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Educational Issues
Въпроси на преподаването

MOBILE GAME-BASED MATH LEARNING FOR PRIMARY SCHOOL

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Abstract. The paper discusses modern learning approaches in which mobile devices are increasingly used. It presents an experiment to apply mobile game-based learning to primary school students. A suitable learning model has been designed using adaptive, micro lesson, behavioural and game-based approaches. Based on the model, a mobile math educational game was developed to complement traditional classroom learning and be used at home. The mobile game was tested in a real learning environment. A survey was conducted also with the students and teachers, participants in the experiment, which investigated the attitude toward using mobile game – based learning in mathematics in the direction of – practical applicability, motivation, design, accessibility, support and feedback.

Keywords: game-based learning; adaptive learning; mobile game; game elements; micro lesson; primary school; mathematics

1. Introduction

Modern children of the so-called Generation Z are open to the world and quickly get used to changes in Information and Communication Technology (ICT). They use various modern technological devices with ease. The modern generation of children also has a different approach to learning. Students want fast, quality and effective learning through the latest technology. That is why modern education must change or adapt pedagogical methods and approaches.

Mobile devices have now reached such widespread use that smartphones and tablets are now overtaking traditional desktop computer systems in popularity and application, so their use in learning is only natural.

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. Combining both m-learning (mobile learning) and mobile games, it will provide the user with a new experience like no other (Diaha et all. 2010).

The main goal of the paper is to present an experiment to apply mobile game-based learning to primary school students. A suitable learning model is designed using adaptive, micro lesson, behavioural and game-based approaches. Based on the model, a mobile math educational game is developed to complement traditional classroom learning and be used at home.

Section 2 shows the state of the art in the field of modern innovative learning approaches. Section 3 describes the model of mobile game-based learning. Section 4 describes the developed mobile educational game prototype. Section 5 shows the setup of the experiment, the methodology of the conducted experiment step by step and the results of the surveys conducted with students and teachers. The article ends with a conclusion which focuses on the contributions of the study and the future plans of the authors.

2. Modern educational approaches

Vitanova in (Vitanova 2019), trying to present forecasts for the development of education and its features in the XXI century, concludes that modern education needs a revolutionary change. Modern education follows the trends of ICT development, with innovative forms of education emerging alongside traditional forms. For example (Aleksieva 2021) presents a theoretical study of electronic resources intended for teaching mathematics in primary grades, including online learning, which has become ubiquitous as a result of the COVID-19 pandemic.

Games are integrated into learning in various forms: game-based learning, gamification, simulation games, etc. In **game-based learning**, games are used as a medium for teaching content as well as for testing and assessment (Terzieva et all. 2017). Authors of (Stoyanova et all. 2016) examine the game approach in the learning process, implemented in an interactive learning environment using the free web-based platform Kahoot! to create and share educational tests (quizzes) in the form of a game (allowing real-time play from around the world, from any device with a web browser and internet connection).

Board and electronic games include a variety of game elements and techniques that motivate players to strive for better results. Examples of using these game elements and techniques in e-learning are discussed in (Gachkova & Somova 2016). (Sharkova et all. 2020) makes a correlation between game elements, game techniques, and player actions.

According to (Kasakliev 2015), **mobile learning (m-learning)** is a form of e-learning based on portable devices that provides many advantages such as accessibility, availability, personalization, collaboration, etc.

Learning through **mobile educational games** is one of the fastest growing trends among interactive learning methods. They provide many opportunities for team or individual, formal or informal learning.

M-learning can be very effective in learning mathematics, and there have been many authors working in this area. (Yussop et all. 2019) designs and develops a mobile app called Hi-Math as a game-based learning experience for children in grade 3 aimed at acquiring basic numeracy skills. Shih (Shih et all. 2018) has also developped a game-based mobile app for learning mathematics for primary school learners. According to (Alkhateeb 2019), mobile games reveal learning material in an interesting way – images, sound effects, and movements complement each other in an attractive way, making the student active, effective, and willing to learn.

Adaptive learning is an educational approach that provides learning resources and activities tailored to the specific needs of the individual learner. The aim is to identify the specific needs of a learner and to implement an appropriate pedagogical strategy to improve the learning process. The main characteristics of adaptive learning are: flexibility, motivation, engagement, personalization, adaptation, feedback, accessibility, etc. The literature most commonly refers to three types of e-learning system adaptability (Velsen 2008): user interface-based adaptation, learning process adaptation and learning content-based adaptation.

Micro learning is learning that is implemented on the basis of very short lessons lasting no more than 5 minutes (Janke 2020). Recently, there has been a lot of focus on mobile-based microlearning integrated with traditional learning methods. According to (Coakley et all. 2017), it makes learning more accessible at anytime, anywhere, just-in-time and on-demand, adaptive and learner-centred.

Krasnova (Krasnova 2015) highlights the benefits of **blended learning** as a method that combines the most effective face-to-face teaching techniques with online interactive collaboration. On the other hand, so-called **ubiquitous learning** means learning anywhere, anytime, and is therefore directly related to mobile technology. It can be seen as an integration of m-learning and e-learning, which allows customization to the learner‘s actual needs (Zhang 2008).

3. A learning process model

A general cyclical learning model containing the following phases is proposed for m-learning of the target age group through the implementation of modern learning approaches:

- Exercise – learners solve tasks in the form of games;
- Evaluation – automatic evaluation of the solved tasks;
- Rewarding – receiving various rewards from the game;
- Support – learners receive support when they first fail to solve a task;
- Training – trainees receive training through micro-lessons when they repeatedly fail to solve a task;
- Ranking – based on the results obtained.

Detailed learning sub-models implementing the selected approaches: game-based, adaptive, micro-lesson learning and behaviour monitoring learning are presented.

The designed model of mobile game-based learning depends on the learning objectives, learning resources, and learning activities, which depend on the difficulty level and time to implement the learning with the corresponding element.

A **learner model** was constructed based on three sub-models: a learning model (achievements during learning), a game model (achievements in the game) and a behavioural model (data during the game reporting on different indicators of the learner's behaviour).

To implement **game-based learning**, research has been done on game elements and techniques that exist in games and can be used in m-learning for this age group (Gocheva 2021). The following elements and techniques have been selected:

– **game elements**: bonus, badge, reward, progress, status, level, time, feedback message, missions;

– **game techniques**: reward system, progress tracking, current status tracking, time limit, game rules, feedback, mission, story.

Adaptive learning is implemented by using different types of tasks located in the game levels, considering the difficulty of the tasks, supporting the success/failure of the learner, and detecting the time to solve the game tasks. Adaptability is implemented in two directions: **adaptability of the learning content and adaptability of the learning process.**

Micro learning is implemented through short text hints (on the first failure) and through a video example (**micro lesson**) on the second failure at the same level of the game. The application of micro lessons helps to achieve the goals of the adaptive methodology; students learn to cope with difficulties, not to lose motivation, and without feeling lost to move forward in the game.

Behaviour monitoring learning is based on the reporting of player behaviour data during game play. Possible data that can be collected automatically are, for example, the following: noise level (in decibels) around the mobile device; the number of sudden movements of the mobile device; the number of switches to other applications; and the presence of a connection to a WiFi network and the Internet. Data can be an indicator of emotions experienced and specific behaviours of the learner during play. The data collected could assist the teacher in forming an assessment or in analysing behaviour. The data may also be useful to researchers in other professional fields who study child behaviour during play.

A **functional model** was also developed in two directions – user functionality design and data synchronization.

4. Prototype of the mobile educational game

Based on the created model of game-based learning, a mobile game application for mathematics education for students in grade 3 was developed.

The prototype of the mobile educational game consists of 8 levels whose interface is based on different templates with interesting and fun designs. The learning activities are implemented through missions – mathematical problems that are randomly generated. For the missions, three types of difficulty are applied (1 – low, 2 – medium, and 3 – high). The game starts with a medium difficulty level and a target time (60 seconds) for each level.

The game uses an adaptive methodology depending on the correctness of the answer, the difficulty of the mathematical problem, and the time to solve it. Students form an individual learning path that is unique to each due to the adaptive approach.

In the case of wrong answers, students receive support: a hint on how to solve the problem (short text) on the first failure, and on the second failure at the same game level – video example (micro lesson).

For correct answers, students get bonus coins that are different for each difficulty level: 3 coins for high, 2 coins for medium, 1 coin for low, and 0 coins for failure. For every six coins, students win a gold bar as a prize. With correct answers, students save unused time to solve a problem, which they can use later in the next mission (as a combo). The player‘s goal is to collect the maximum number of virtual objects in the minimum amount of time. The game ends with the final leaderboard.

Once the game is completed, each participant‘s data is sent to a web server for synchronization. The sorted data is returned to mobile devices (on demand) and sent to a web application designed for the educator to display as a ranking or other type of report. The reports are used to help tutors decide how to support learners in subsequent learning.

For the construction of the prototype, several logically connected software modules have been implemented, which implement the designed functionality of the system: the “Game Environment” module, the “Synchronization” module, and the “Reports” module.

The “Game Environment” module is an Android application of the game type and contains the following layers:

– Layer **“User Interface”** – a graphical interface visualizing all the elements of the game, i. e. the contact between the game environment and the participant happens here (Figure 1, Figure 2);

– Layer **“Functionality”** – contains all the functionality representing the game logic, implemented with programming code;

– Layer **“Databases”** – contains the game DB where the game learning flow data is stored;

– Layer **"Libraries"** – implements processes and configures settings that are specific to building and testing Android apps.

The "Synchronization" module implements a process in which data with participant scores and game data is sent to a web server, where it is processed and sent back to the mobile devices in the form of a leaderboard. The module uses a web server (Apache HTTP Server) and a database server (MariaDB).

The "Reports" module contains processed information obtained from the synchronization module in the form of various sorted data lists that are available to the teacher for evaluation and analysis.

Figure 1. Level 2 of the game

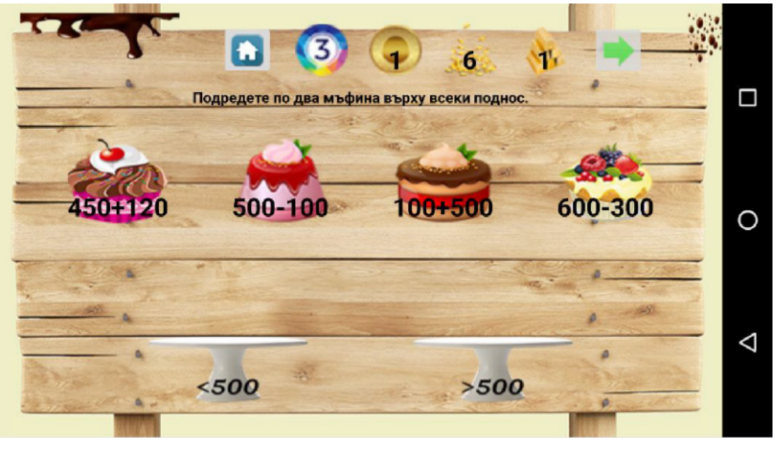

Figure 2. Level 3 of the game

5. Experiment

The software prototype has been tested in a real classroom environment with 17 third grade students from Yane Sandanski Primary School, Plovdiv, Bulgaria and 10 primary teachers. A survey with questions (for students and teachers) was conducted to gather opinions, impressions and recommendations. The experiment aims to find out whether:

– mobile game-based learning generates interest in students;
– mobile educational games are useful and support math learning;
– the adaptive approach is a good choice in mathematics education;
– educators would use mobile game-based learning.

The research methodology is based on surveys designed with Google Forms. The survey questions are organized into several categories. Each of the categories was examined and Cronbach‘s alpha coefficient was calculated. Cronbach’s alpha coefficient is a measure of internal consistency, that is, how closely related a set of items are as a group. It is considered to be a coefficient of reliability (or consistency). Cronbach’s alpha coefficient can be written as a function of the number of survey items and the average inter-correlation among the items:

$$\alpha = \frac{N\bar{c}}{\bar{v} + (N-1)\bar{c}}$$

where N is equal to the number of items, $\bar{c}$ refers to the average of all covariances between items and $\bar{v}$ refers to the average variance of each item.

There are 15 questions in the survey for students and 4 of them are open-ended, and 21 questions for teachers, 2 of them open-ended. Each of the multiple-choice questions has several possible answers, and for students, they are: yes; somewhat; and no. The teachers are asked to indicate the extent to which they agree with the statements in the survey on a five-point Likert scale: strongly agree (SA); agree (A); undecided (U); disagree (D); and strongly disagree (SD).

5.1. Results of the survey conducted with students

The **“Practical Applicability”** category shows that 94.1% of learners would prefer to use a mobile game in a math class. All (100%) students respond that they like learning through a mobile game and would play it at home. To the question “Did you learn something new while playing this educational mobile game” 70.6% – 12 children answered yes, 11.8% – 2 children answered “somewhat” and 17.6% – 3 children answered yes “no”, indicating that for the majority of the group, the game contributed to the acquisition of new knowledge. The Cronbach’s alpha coefficient for this category is α = 0.92.

In the category **“Motivation”** (with Cronbach‘s alpha coefficient $\alpha = 1$) all students (100%) expressed the opinion that they like mobile game-based learning. 94.1% of them shared that receiving awards motivated them, and the remaining 5.9% – that it only somewhat intrigued them.

In the category **“Design”** (with $\alpha = 1$) the students strongly agreed (100%) that they liked the game design and that they found the game interesting. The adoption of game-based and visually interesting design is a prerequisite for mathematics learning resources, which are not easy and engaging for most students, to be studied more willingly by learners.

Category **“Accessibility”** (with $\alpha = 0.88$) shows that 76.5% of students have already used a mobile math educational game and have experience with such learning. 12 of the children (70.6%) answered that the game was not difficult for them and it was not complicated to move from one level to another. The remaining 5 children (29.4%) encountered some problems with the difficulty of the game and when switching between levels. Using the adaptive approach by changing the difficulty on each success/fail has given the learners confidence that the game is not difficult and they can handle it with ease.

In the category **“Support and Feedback”** 88.2% of the children (15 children) answered that the support they received when they got a wrong answer helped them, which is again a positive assessment of the effectiveness of the adaptive approach.

The **“Open-ended Questions”** category shows that all children performed above average. The answers to the question „How many gold bars did you end the game with?“ – according to this indicator, most children did very well – 7 children won 4 bars each, 8 children won 3 bars each and 2 children won 2 bars each.

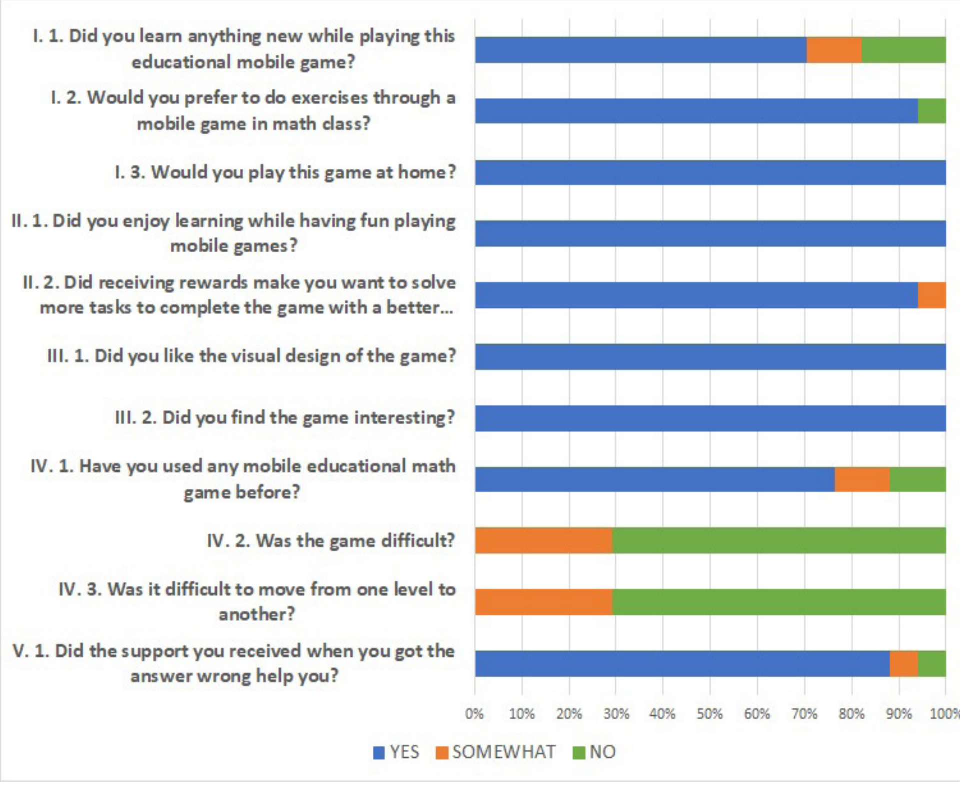

Figure 3. Summary results of surveys conducted with students

5.2. *Results of the survey conducted with teachers*

According to the category **"Practical Applicability"** (with $\alpha = 0.86$)**,** all teachers believe that gamification is suitable for use in mathematics lessons at the primary stage (60% strongly agree, and 40% – agree). Absolutely all teachers believe that the game approach supports the effective achievement of educational goals in mathematics at the primary stage. 40% of respondents tend to agree strongly and another 40% tend to just agree that they would use gamification in their teaching activities. Teachers think that the learning process supported by the mobile game develops students' learning skills (60% of teachers strongly agree and 40% agree). The result that all (100%) teachers think that the complexity of the game is consistent with the age of the 3rd-grade students is very telling. They also support adaptability as a good methodological approach in this age group (80% answered that they agree strongly and 20% just agree).

Category **“Motivation”** (with $\alpha = 0.81$) shows that all teachers believe that the learning process supported by the mobile game awakens students‘ interest in mathematics (80% strongly agree and 20% just agree), which again confirms the thesis that mobile games can be key a supportive tool for both classroom learning and self-study outside the classroom. Here, the teachers again support the statement that adaptability in the game is a flexible approach that motivates every learner – both in success and failure in learning (80% answered that they agree strongly and 20% – that they agree).

In the category **“Design and Accessibility”** (with $\alpha = 0.94$) 80% of educators strongly agree that using game-based design and game techniques makes mobile learning more enjoyable than traditional learning, and the remaining 20% do not have an opinion. All educators surveyed with their scores above average stated that the game elements were sufficiently intuitive and appropriate for this age and the game design was sufficiently intriguing.

In the category **“Interactivity, Feedback and Communication”** (with $\alpha = 1$) teachers gave positive opinions to all three statements (80% strongly agree and 20% agree). They also support the claim that feedback and support in the mobile game encourage learners to address learning gaps, which is one of the most important features of the developed game.

An overall conclusion can be made that teachers approve of the proposed game prototype, the adaptive methodology applied the timely personalized support of the learner with appropriate tools and the game design. Teachers give some recommendations for expanding the game.

All of Cronbach’s alpha coefficients that we calculated from the results of the surveys for both students and teachers in all categories are over 0.70, which is a frequently cited acceptable range of Cronbach’s alpha coefficients. Values closer to 1.0 indicate a greater internal consistency of the variables in the scale. Also, higher Cronbach’s alpha values show greater scale reliability.

Conclusion

The paper has presented a model of mobile game-based learning, using adaptive, micro lesson and game-based approaches, which is suitable for students in primary school. Based on the proposed model, a software prototype of a math educational game was created. The game has experimented with grade 3 students from primary school in a real learning environment.

A survey was conducted with the students and teachers participating in the experiment to explore attitudes towards the use of mobile game-based learning in mathematics. Respondents were strongly positive about the proposed mobile game.

Using the technical capabilities of mobile devices, a range of data on learner behaviour can be collected. The analysis of this data can support the tutor‘s decision making about how to support learners. And their systematization will eventually lead to the creation of game patterns of players (learners).

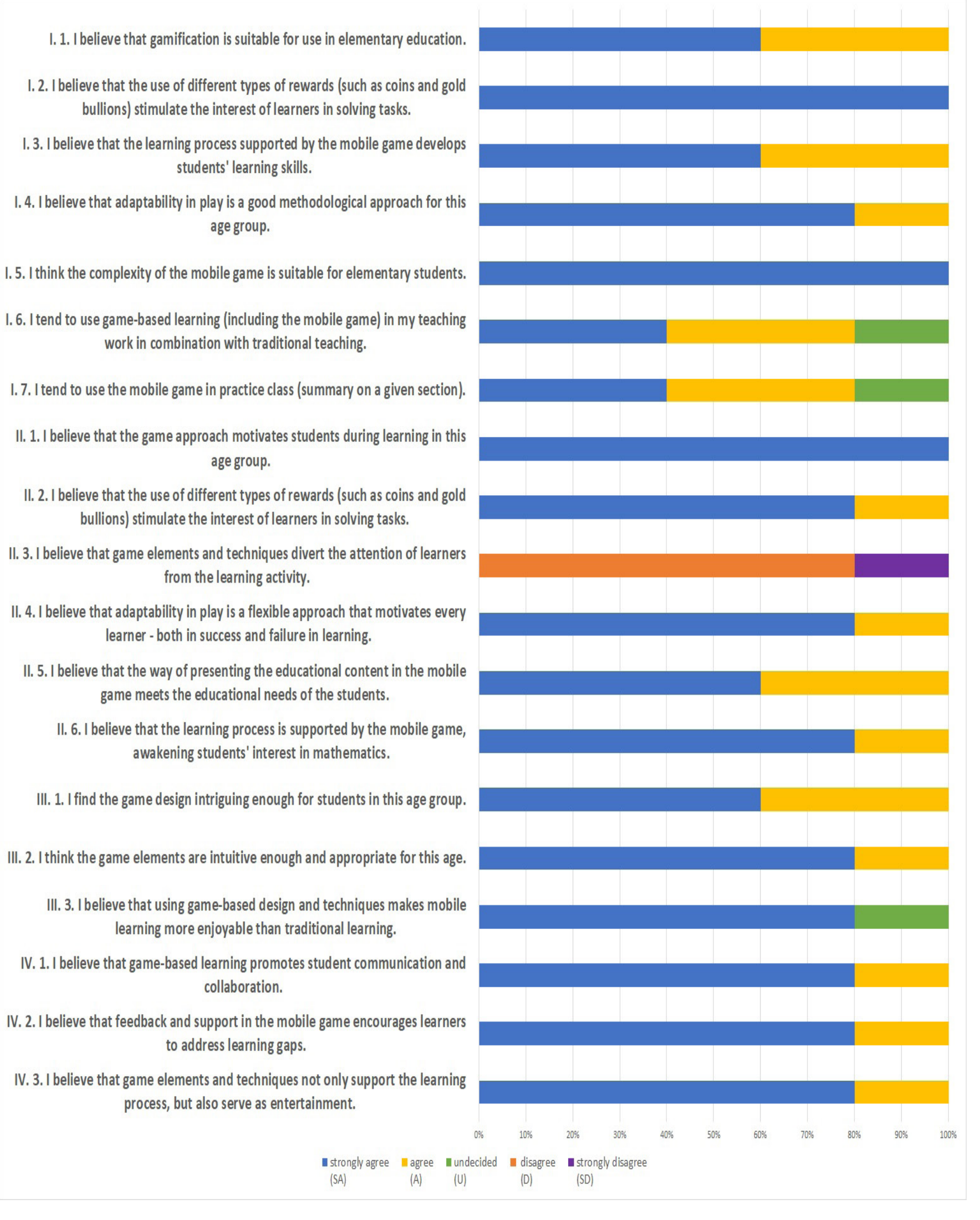

Figure 4. Summary results of the surveys conducted with the teachers

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