Mobile Game-based Learning Model for Primary School Learners

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Abstract

Games have a strong motivational mechanism and are increasingly used in education, especially for children in the primary stage. The paper proposes a generic cyclical learning model suitable for children in the primary school stage using the approaches of game-based learning, adaptive learning, micro lesson learning, and behavior-monitoring learning. A formal model of mobile game-based learning, including a learner model based on learning achievements (learning model), game achievements (game model), and children's behaviors during play (behavioral model), is made.

Based on the model, a prototype mobile application has been developed that can complement traditional classroom learning or be implemented independently at home. The prototype was tested in a real learning environment.

Keywords

Game-based learning, mobile learning games, adaptability, micro lesson

1 Introduction

With the massive use of the Internet and modern Information and Communication Technology (ICT), the use of e-learning resources has become a particularly relevant issue. New learning approaches are applied and old ones are adapted for greater efficiency in the educational process. Attention is paid to the personality, individual qualities, and needs of the student. Currently, in the COVID-19 reality, mobile learning (m-learning) is being increasingly developed and used. Many scholars, such as psychologists, educators, and computer scientists, have explored the use of mobile devices as a tool for learning, including that of schoolchildren and young children. Today's students easily use mobile devices daily, which could also be a tool for learning, not just for entertainment. On the other hand, pedagogy, as well as didactics have long emphasized the role of game in learning and education. Educational games incorporate elements that make them a powerful learning tool, with many having a competitive motif and/or techniques that encourage creativity and the use of imagination. Each game contributes to a different degree to the development of one or another cognitive process in the student (perception, ideas, memory, and thinking). Combining m-learning and games can create a learning environment in which children learn while having fun.

The authors' main research goal is to create a model of mobile game-based learning suitable for primary school children. Such learning would be more exciting and motivating. Based on the proposed model, a mobile game application was developed for learning mathematics for students in the 3rd grade, which could be applied alongside traditional learning in a classroom or independently at home.

Section 2 shows the state of the art in the field of modern innovative learning approaches. Section 3 describes the model of a mobile educational game, including the learner model, didactic model, behavioural model and functional model. Section 4 describes the developed mobile game application

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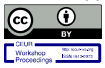

and the conducted experiment. The article ends with a conclusion which focuses on the contributions of the study and the future plans of the authors.

2 Modern innovative educational approaches

The advent of new technologies helps to integrate innovative learning approaches into traditional teaching. Particularly in recent years, with the constraints caused by COVID-19, the use of m-learning has increased dramatically. Some authors define the concept of m-learning in terms of the devices used, others in terms of the pedagogical approach applied. **M-learning** helps students create social interaction, promotes collaborative learning, and improves their learning, achievement, and motivation [1]. [2] states that students are more likely to engage when learning with mobile technologies. Another contemporary approach that is increasingly used in schools is **game-based learning**, where games are used as a medium for teaching content as well as for testing and assessment [3]. One of the fastest growing trends among interactive learning methods is the use of **mobile learning games**. Mobile educational games, unlike other games, in addition to offering fun, should be able to capture children's interests and make them think logically, think spatially, draw conclusions, make connections to their daily lives and apply what they learn in school. The effectiveness of mobile educational games is due to the following important features: motivation, interactivity, adaptability, personalization, feedback, game design, etc.

M-learning can be very effective in learning mathematics in primary school. In an attempt to engage children in learning in mathematics classes, many teachers use math games and fun activities, and many researchers design and develop mobile educational games. [4] designs and develops a mobile application called Hi-Math as a game-based learning experience for children in the 3rd grade aimed at acquiring basic mathematical skills in arithmetic. [5] develops a game to help children understand fractions. The game includes an adaptive mechanism that records player performance (correct and incorrect answers) and adapts the next level questions to meet the player's specific learning needs. [6] also develops and presents a game-based mathematics learning mobile app for primary school learners. Students must solve the math problems to complete the mission challenge. Mobile game-based learning has many advantages. According to [7], mobile games reveal learning material in an interesting and enjoyable way – images, sound effects, and movements attractively complement each other, making the student active, effective, and willing to learn. The mobile game also allows you to play without time and place restrictions.

M-learning is fully compatible with the **flipped classroom** approach – a pedagogical method in which the typical class lesson and homework switch places. [8] describes the four pillars of the flipped classroom method: F (flexible environment) – learners choose when and where to learn; L (learning culture) – students make the transition from being the product of teaching to being the center of learning; I (intentional content) – learners are required to plan content and consider what they need to teach in the classroom; and P (professional educator) – qualified professional educators are more important than ever, as they determine when and how discussions, exercises, and other learning activities take place. Mobile learning applications can be used for independent learning at home.

Adaptive approaches can be used to provide personalized learning. **Adaptive learning** is an educational approach that provides learning resources and activities tailored to the specific needs of the individual learner, which supports better learning. The main characteristics of adaptive learning are flexibility, motivation, engagement, personalization, adaptation, feedback, accessibility, etc.

Three main types of adaptability of e-learning systems are most often mentioned in the literature [9]:

- User interface adaptation – the interface is dynamic, with its elements changing their appearance and position;
- Adapting the learning process – the learning path is dynamic, going through activities depending on the knowledge and skills of the learner;
- Adapting learning content – learning resources dynamically change their content.

Suitable for use in m-learning is **micro learning**, which is implemented on the basis of very short lessons lasting no more than 5 minutes [10]. Micro learning provides small learning units or short-term learning activities. Even through micro lessons, some of the learners' knowledge and skills on a specific topic can be assessed in a shorter time without the need to create special testing conditions [11]. [12]

notes the following advantages of micro learning: better knowledge retention, ideal for mobile learning, more cost-effective, quickly fills gaps in knowledge presentation and increases learner motivation.

The most widely used approach during the COVID-19 pandemic was **blended learning**, a method in which the positive aspects of face-to-face learning and e-learning complement each other [13]. [14] highlights the following advantages of blended learning: greater effectiveness with larger groups of learners; skills development support; flexible learning; broad access to digital resources, shared tools and information systems.

Anywhere, anytime learning, which is most directly related to mobile technology, is known as **ubiquitous learning** (u-learning). It offers teaching where computer-based learning processes are fully integrated with the learner's daily activities. Sometimes it can be seen as an integration of m-learning and e-learning, which allows customization to the actual needs of the learner [15].

3 A model of a mobile educational game for children in primary school stage

A mobile game-based learning model suitable for primary school students is proposed. The approaches chosen to implement mobile learning are game-based learning, adaptive learning, micro lesson learning and behaviour monitoring learning.

Initially, a **generic cyclic learning model** containing the following steps was developed (Figure 1.):

- Exercise – learners solve problems presented as games;
- Evaluating – solved problems are graded automatically;
- Rewarding – based on the evaluation "rewards" are received from the game;
- Support – learners receive it the first time they fail a task;
- Teaching – learners receive micro lessons when they repeatedly fail to solve a given problem type;
- Ranking – learners are ranked at the end of the game, based on their scores against the other participants in the game.

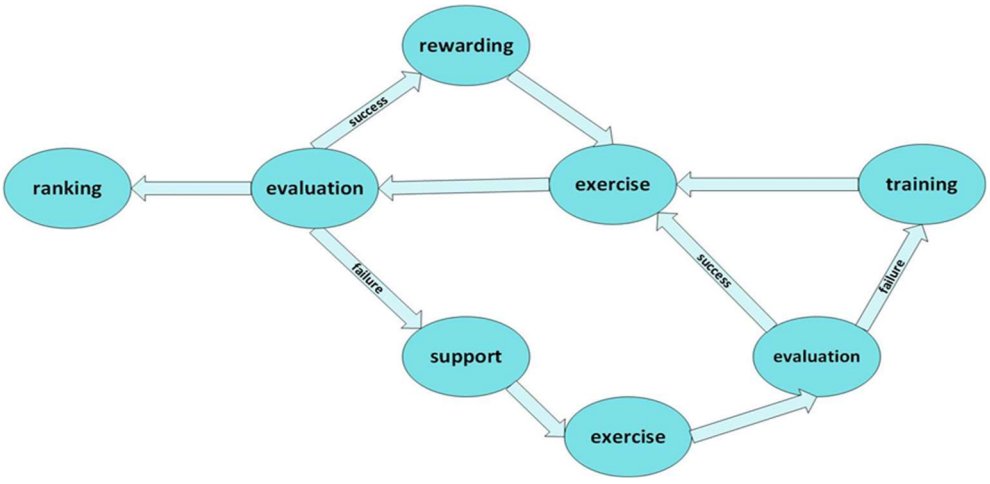

Figure 1: A generic cyclical learning model

3.1 A learner model

The triple *(G, S(d, t), A(d, t))* is a formal **model of mobile game-based learning**, where *G* is the set of learning objectives, *S* is the set of learning resources, and *A* is the set of learning activities that depend on *d*, the difficulty level, and *t*, the time to complete the learning with the corresponding item.

A learner model is constructed which can be formed based on three submodels:

- **learning model** (learning achievements),
- **game model** (in-game achievements) and
- **behavioural model** (data reported during play).

The **learner model** is the triple *M = {Me, Mg, Mp},* where the **learning model** *Me = {G, S, A, Gs, Gu}* is a quintuple of the sets *G* – learning goals, *G = Gs U Gu*, *S* – learning resources used, *A* – learning activities performed, *Gs* – goals successfully achieved and *Gu* – goals failed.

The learner's **game model** Mg={a, l, R, T, c} represents a quintuple of the sets *R* – rewards received of different types (bonus, reward, combo, and badge) and *T* – time saved from activities performed and the elements: *a* – avatar used, *l* – level achieved, and *c* – rank relative to other learners.

The **behavioural model** of the learner *Mp={I, B, E}* represents a triple of sets that are interrelated: *I* – interactions with the environment, *B* – behaviour of the learner, and *E* – emotions of the learner.

3.2 Application of game elements and techniques

Research has been done on the game elements and techniques that exist in games and can be used in mobile game-based learning [16]. The following elements and techniques have been chosen for the design of an individual game:

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

In Figure 2. a model of a game-based learning process with the application of game elements and techniques is presented.

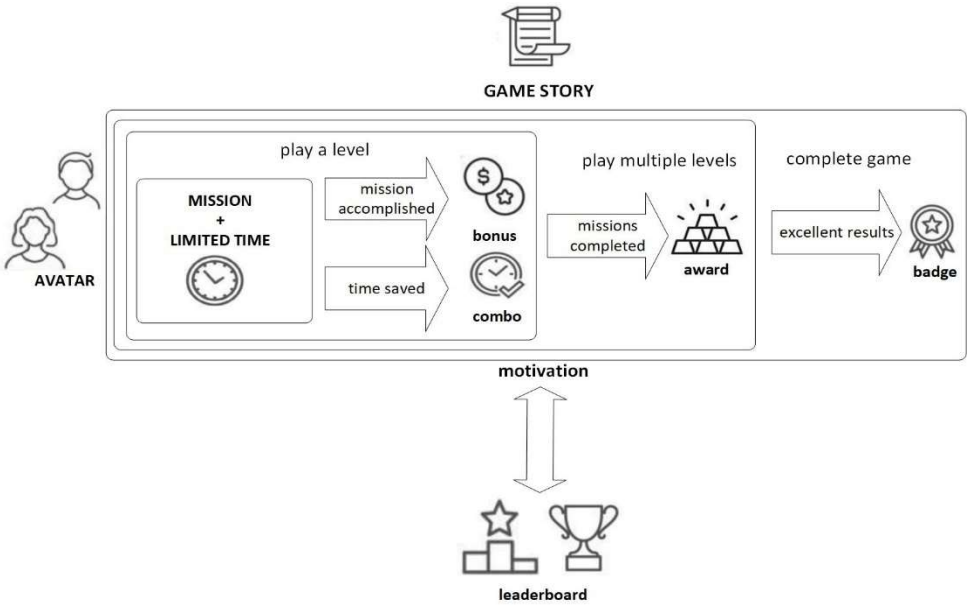

Figure 2: Learning process model – game-based part

An adaptive methodology is implemented depending on the correctness of the answer (Figure 3), the difficulty of the mathematical problem, and the time to solve it. Students are given **randomly generated math problems (missions)** that are of varying degrees of difficulty, depending on the previous mission. The missions (tasks) have to be accomplished in a certain amount of **time**.

Students receive **automatic feedback** indicating the correctness of their answer after each solved math problem.

For successfully completed missions (if answered correctly), students receive **bonus** points (or virtual objects) to collect. The prototype implementation of the methodology used coins as bonuses. The amount of coins you receive varies by mission difficulty level and corresponds to the difficulty of the missions: 3 coins for high, 2 coins for medium, 1 coin for low, and 0 coins for failure. The difficulty of the problem depends on the time it takes to solve the previous problem. Therefore, the coins received depend on both the difficulty of the tasks and the time it takes to solve them.

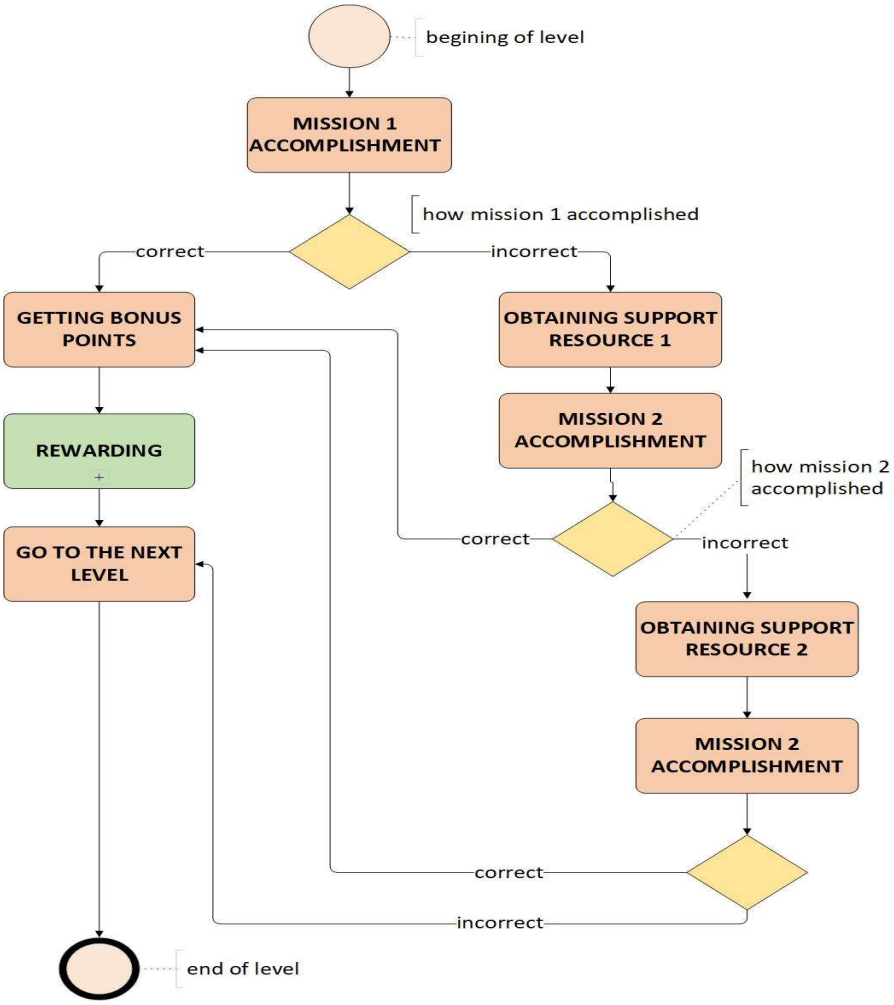

Figure 3: Game level model

Upon collecting a certain amount of bonuses, learners receive **rewards** – virtual items. In the implementation of the methodology, for every 6 coins, students receive 1 gold bar as a reward (Figure 4).

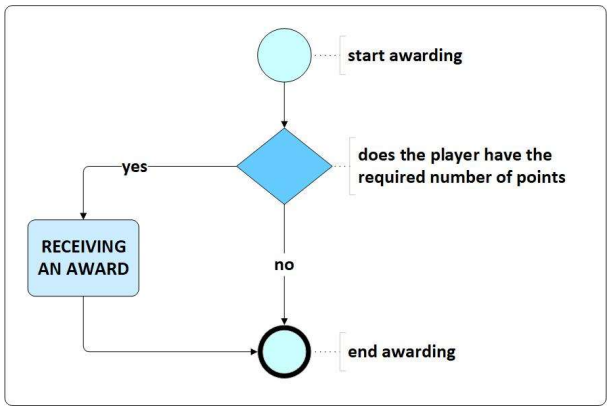

Figure 4: Receiving an award

For good results, learners get **a combo** to use as an advantage over other players. When correct answers are given in less time than the target time, students save unused time that they can use later in subsequent missions. In the case of an incorrect answer, the students receive **a hint** (a guiding text to

help with the solution) and a second problem of the same type in the same game level but one difficulty level lower, if available, or the minimum difficulty level is maintained. In the case of repeated incorrect answers, learners are given a short educational video (**micro lesson**) to bridge the knowledge gap. The same problem is then repeated. The aim of the game is to collect the maximum number of virtual objects (coins and gold bars) in a minimum amount of time. After the game is completed, the results of the participants are displayed in **leaderboard** by the number of coins won and by time, in case of a tie. The true identity of the learners is hidden, as they are displayed on the leaderboard through an avatar. Also, at the end of the game, upon successful completion, students can receive **a badge** depending on their score (Figure 5).

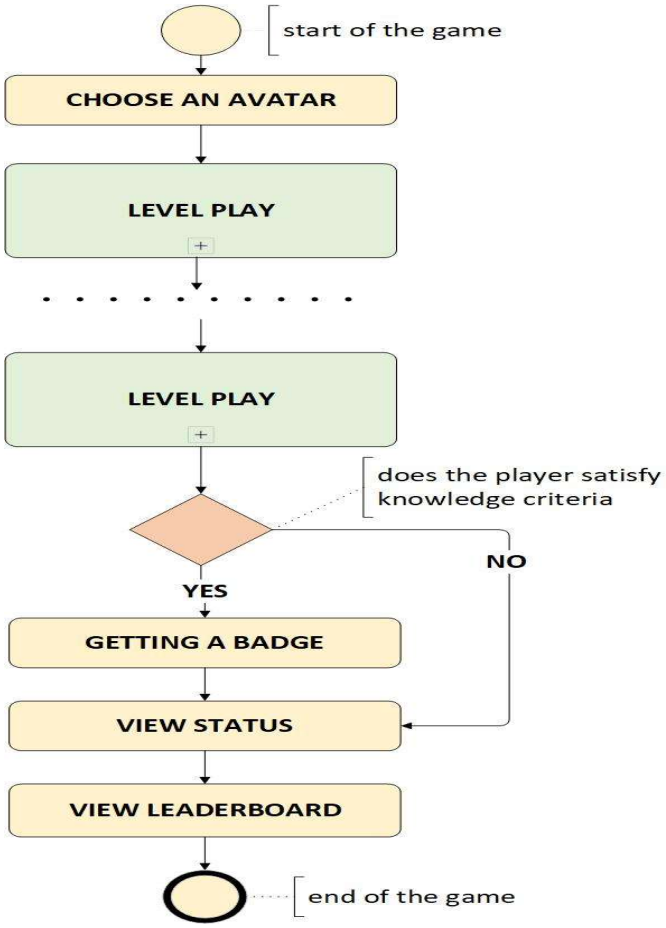

Figure 5: Model of game

At each level, learners should see their current **status** (e.g., total points (coins) earned, number of points (coins) for the current level, number of rewards (gold bars) earned, time spent on the current level (current timer), unused time earned from previous levels, and current **progress**.

A complete presentation of the game model implemented in the game prototype is given in [16].

3.3 Application of adaptability

The instructional model is designed to implement adaptability of learning content and adaptability of the learning process.

The adaptability offered is based on different types of tasks arranged in game levels; the difficulty of the tasks; the success or failure of the learner; and the time taken to solve the game tasks.

The adaptability of the learning content is achieved by:

- selecting different types of tasks for different levels in the game;

- choosing tasks of a certain difficulty;
- the automatic generation of tasks with different values of a given type;
- offering different kinds of help for the learner as additional learning content.

The adaptability of the learning process is realized through:

- change in the difficulty of the levels (the type of tasks);
- change in the difficulty of the tasks to the next level depending on the success or failure of the learner;
- change in the difficulty of the tasks depending on the time used to solve;
- level repetition with a task of lower difficulty on failure;
- providing help when the learner fails;
- providing incentives for learner success.

The methodology of the adaptive approach is represented using an activity type UML diagram in Figure 6. where the following notations are used:

d – difficulty; *dmax* – maximum difficulty; *dmin* – minimum difficulty; *t* – target time; *tu* – time used; *ts* – time saved.

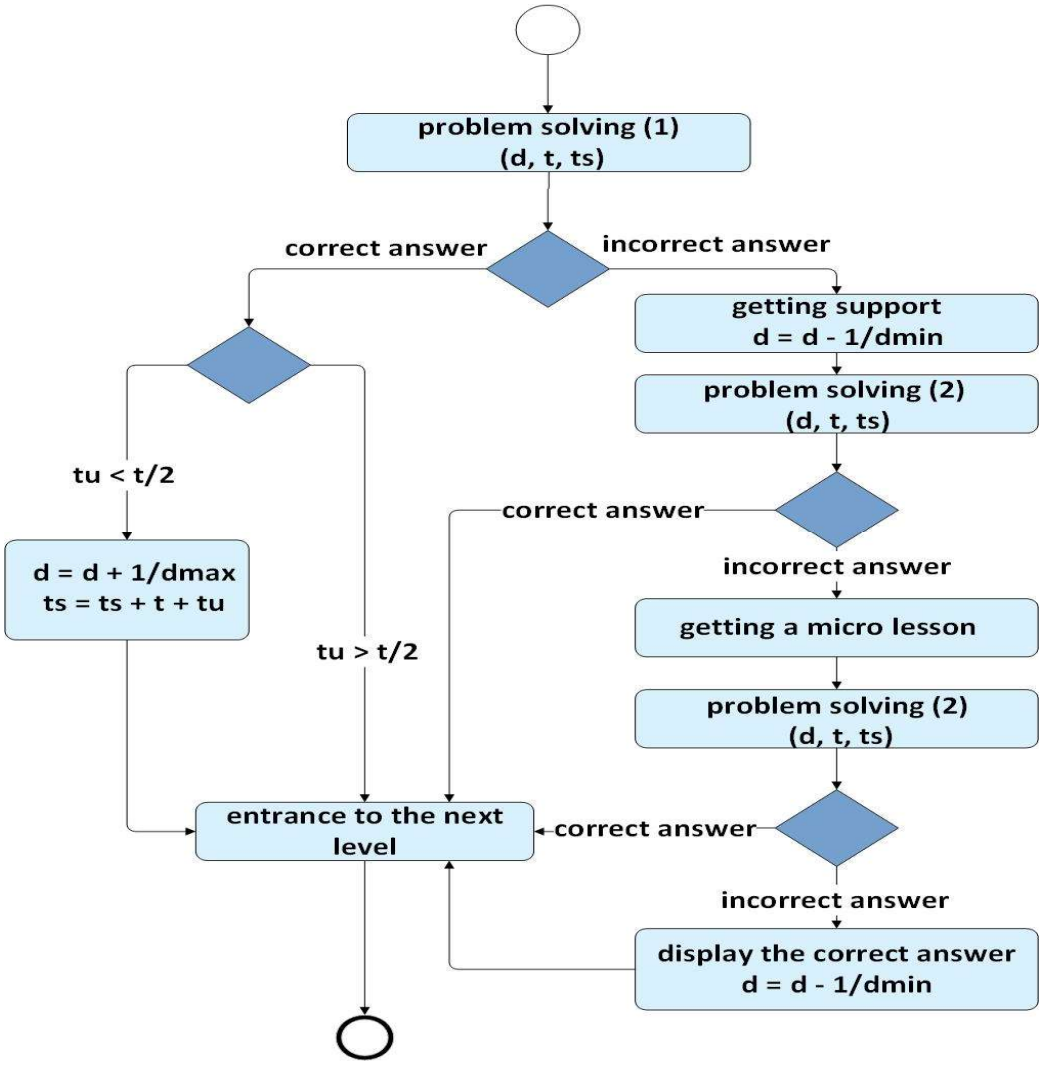

Figure 6: Methodology of the adaptive learning process

A complete presentation of the implemented adaptability in the game prototype is given in [17].

3.4 Application of micro learning

In the proposed mobile game model, **short textual hints** are used on how to solve the problem (on the first failure), on the second failure at the same level of the game – a video example (**micro lesson**), and on the third failure – a correct answer to the wrong mathematical problem (Figure 7.).

The application of micro tutorials plays an important role in the proposed model of mobile game-based learning with an adaptive approach, thus learners receive a personalized approach and support. Through them, the goals of the adaptive methodology are achieved, namely that students cope with difficulties, do not lose motivation and without feeling like losers move confidently forward in the game.

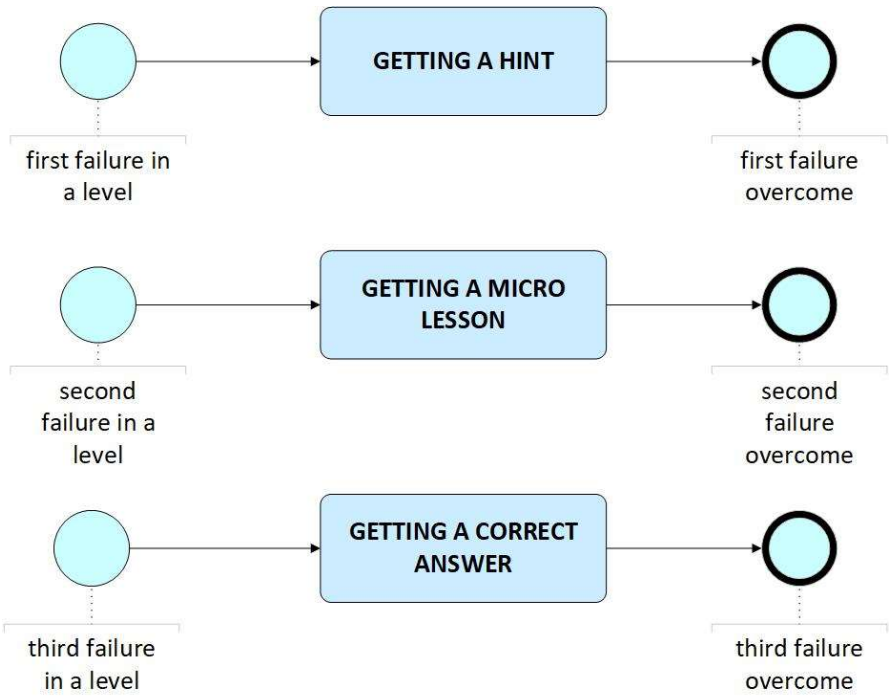

Figure 7: Getting support at the game level

A complete presentation of the implementation of micro learning in the game model underlying the game prototype is given in [16].

3.5 Didactic model

A didactic model of mobile game learning is proposed, which presents in a generalized form the stages in the process of knowledge formation in a mobile game environment. The tools, objectives, principles, methods, and forms of interactive learning find their place in the built structure of the model, being integrated directly into the mobile game. In Figure 8., a didactic model of learning in a mobile game environment is presented. The main activities of the two main roles (teacher and student) in the learning process are presented. The teacher, using interactive mobile game-based learning, delivers the learning content in an optimal, easy, accessible, and interesting way, tailored to the students' abilities.

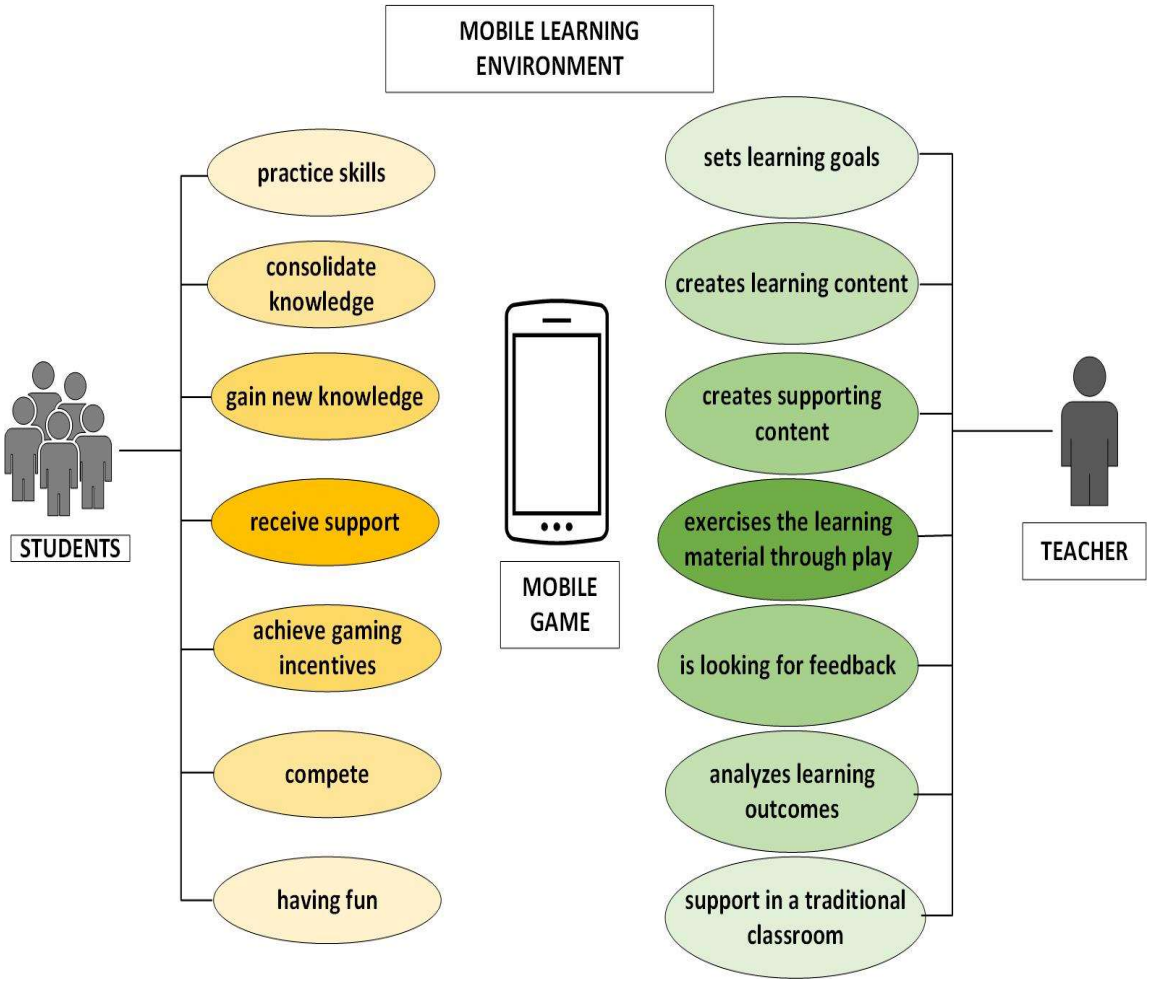

Figure 8: Didactic model of a mobile educational game

3.6 Behavioural model

Data is needed to analyze a child's emotions and behaviour during or after a learning game. Data can be reported during game play with the appropriate software. Possible data that can be collected automatically are, for example: noise level (in decibels) around the mobile device, number of sudden movements of the mobile device, number of switches to other applications, and presence of a connection to the Wi-Fi network and the Internet. The behavioural data collected can help the teacher in forming an assessment or analyzing student behaviour. Different combinations of values of these indicators can define different behaviour profiles. The increasingly popular personalized learning approach requires teachers to provide instruction and support based on students' specific characteristics and their ongoing academic progress.

Another paper focuses on the detailed representation of the behavioural model in the game prototype.

3.7 Functional model

The main idea is to use the prototype on different mobile devices to learn, exercise, test and entertain learners. The proposed functional model is developed in two directions – **building user functionality and data synchronization.**

The mobile game-based learning model is subordinated to constructivist ideas – the learning material is structured in logically connected levels (missions) and requires solving certain tasks. Pedagogical situations are created in which learners become active participants. The educator can apply mobile game-based learning in introducing new knowledge or in reinforcing knowledge (Figure 9.).

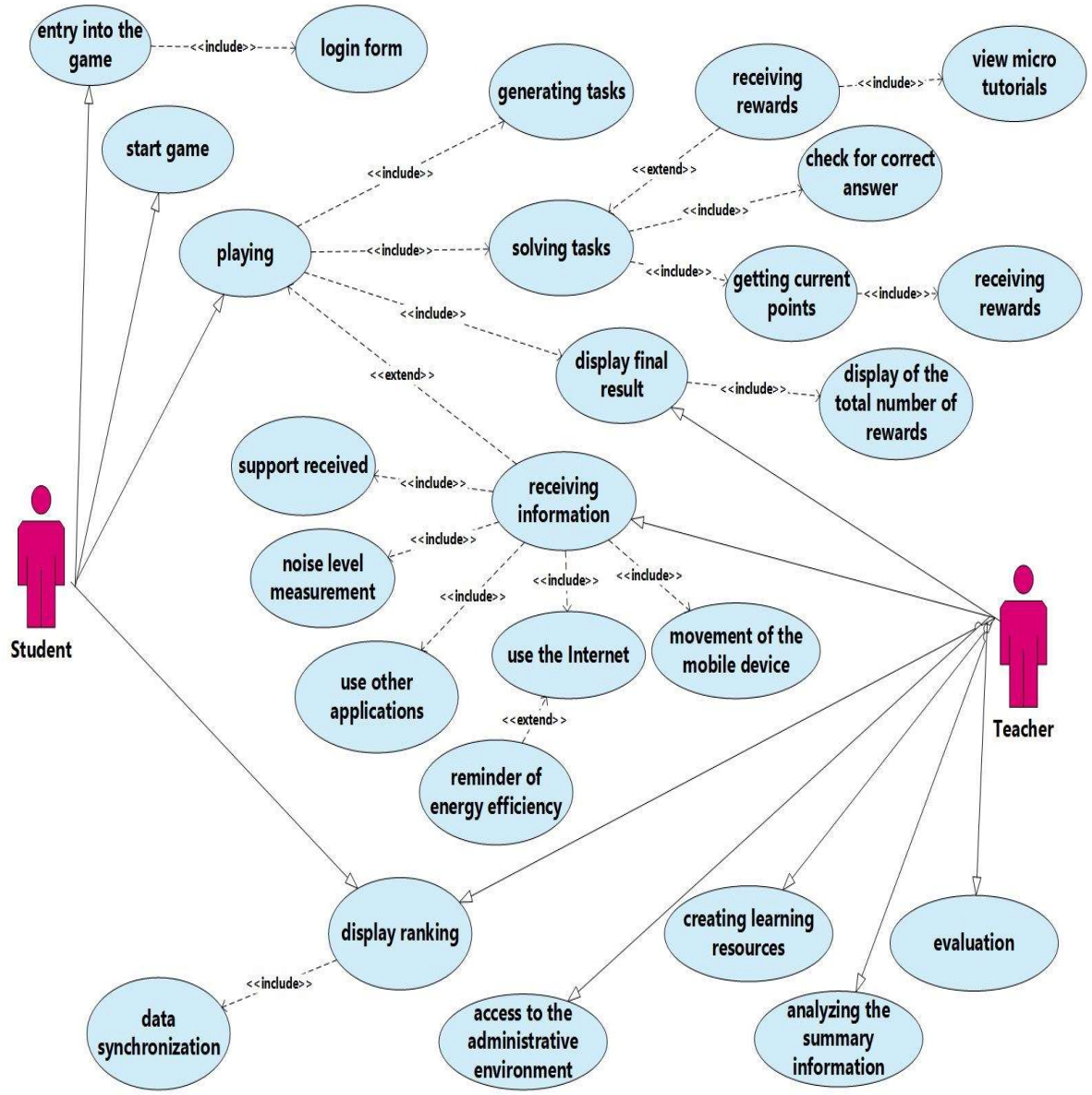

Figure 9: The Game environment and roles of participants in the learning process

During a game, players' scores are recorded in a local database. When the game is played by multiple participants on different devices, anywhere and anytime, the need for synchronisation of results arises. It is necessary to synchronize the data (results) between all players and to generate an up-to-date ranking at each moment of completion for a specific player. In the proposed model, an approach using **web services** is chosen. Mobile applications send requests to the web server. The received requests are processed by the web server, which communicates with the server database (Figure 10.).

The data is sorted by specific criteria (according to the query) and returned as a response on demand to mobile devices. Finally, a synchronized ranking is displayed for all participants. It can be organised according to different criteria, e.g. number of points, time, etc. In the proposed model, the ranking data is also visualized in a web application. From it, the teacher will have access to all the information about the players. The teacher will have insight into the overall performance of the children during play and can analyse results, implement support, adapt teaching strategy and set assessments.

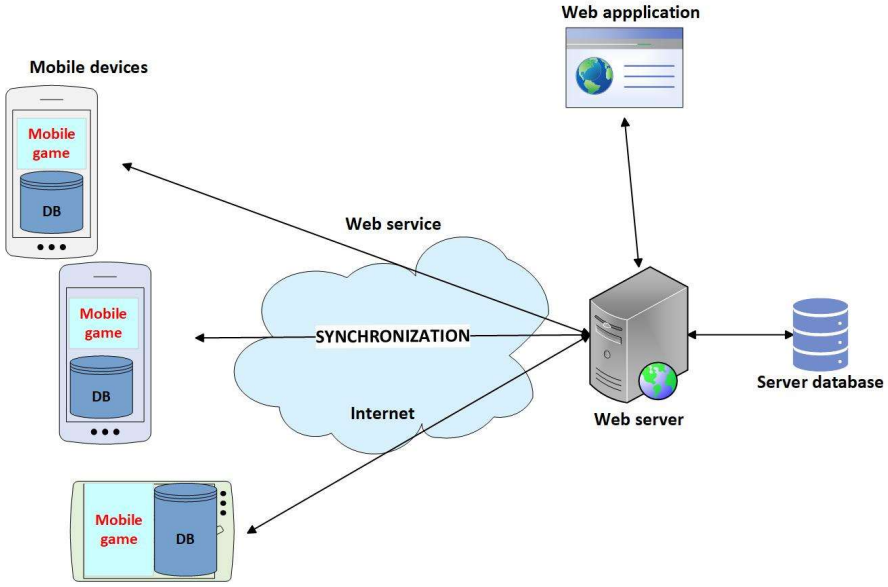

Figure 10: Mobile data synchronisation via web service

4 Prototype of a mobile game-based learning system

Based on the created model of game-based learning, a prototype of mobile game application for mathematics education for students in 3rd grade was developed (Figure 11.). The game application uses the classification of game tasks [18], which is suitable for mobile implementation and for the corresponding age group of learners, and the corresponding game task templates created [19]. The game follows 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. 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 request) 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 teachers decide how to support learners in subsequent learning.

Figure 11: Level 7 – free-fill-in-answer template

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: "User Interface" (for a graphical interface visualizing all the elements of the game), "Functionality" (contains all the functionality representing the game logic), "Databases" (where the game learning flow data is stored) and "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.

The software prototype has been tested in a real classroom environment with 17 third grade students from Yane Sandanski School, Plovdiv, Bulgaria and 10 primary teachers. A survey with questions (different for students and teachers) was conducted to gather opinions, impressions and recommendations. The research methodology is based on surveys designed with Google Forms. The survey questions are divided into the following five sections: Practical applicability, Motivation, Design, Accessibility, support and feedback, and Open-ended questions.

5 Conclusion

When implementing an innovative learning model, it is necessary to look beyond the traditional boundaries of the classroom to use best practices to maximize results. Every learner should be given the opportunity to become an active participant in the learning process.

A common model of mobile game-based learning suitable for primary school children has been created. A player (learner) model is proposed based on the following approaches: game-based learning, adaptivity, and micro learning. Appropriate game elements and techniques are chosen to be used in the proposed model and to increase the learners' interest and motivation to learn. The learning model incorporates an adaptive methodology based on task difficulty, learner support or assistance, and problem-solving time. In the case of failure, the micro learning methodology is also applied, with learners receiving either text prompts or micro lessons, depending on the order of failure. Didactic, behavioural, and functional models are proposed that can be used to create both a game application and a mobile game platform.

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