecture

The applications were written in JavaScript and the digital lessons are stored in a JSON format on a central cloud storage server. The authoring tool allows lesson designers to add and edit content slides, write text, insert images or video, and define custom actions to specific events, such as the slide change on click or tap, object drag on the screen, increase of a variable value and similar [13] (Figure 3).

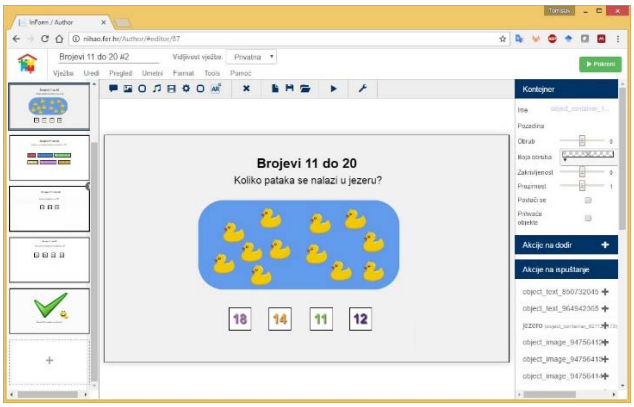

Figure 3 The [in]Form Author learning system - editor component

To allow for additional flexibility and to further enhance the interactivity of digital lessons, small and self-contained applications that can be integrated into existing lessons were customized trough the common [in]Form Author user interface. These so called *widgets* allow for a greater freedom and flexibility in creating interactive content to an experienced content developer. From the palette of the developed widgets in

the SCOLLAm project (i.e., Memory and Pair matching games, Q&A widget and Math widget), the Math widget was chosen to be used in this study. The widget resembles a simple calculator that displays mathematics tasks from a predefined list and awaits for user interaction, checks the solution, records a log, shows an appropriate message ("correct" or "wrong, try again") and repeats the cycle. The widget can be configured to vary problem sets and complexity levels, and can work in a *time-limited* or *number of problems* mode (Figure 4).

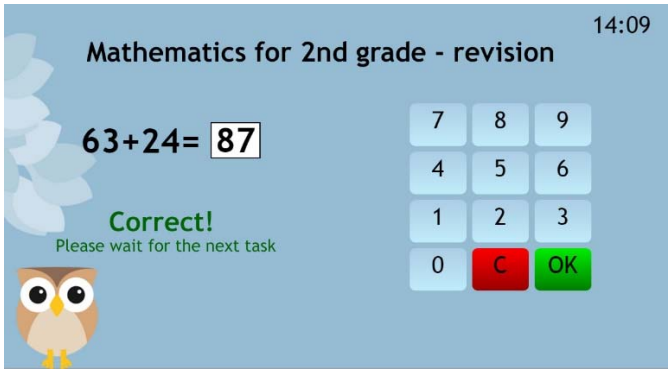

Figure 4 Mathematics widget

To explore and test the impact of gamification as part of the digital mobile learning lessons, several math lessons for 2nd and 3rd grade were created using the Math widget. The lessons were aligned with the students' learning schedule (the 2nd grade at the time practiced adding and subtracting numbers up to 100, while the 3rd grade was practicing the multiplication table). The Math widget was configured as follows: a random problem was drawn from the predefined set, log data was sent to server after each solution check, and time for the exercise was limited to 15 minutes. A simple leaderboard application was developed pulling and aggregating log data every 5 seconds, and creating and displaying a "real time" list of students with the highest score (only top 6 students were shown). Score was calculated as a simple sum:

$$score = 3 \cdot (N_{correct\ solutions}) - 1 \cdot (N_{wrong\ solutions})$$

C. *Experiment design*

The experiment was carried out in two rounds: firstly, the students were unaware of the leaderboard application and they were only told to do their schoolwork on tablet computers for 15 minutes of a regular lesson. In the second round which occurred two weeks later, students were presented with the equivalent mathematics lesson, with a comparable set of problems, but this time the leaderboard application was projected on a screen, in front of the whole class and a 15-minute countdown was visible on their tablet computers (Figure 5). In total, the experiment lasted for 30 minutes.

IV. Results

The data on the system usage generated by each student was collected via the log-file mechanism. All actions and correct and incorrect answers were logged onto the centralized server location to be further analyzed. The analysis was performed by segmenting the overall activity timeframe of 15 minutes into 5 smaller intervals of 3 minutes each. For each of the 5 intervals, the frequency of correct answers was calculated. Figures 6 and 7 show the chart representation for one particular example student for both gamified and non-gamified activities.

Figure 5 In-class experiment with a leaderboard

To measure student interest trend throughout an activity, linear regression was used. The intersections of interval boundary values and the number of correct answers for the interval were used as points to be connected with a linear regression line as indicated in Figures 6 and 7. Since every linear regression line can be depicted with the equation "y=ax+b", the coefficient "a" indicates the student interest trend, which can be increasing (positive), decreasing (negative) or neutral (zero). For example, the interest trend values for the example student in Figures 6 and 7 are -0.7 (negative trend) and 0.8667 (positive trend) for non-gamified and gamified activities, respectively.

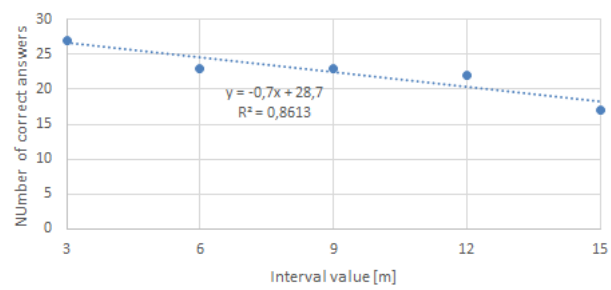

Figure 6 Performance of one example student in a non-gamified game setup

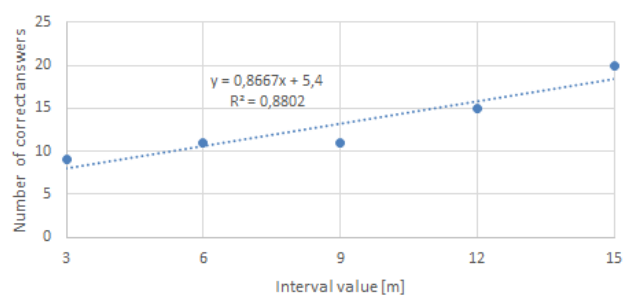

Figure 7 Performance of one example student in a gamified game setup

Table 1 displays the average student interest trend for both non-gamified and gamified activities for the three classes for which the experiment was conducted.

Table 1. Interest trend in gamified and non-gamified digital lessons

Class	Non-gamified interest trend	Gamified interest trend
Class 1	Median = .0000 Mean = -.0511 (SD = .3814)	Median = .1000 Mean = .0444 (SD = .5575)
Class 2	Median = -.0333 Mean = .0846 (SD = .3985)	Median = .1666 Mean = .0641 (SD = .4473)
Class 3	Median = -.2000 Mean = -.0205 (SD = .5259)	Median = .1333 Mean = .2167 (SD = .4275)

In order to compare the non-gamified and the gamified activities, student interest trend values were calculated for each students in non-gamified and gamified activities. These values were compared via the paired-samples t-test. The conducted test shows there is a significant difference of .21 between the non-gamified (M=-.08, SD=.46) and gamified conditions (M=.13, SD=.47) for student interest level trend $t(49)=-2.072$, $p<.05$.

V. Conclusions and Future Work

In this paper, the introduction and implementation of gamified digital learning mathematics lessons in the 2nd and 3rd grade of primary school classes was presented. The study consists of two lessons, a non-gamified digital lesson, and a digital lesson gamified using the live leaderboard game element. The analysis of recorded log data revealed that the gamified environment had a positive effect on student motivation, resulting in students retaining the focus on the given exercise for a longer period of time, thereby solving more tasks. Conversely, in a non-gamified environment, students became bored more quickly, slowing or interrupting the exercise, and in the end, solved a smaller number of mathematics tasks.

Improved motivation and student interest in the digital math lesson caused the increase of the number of tasks that students managed to solve in the observed 15-minute sessions. Since there were negative points for wrong answers, students thrived to solve tasks as both accurately and quickly as possible. Informal observations and interviews with the teachers indicate that with the increased student motivation, higher number of solved tasks and higher accuracy could improve students' math knowledge and skills.

Although the analysis shows that the general trend was in favor of gamified lessons, the employed gamification mechanisms occasionally, in case of particular students, led to non-favorable results. The leaderboard game element was, in a small number of cases, counterproductive and demotivated students who were not able to achieve a good rank. These findings are in line with other literature claims and reports - e.g., Werbach & Hunter [1] consider leaderboards potentially highly demotivating for underachievers, because there is a high probability for them to give up easily when they see they are far behind the top players. Similarly, Dominguez et al. [9] found that their gamification system with a leaderboard was not motivating enough for all participants, and in some cases even discouraging, attributing this to the fact that some people do not find competition interesting and motivational.

Future work will focus on the improvement of gamification strategy, including a variety of game elements (e.g. storytelling, badges) or modifying the leaderboard to avoid demotivation among underachievers. Additionally, adaptivity and collaboration strategies in combination with gamification will be considered to further improve student motivation and engagement from the perspectives of social learning.

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