

Game-based Approach in Mobile Learning for Primary School

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Abstract. The paper proposes an approach based on different types of game elements and techniques to support the study of mathematics in primary school using mobile devices. The state of the art of games in education (in particular for learning mathematics) and the game elements and techniques are presented. The appropriate game-based learning methodology for young students, for individual and collaborative play, is described. The experience and emotions that the game elements and techniques provide to the learners are shown. Game elements and techniques suitable for young students and to motivate all different types of learners are explained. The integration of the concept of microlearning in the proposed game-based learning is shown. A prototype of a math educational game on the basis of game templates and the proposed methodology is created.

INTRODUCTION

Game-based learning is a preferred approach for younger students who have not yet completely detached themselves from children's games. The modern generation of children from an early age is accustomed to using modern information and communication technologies, so mobile educational games for them are both exciting and fun, and accessible and effective. The motivating power of the games is indisputable, and if they are supported by appropriate methodology, they become the most successful learning resources.

The game-based learning fits perfectly into the concept of microlearning, which can be defined as a short and clear learning content, mainly short paragraphs, photos, illustrations, short audio and video, short tests and games. Microlearning is not suitable for all learning needs, such as learning complex concepts and in-depth learning, but it is affordable, fast and easy to consume [1], [2]. The key feature of microlearning is the duration, so this approach is applicable to children in primary schools.

The paper presents an attempt to apply many game elements and techniques to stimulate different types of primary school students in their mathematics education. The main goal is to develop appropriate game learning methodology for younger students and to apply it in real mobile application. The mobile application is intended for self-study or as an additional resource in the classroom. Section 2 discusses the game elements and techniques of electronic games and their application in learning. Section 3 presents the designed game-based approach, whereas the created game prototype is described in Section 4.

GAMES IN EDUCATION

The motivating power of the games is discussed by many authors. [3] points 12 characteristics that make computer games so engaging for millions of people, which can be interpreted for learners in this way:

- form of fun – provide enjoyment and pleasure to the students during their study;
- form of play – provide intriguing active participation of the students;
- have rules – provide definite learning rules to students;
- have goals – motivates students;
- interactive – provoke students to act;
- adaptive – ensure adaptability of the students' learning flow;
- have outcomes and feedback – give information about students' learning progress;
- have win states – give satisfaction to students from achieved learning goals;
- have conflict/competition/challenge/opposition – give students adrenaline in overcoming challenging learning tasks;
- have problem solving – build creativity in students;
- have interaction – provide social contacts, communication and collaboration;
- have representation and story – provide emotion and interesting experiences to the students.

Game elements and techniques

Electronic games include a variety of game elements and techniques that motivate players to strive for better results.

Deterding [4] describes the game elements as elements that are found in most (but not necessarily all) games and play a significant role in the game, and also clarifies that not every element will work the same way if applied in different contexts.

Examples of the use of game elements and techniques in e-learning, which are borrowed from the board and electronic games, are considered in [5]. Also, in [5] game-specific elements are determined, which can be used in game-based learning (especially in gamification) to increase students' motivation: story, level, challenge, hidden treasure, reward, bonus, combo, badge, game rules and socializing activities.

In [6] the interrelation between game element, game technique and game action are made. In [6], the list of game elements, which we use as a basis of our methodology, is determined as follow:

- avatar – visual presentation of the different roles of the learners in which they can be embodied;
- bonus – expected remuneration for completed learning activities (e.g. points);
- badge – sign for achievements in various educational activities;
- combination/combo – gaining an advantage over other learners;
- reward – unexpected prize for certain learning successes (incl. virtual goods);
- leaderboard – ranking of learners based on their current success;
- level – different levels of the learning process;
- progress – percentage of the fulfilled learning objectives;
- status – current state of the learner (current avatar, assessment results, realized learning activities, etc.);
- team – group of learners for group learning activities;
- time – setted time limits for learning activities;
- resource – different types of helping learning resources;
- message – communication message.

The list of game techniques in [6] contains:

- change of identity – getting a new avatar to play a new role;
- reward system – giving additional benefits (under different rules) in different forms: badges, rewards, bonuses, combos and hidden treasures;
- progress tracking – getting information about the progress of the learning;
- current status tracking – getting information about the current state;
- teamwork – group collaborative learning activities;

- time constraint – limitation of learning activities and learning resources, closely related to the game rules and the reward system;
- game rules – learning rules;
- feedback – feedback after completion of learning activities;
- communication – students can share ideas and problems, collaborate to work on group learning activities and socialize;
- challenge/mission/adventure – learning activities that the learner must complete as part of the learning course, sometimes with an added game plot describing the purpose of the mission;
- hidden treasure – hidden learning resources that can only be discovered when certain conditions are met (e.g. when completing a certain mission);
- story/plot – an interesting context of the learning process describing a story with different missions to accomplish.

[7] also summarizes the list of the game elements as follow: achievements (that is earned by player behaviour), avatars, badges, boss fights (final challenges), collections (sets of in-game items), combat (fights within games), content-unlocking (content withheld until a certain level of ability is reached), gifting (giving in-game virtual goods), leaderboards, levels, points, quests (specific tasks acting as goals), social graphs (information data sets presented to groups to encourage them to compete with others), teams and virtual goods.

In most classifications of game elements, it is noticeable that there are no standardized names of the elements and that they are mixed with game techniques (as in [7]).

According to [8], in addition to the game elements and techniques used, the main principles of game design are also important, which according to her are: goals, challenge, personalization, quick feedback, visible status, content unlocking, freedom of choice, freedom of failure, plot, new identities, time limitation and social engagement.

On the other hand, Bartle [9] defines four types of video game players, which are distributed according to what motivates participants the most in the games:

- Killers – act on other players, they want to win by making others lose;
- Achievers – act on the environment, they want to win everything that is offered in the game;
- Explorers – interact with the environment, they want to get to know in detail the environment;
- Socializers – interact with other players, they use the environment as a bridge to get in touch with other players and interact with them.

Therefore, to increase the motivation of different learners, different game elements and techniques should be offered.

For four user types, [10] proposes proper motivating game elements:

- for killers – leader board, points, course progress, status, combos;
- for achievers – badges, levels, course progress, bonuses;
- for explorers – quests (individual assignments), rewards, history;
- for socializers – forums, quests (group assignments), history.

Games in math

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 [11], 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.

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. A number of examples of software applications are trying to bridge this gap.

A framework 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 is presented in [12]. The apps are also grouped into three clusters: explorative, productivity and instructive tools, each of the clusters with different mobile learning pedagogy. [13] designs and develops a mobile application called Hi-Math as game-based learning that is fun for children in 3rd grade and aims acquisition basic mathematical skills in arithmetic. Testing shows that all students agree that the Hi-Math mobile app is useful and appropriate to help them easily learn math. [14] also develops a mobile application for learning mathematics based on games for primary

school students, where students have to solve math problems in order to complete a challenging mission. In case of difficulties in the game, the application offers gradual intervention in real time to help overcome the challenge. The results from conducted an expert evaluation and training experiment shows a high rating for this application.

LEARNING METHODOLOGY USING GAME-BASED APPROACH

We use a game-based approach to propose attractive and effective learning resources through which to study mathematics in a more motivated way at primary school. The game elements and techniques together with the experience and positive emotions they provide to the learners, before and after using the game element/technique, are presented in the Table 1. The Table 1. shows that game elements and techniques not only entertain, but also motivate students to strive for better results. Failure (e.g. when not receiving a bonus) usually causes frustration, which also leads to positive results because it causes a desire for a "second try" and a desire for further success.

We offer a design methodology of learning games on the basis of small **game templates** in combination with appropriate game elements and techniques to influence each type of learner. The templates from 13 game types are chosen (to be appropriate for younger students) and designed [15] - Multiple choice of images (texts), Choice between parts of an image, Alternative answer, Multiple choice between images (texts), Choice between parts of an image, Establishing order between the images (texts), Matching (1 to 1) between two types of objects (text-text, text image, image-image), Matching (1 to many) between two types of objects, Multiple-choice fields without repeating, Multiple-choice fields with repetition, Short answer, Filling in an open answer template and Open answer.

On the one hand, the more types of game elements and techniques used, the more types of learners will be affected. But on the other hand, the more game elements and techniques are used, the game algorithm becomes more complex and larger, which is not particularly suitable for young students. We propose two groups of appropriate elements and techniques – for individual game and for collaborative game.

For designing **individual game**, we chose the following elements and techniques:

- game elements – bonus, badge, combo, reward, reward/treasure resource, progress, status, level, time, feedback message/resource, various elements as missions;
- game techniques – reward system, progress tracking, current status tracking, time limit, rules of the game, feedback, mission, hidden treasure, story.

To implement a **collaborative game**, the other elements and techniques must be added:

- game elements – avatar, leaderboard, team, message;
- game techniques – changing identity, team work, communication.

The game methodology is built on levels of different types of game templates suitable for the math topic. The same concept/mathematical algorithm is proposed to be studied/consolidated many times in different ways in the different levels (repetition for consolidating the knowledge), which leads to learning based on understanding. This helps the students to integrate mathematical concepts into their knowledge structure in an organized and reproducible way.

It is not recommended that learning activities for young students be too long to keep their attention: missions (math problems) should be short and the support resources and hidden treasures should use microlearning. Using time constraints for missions will increase the adrenaline in the game.

The reward system gives a lot of incentives to students: bonuses, rewards, badges, combos, resources and leaderboards. The reward system should use mainly virtual goods (virtual subjects like coins and golden bars), as more appropriate for younger students.

For more complex games is suitable using avatars and team collaboration activities.

Learners need to feel confident and informed about their progress at all times, which could be achieved with the elements: status, progress and feedback message.

GAME PROTOTYPE

A game prototype, using the presented methodology from previous section, has been developed, supporting the learning on the topic “Addition and subtraction of numbers up to 1000 without passing”, with mathematical problems from the math's textbook for 3rd grade in Bulgaria [16].

We chose the following elements and techniques to apply in the prototype of our game:

- game elements – bonus, badge, leaderboard, combo, reward, progress, status, level, time, feedback message/resource, various elements as missions;

Game element	Game technique	Experience/ Emotion before	Experience/ Emotion after
Avatar	Changing Identity	challenge, wish for self-improvement	enjoyment, excitement
Bonus	Reward System	purposefulness	happiness, enjoyment
Badge	Reward system	purposefulness	satisfaction, pride, enjoyment
Leaderboard	Reward System	striving for victory, competitiveness	pride, satisfaction
Combo	Reward System	purposefulness	satisfaction, enthusiasm
Reward	Reward System	collector's spirit	joy
Resource	Reward system	conquering spirit	joy
Progress	Progress tracking	purposefulness	satisfaction, pride
Status	Current status tracking	confidence	satisfaction
Level	Progress tracking	striving for victory	satisfaction
Team	Team work	responsibility, usefulness	collaboration, enjoyment
Time	Time limit	competitive spirit	satisfaction
–	Rules of the game	certainty	confidence
Resource, Message	Feedback	need reassurance, uncertainty	confidence
Message	Communication	communicativeness	socially satisfied, influential
Various Elements	Challenge/ Mission/ Adventure	conquering spirit, adventurous spirit	adrenaline, satisfaction
Resource, Combo	Hidden Treasure	discovering spirit, curiosity	satisfaction
–	Story / History	curiosity, imagination	enjoyment

TABLE 1. Game elements and techniques used in the learning approach (incl. student's experience).

- game techniques – reward system, tracking progress, current status tracking, time limit, rules of the game, feedback, mission, story.

The game contains 8 **levels** of different game template types suitable for this math topic. All game templates have an interesting and entertaining design based on a short **story**, in which learners have to get involved to solve a certain problem, applying their mathematical knowledge. An adaptive methodology is implemented depending on the correctness of the answer, the difficulty of the mathematical problem and the **time** for solving it. Students receive randomly generated mathematical problems (**missions**) that are of various degrees of difficulty, depending on the previously solved problem: with less (or least in the final situation) difficulty in a wrongly solved problem, the same difficulty in a correctly solved problem for normal time and greater (or greatest in the final situation) difficulty in a correctly solved problem in a short time. After each solved mathematical problem, students receive automatic **feedback** showing the correctness of their answer.

For correct answers students receive as **bonuses** coins, which are different amounts for each level of difficulty: 2 coins for medium, 3 coins for high, 1 coin for low and 0 coins for failure. For every 6 coins, students receive as a **reward** – 1 gold bar.

For correct answers, students also save unused time in solving, which they can use later (as **combo**) in the next math problem, where they have the advantage of having more time to solve the next math problem.

For wrong answers students receive help: a hint on how to solve the problem (in the first failure) and a video example (**microlesson**) and a correct answer to the wrong mathematical problem (in the second failure of the same game level).

The game shows **leaderboard** with ranking, if more than one player is registered on one mobile device. Also, at the end of the game, upon successful completion, students can receive a **badge** depending on the result achieved: “Excellent Mathematician” (for the highest number of correct results), “Quick Mind” (for the fastest playing game with good learning results) and “Genius” (for the fastest game play and the best learning results). When playing the game individually (without statistics from other players) there are thresholds for receiving the badges.

At each level (Figure 1), learners see their current **status** (total number of coins won, number of coins for the current level and number of gold bars received) and current **progress** (at what level students have reached relative to the total number of levels). Figure 1 shows a current level.



FIGURE 1. Example of the mobile math game.

CONCLUSION

The paper presented game-based methodology for learning as well as the prototype of the game, following this methodology.

Game learning resources usually provide active student participation. Therefore, the proposed game prototype can be used for self-learning at home or as activating the work of students in the classroom.

The game elements make the learning more interesting, more exciting, more fun and more motivating. But different game elements and techniques affect different learners in different ways and to different degrees, so more types of game components must be applied in learning resources in order to be able to motivate all types of learners.

Our future plans are the creation of a whole package of mobile games for learning mathematics on all topics in 3rd grade at school, as well as the incorporation of currently missing game elements and techniques.

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