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MOBILE MATH GAME PROTOTYPE ON THE BASE OF TEMPLATES FOR PRIMARY SCHOOL

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Abstract. The paper presents the first steps in the creation of a package with mobile math educational games for primary school. Examples of mobile math learning games in primary school are examined. The role of games and especially mobile games in learning and game specific elements are presented. Classification of game problems with 13 types, suitable for mobile software development, is shown. For each type, the software template is designed and developed, appropriate for the target group. The prototype of an educational game on the base of the templates is created, where learners have to pass levels, solve math problems and receive bonuses and virtual rewards.

Keywords: game-based learning; mobile learning games; templates for mobile educational games

1. Introduction

Today's children are no longer referred to as "digital kids" but rather as "mobile kids" (Leonardou, 2016) because mobile phones become an integral part of the daily culture for the young generation and change all spheres of their life. Children use mobile phones and other mobile devices from a young age for a variety of activities – playing games, watching videos, searching or sharing information, communicating with friends, etc. Using mobile devices in learning gives many benefits such as easy communication, accessibility anywhere and anytime, personalization, numerous online services, own pace of learning and good replacement of traditional classroom in extreme situations, as it is today.

Games are an important part of every child's life. The fact is that games have a strong motivating force, regardless of the age group, which causes the player to strive to win, even if he/she has to repeat the game over and over again. In the pedagogic, there are thorough and detailed researches on how important it is the role of games in teaching through which children learn while having fun. Modern learners want attractive training through the latest technologies and tools. They tend to learn from different sources like questionings, findings, constructing, interaction and having fun (Hartono, 2016). That is why contemporary training has to change

or adapt the pedagogical methods, approaches and strategies and use the learners' technologies.

The authors' main research goal is to create a package of mobile math educational games for children in the early stages of education, to support classroom study or to develop math skills while having fun at home. The authors intend to conduct their first experiments with 3rd-grade students.

Section 2 shows the state of the art in the field of mobile game applications in primary school age. Section 3 describes the authors' classification of game math problems, suitable for mobile development. Based on this classification, software templates are designed and developed (see Section 4). Section 5 presents the developed game prototype with software requirements, game methodology and implementation. The article ends with a conclusion which focuses on the contributions of the study and future plans of the authors.

2. Mobile games in primary math education

A game is a physical or intellectual form of social or individual activity organized following specific rules. Through the use of games, students can acquire knowledge and skills in any subject matter. On the one hand, the development of modern information and communication technologies allows many well-known didactic games to become digital games, which can be successfully used for the realization of cognitive activities, motivating children to study actively and to support the learning content. On the other hand, statistics (Stoimenovski, 2016) indicates that the largest shares of downloaded mobile applications are freeware and the most numerous of downloaded applications are games.

Mobile learning (m-learning), as a form of e-learning based on portable devices, gives some advantages such as accessibility, availability, personalization, collaboration, and much more (Kasakliev, 2015). It provides many opportunities for a team or personal, formal or informal, spontaneous and situated learning. By combining both m-learning and mobile games, it will provide the user with a new experience like no other (Diaha, 2010).

Recent studies conducted to explore the effectiveness of math games in learning motivate us to use mobile games in learning mathematics especially, at the primary level. An empirical study (Jagušt, 2018), conducted on three different types of gamified learning activities – competitive, collaborative and adaptive, shows that gamified activities contributed to the increase of student performance levels in math learning.

The games (AlKhateeb, 2019) display the academic material in an interesting and enjoyable way, like the photos, drawings, sound effects, and motion overlap in an attractive manner, which makes the student active, effective and willing to learn. On the other hand, the mobile games allow the student a chance of gradual and self-progress in the scientific materials, according to his/her ability in achieving the educational

tasks and realizing the winning in every level of the game. They handle the same concept many times in different ways, and in more than one of the game levels.

A survey (Kraleva, 2017) presents the views of children (from 4 to 13 years old) in Bulgaria on the possibilities and characteristics of the interface of the mobile applications. Educational mobile games should have proper guidance and learning design (Hwang, 2015) otherwise, their learning performances could be disappointing.

The authors of several mobile math games showcase their best practices and core application capabilities. Mobile math game "Color switch" (Batzogiannis, 2018) for practicing basic math skills is developed on the base of levels.

Some games propose an adaptation of the next level on the base of learner's results from the previous level, e.g. (Gaggi, 2018) presents an adaptive mobile math game for primary school, for developing skills in the multiplication table.

Authors of the mobile app Hi-Math (Yussop, 2019) present the effectiveness in improving arithmetic skills in the third year at school.

Mathematics is often a hard subject for children, especially because they are usually not able to perceive any concrete connection between math and the real world. There is a rift between what they do for fun and what they are required to do at school. (Gaggi, 2018) develops "Pizza al Lancio", a serious game to help children understand fractions, where game tasks are presented in the context of the interesting pizza story.

Other authors use more interesting game elements like finishing challenging missions and using dynamic assessment in role-playing math games of (Shih, 2018) for solving math problems.

A framework, presented in (Handal, 2013), with educational math apps, classified according to their instructional role – emulation, simulation, guided discovery, measurement, drawing/graphing, composing, informative, drill and practice, and tutorial apps. The apps are also grouped into three clusters: explorative, productivity and instructive tools, each of the clusters with its mobile learning pedagogy.

Most of the applications are tested with measurement of learners' skills before and after the software usage (Yussop, 2019). Research (Brezovszky, 2019), comparing results (through pre- and post-tests) of traditional math teaching with traditional teaching enriched with gameplay using the Number Navigation Game (NNG), shows that the group, using games has outperformed the group, using only the traditional approach of learning.

The game specific elements are determined in (Somova, 2016), which can be used in game-based learning (incl. gamification, where is the accent of (Somova, 2016)) to increase students' motivation: story, level, challenge, hidden treasure, reward, bonus, combo, badge, game rules and socializing activities. In our first prototype, we will implement the following game elements: story, level, challenge, reward and bonus.

3. Classification of game math problems

A thorough study (Gocheva, 2020) of the games for preschoolers and in the early educational stages is done, mainly on Google Play and the App Store. 66 games have been reviewed, most of them are in English, which limits their use because of the language barrier at this age. Some applications have multilingual support, but most do not support Bulgarian. Most of the games are free and the rest are either fully or only part of the levels paid. Particular attention is paid to the games in Bulgarian, which are intended for training in mathematics and Bulgarian for the age group of 5 to 10 years. Also, the applications satisfy the State Educational Requirements of the Republic of Bulgaria in only a very small proportion, most of which cannot cover even one area.

We propose a classification of game types of mathematical problems, suitable for implementation as mobile gaming applications to support primary school mathematics education. The classification is based on the classification proposed by (Raikova, 2011) and the recommendations for the preparation of e-resources in (Totkov, 2014). The classification contains 13 types of game assignments that are suitable for young students, divided into 8 categories.

Types of math game assignments are:

1. Multiple choice

1.1. Multiple choice of images – students make a choice between several images with math expressions, but only one is the correct answer.

1.2. A choice between parts of an image – students make a choice between parts of an image to solve the math task, but only one is the correct answer.

2. Alternative answer

2.1. Alternative answers – students indicate whether or not a math statement is true or false.

3. Multiple answers

3.1. Multiple answers between images – students make multiple choices between several images with math expressions and not only one is the correct answer.

3.2. Choices between parts of an image – students make multiple choices between parts of an image to solve the math problem and not only one is the correct answer.

4. Ordering objects

4.1. Establishing order between the images (texts) – students have to solve some math problems and then order the answers in some sequence.

5. Matching

5.1. Matching (1 to 1) between two types of objects (text-text, text-image, image-image) – students have to solve several math problems and then make the corresponding matches 1 to 1.

5.2. Matching (1 to many) between two types of objects – students have to solve several math problems and then make the corresponding matches 1 to many.

6. Filling in fields with multiple choice

6.1. Multiple-choice fields without repetition – students have to solve several math problems and then fill the answers in the fields without repeating.

6.2. Multiple-choice fields with repetition – students have to solve several math problems and then fill the answers in the fields with possible repeating.

7. Filling in fields in a template

7.1. Short answer - students have to solve a math problem and then write the correct answer with numbers or characters.

7.2. Filling in an open answer template – students have to solve several math problems and then put the answers in a template (table, image or text).

8. Open answer

8.1. Open answer – students have to solve several math problems and describe them as a free format solution.

9. Mixed answer type – unsuitable for the age group.

4. Game templates

The appropriate game template for each game type, from the above classification, is designed and developed – a total of 13 templates. The design of the templates is consistent with the age of our target group - colourful, funny and with a lot of images.

Basic mobile applications for each template are implemented with the following functionality:

– **Visualization** of the math problem on the learner's mobile device;

– **Interactivity** with the learner – solving the problem through the favourite child actions "click" and "drag and drop" to choose and order, and very rarely through writing answers to fill in fields;

– **Assessment** of the learner's answer – for every wrong answer, the player will receive a sound and a Toast message with text "wrong", and for the correct answer will receive a Toast message with text "correct";

– **Giving stimulus** for several correct answers – the player will receive praise and reward in the form of virtual goods (bullions, stickers, balloons, fireworks, etc.).

4.1. Template interface

Some examples of the designed application interfaces are shown in this section. Figure 1 presents a math problem from type 1.1, where the learner has to click on the correct balloon. Math problem from type 3.1 is shown in Figure 2, where the student has to put muffins on the exact plate. In the last Figure 3 (type 4.1), the student has to order the numbers. An example template for type 5.2 is demonstrated in Figure 4, where the learner has to sort the fruits in the baskets. Figure 5 (for a problem from type 7.2) introduces a template, where the student has to fill in the missing numbers, performing some mathematical actions.

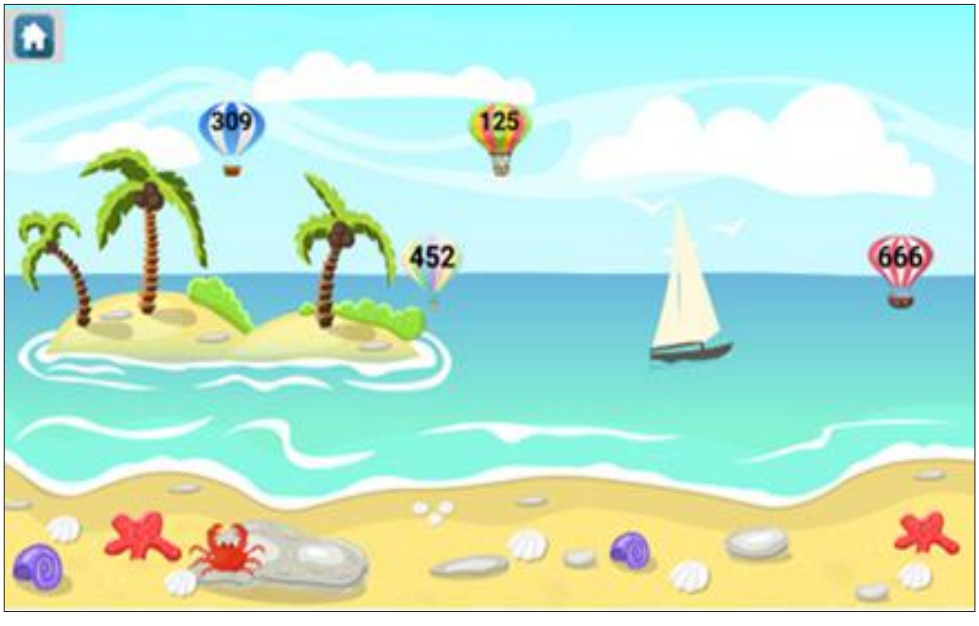

Figure 1. Template for „Multiple choice of images”

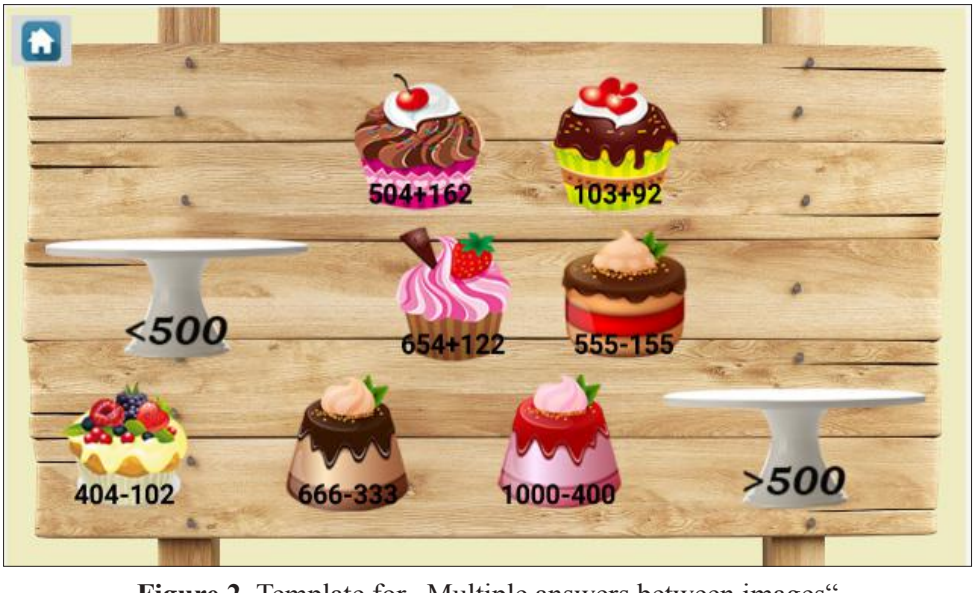

Figure 2. Template for „Multiple answers between images“

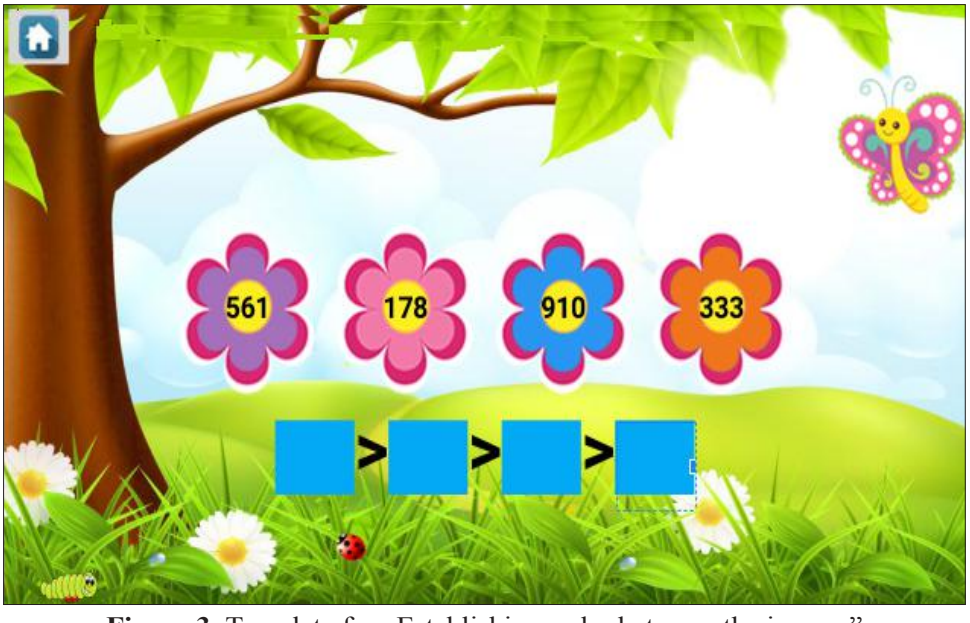

Figure 3. Template for „Establishing order between the images”

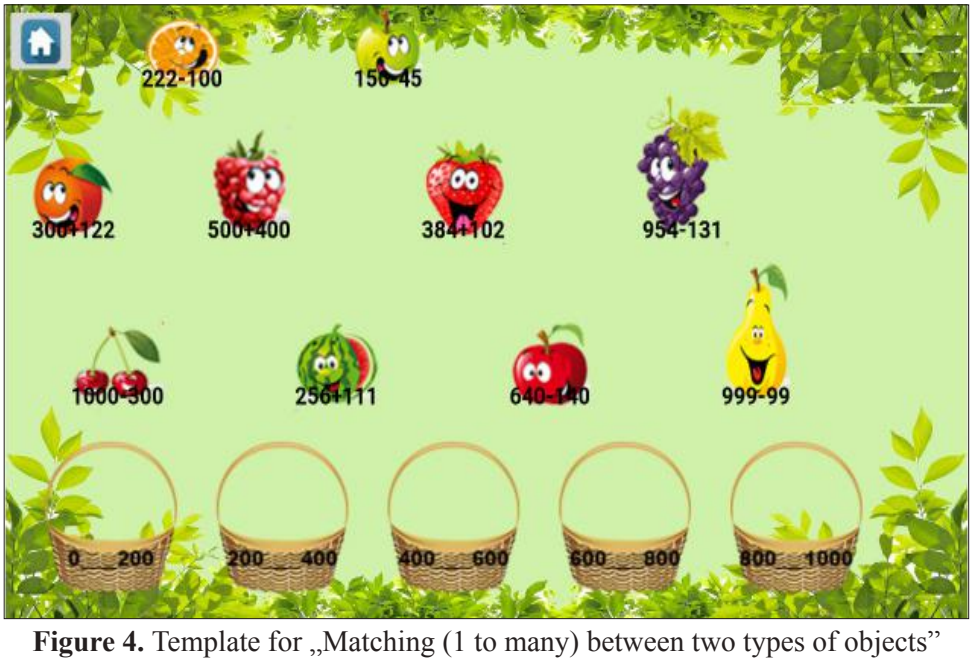

Figure 4. Template for „Matching (1 to many) between two types of objects”

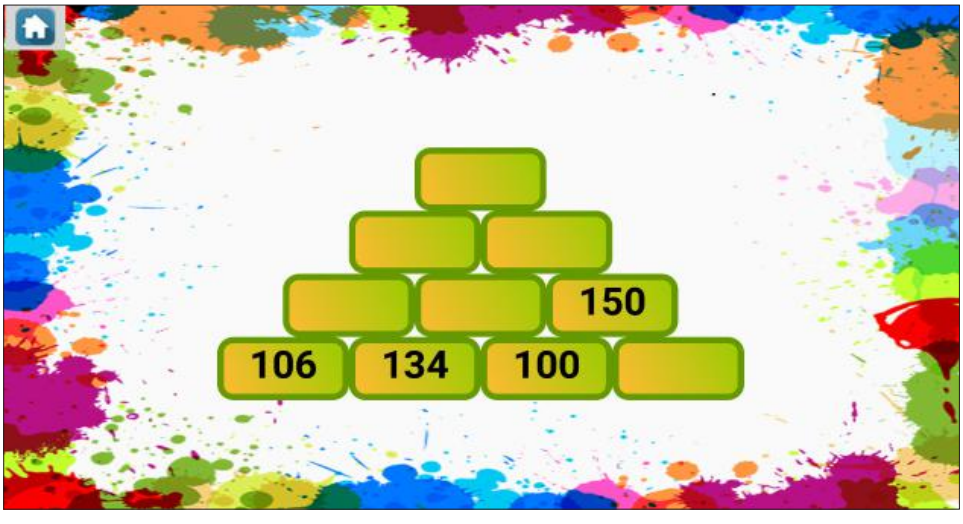

Figure 5. Template for „Filling in an open answer template"

5. Game development

Our main goal is to design and develop a package of mobile games which supports math lessons with practical problems in an entertainment environment. Never mind that we develop educational software, we use game specific elements and techniques. The prototype of one game is created till now on the base of section "Addition and subtraction within one thousand without regrouping" of math's textbook for 3rd grade in Bulgaria (Angelova, 2018).

The game is organized by levels, to satisfy the natural impulse to achieve or to conquer new things. Each level contains three game type problems. Problems are proposed to the learner with a gradual increase in difficulty.

For each game template, a preliminary selection of real math problems, suitable for the target group, is done. Each template is prepared with several values (e.g. math expressions), to provide automation display of different problem conditions for each playing of the game.

In each game problem, the learner has to answer a question or to solve some small math problems, through doing something (drag and drop objects or fill in with answers) onto the interesting graphical objects (image story of the game).

The following game rules are implemented:

1. Each correctly solved problem gives a bonus of 1 coin.

2. The level can be completed with minimum of 2 correctly solved problems.

3 If the level is completed with 3 correct problems (without any failures), learner receive a reward - a gold bullion.

4. If the learner has not enough correct answers, the level is repeated.

5. If the learner has 3 coins, no matter when the learner can spend them and buy an additional gold bullion.

6. The game goal is to collect as many gold bullions as possible.

5.1. Requirements

Based on a survey of existing game applications, we place the following requirements on the mobile game package we create:

– The games must comply with the Bulgarian state educational requirements in terms of methodology and educational content.

– The games must be age-appropriate and therefore have a lightweight and intuitive interface.

– The games must be free of charge and also with user interface in Bulgarian

– The games must lead to achieving of set of learning objectives.

– The games must be creative, intriguing and fun.

– The games should be relatively short to keep the attention of young learners.

– The games should be interactive and animated, if possible.

– The games should support the teacher's work.

– The games must be autonomously usable by the children at home.

5.2. Methodology

The mobile game proposes a software decision for training math skills at home or in the classroom, while children are entertaining. Students deal with the same math concept/skill many times (through repetition) in different ways during game levels in a variety of math problems. If the student fails at any level, he/she will repeat the level with similar, but not the same math problems. The learner can play the same game again and the game will propose similar math problems with different conditions.

The mobile application gives a complex learning environment built on real situations in which the student acquires and consolidates practical experience. Mathematics is a difficult and abstract subject for most of the students. Students search for solutions to math problems in situations as close to real life as possible, which increase their understandability and applicability of math.

The software is integrated with game elements and techniques that motivate, engage, activate and entertain young students.

5.3. Technical implementation

The mobile learning game is created using the application development software Android Studio Version 3.5.3 and Java SE Development Kit 13.0.2 and is tested on the Android emulator (Pixel 2, with 5 inches screen size, resolution 1080x1920 and density 420 dpi) and a real device under the Android OS. Minimum requirements for the user's device to play the game are OS Android 6.0, RAM 2 GB, 2 Core CPU and recommended screen resolution 1080x1920.

Android is preferred over the iOS operating system on the base of statistics for the used mobile operating systems worldwide and in Bulgaria.

All of the vector images in the game are used under a standard license allowing for royalty-free use in design. All the images are stored in the Drawable folder in Android studio. Adobe Photoshop CC was used to design and transform (by colours, sizes, shapes, and text) logos and images.

Animations are set in a way not to prevent students from solving math problems. The texts in the game are short, mainly to set the problem statement.

CONCLUSION

Educational games are designed to help students understand concepts, learn domain knowledge and develop problem-solving skills as they play games. Through the mobile game applications, students discover a new visually expressive, educationally impacting and interesting way to study.

A mobile game, which supports the learning of mathematics in primary school is presented. The game will be able to be used for self-study at home or at school if the teacher wishes to use the new technologies in the classroom. The paper offers a game-based approach for learning through mobile games aims to further develop students' math skills and to offer an entertaining environment where learning is easier and fun even for children who do not fancy mathematics.

The mobile gaming environment consists of levels with different math problems, where game elements like bonuses and rewards are integrated.

Future works will be devoted to add more templates' designs, to prepare adaptive game on the base of student current results, to enrich the game with the usage of more game-specific elements, to involve teachers in the development process through automation creation of games by choosing the game type and design template and filling in with math tasks, and to implement ordering of different students game results in the leaderboard.

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