An Attempt of Adaptability of The Learning Process and Content in Mobile Math Educational Game

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Abstract. The paper presents a design of a mobile serious game, suitable for primary school students, consisting of a set of tasks for solving. The design offers adaptability in terms of the learning process (learning sequence) and content. Adaptability is realized depending on the success/failure of the students and spent time for solving the tasks, the task difficulty and task type. The motivation of the learner is provoked by collecting points and virtual objects. To experiment the applicability of the design, a prototype of an educational math game for the third- grade students based on the templates (12 kinds of elementary games, suitable for mobile realization and this age group) is created. Math problems are presented in different game levels, where students can collect coins and gold bars, depending on their learning progress.

INTRODUCTION

The "digital kids" generation has now grown into "mobile kids" who are very familiar with mobile devices from an early age. That is why mobile technologies have naturally entered the education of even the youngest students. Students are accustomed to use mobile devices for entertainment, playing games whose motivating forces are well known. The number of teachers who turn to educational mobile games to help students achieve their learning goals is increasing. Mobile educational games can be used for both learning and testing, and they can apply on the one hand the pedagogical approaches of traditional or e-learning, and on the other hand the game approaches of e-games.

A trend in educational games is their adaptation in different directions (user interface, learning process and learning content). Adaptive educational games are adapted depending on the player's preferences and behavior, current learning progress/failure, the pace of learning and the mobile device used. In this kind of mobile learning, students' study in a pleasant, self-paced and children friendly electronic environment.

Mobile adaptive games allow the student to gradually achieve educational goals by moving through the game levels. The same knowledge can be presented/evaluated differently in more than one level of the game. In addition, learners are accustomed to repeat the levels in the games, chasing better results, which will naturally lead to the consolidation of knowledge.

The main goal of the research, presented in this paper, is to develop a design of game-based learning with adaptability, which to be implemented in a prototype of a mobile mathematical game for the students from primary school.

Section 2 shows the state of the art in the field of adaptiveness. Section 3 proposes a design for adaptation of the content and learning path in a mobile game for primary school. Section 4 presents the developed game prototype with

the set game adaptive methodology and software implementation. The article ends with a conclusion which focuses on the contributions of the study and future plans of the authors.

ADAPTIVE E-LEARNING

Intelligent tutoring systems [1] are generations of computer-based educational systems that support the teaching and learning processes with the aim of helping students to achieve maximum number of learning goals. Intelligent tutoring systems [1] are made up of four basic components: the student model, the tutor model, the domain model and the user interface model. An important characteristic that distinguished intelligent tutoring systems from the older versions of e-learning systems is adaptiveness, a feature that gives the system the abilities to personalized tutoring services and inspires students to learn both simple and complex cognitive tasks [2].

Three main types of adaptability are distinguished in [3]:

- adaptation of the user interface (interface-based);
- adaptation of the learning process (learning flow-based);
- adaptation of the learning content (content-based).

This paper is oriented to content-based and learning flow-based adaptiveness in e-learning via mobile devices.

Adaptive e-learning is an educational approach that provides e-learning services and learning materials specifically tailored for adaptive learning, aiming to combine the ability to understand and discover the specific needs of a learner with the appropriate pedagogical strategy to improve the learning process [4]. Adaptive learning according to [5] is based on constructivist theory and the theory of cognitive flexibility. It is an active learning, where learners can monitor their learning process and choose the most appropriate learning content according to their real needs.

Adaptive e-learning is a modern educational approach that is designed to provide a unique e-learning environment suitable for the needs of each student. The environment adapts itself according to different learning methods and models that are implemented in the corresponding learning system. The adaptive software system aims to adapt its behavior and provide its functionality to users following their preferences, educational goals, learning style, level of knowledge, behavior in the system, etc., to achieve an effective learning outcome [6]. Balanced formula for adaptability involves three main components: learner, teacher and a set of predefined rules set by the teacher. Adaptability is usually focused on the learner.

[7] models the mobile learning course as a weighted, directed graph where each node represents a course unit. This learning path graph represents and describes the structure of domain knowledge, including the learning goals, and all available learning paths. [7] also proposes a system prototype that implements an adaptive learning path algorithm that uses the student's information from their profile and their learning style to improve the students' learning performances through a mobile learning system that provides a suitable course content sequence in a personalized manner.

Adaptability is a natural feature of game scenarios, so nowadays a lot of adaptive learning is realized through serious games (games designed for learning).

Some games propose an adaptation of the next level only on the base of learner's results from the previous level, e.g. For example, [8] presents an adaptive mobile math game Pizza al Lancio for primary school, for developing skills in the multiplication table and fractions, which adapts the questions of the next level.

Another similar learning game is developed by [9] – an adaptive mobile casual game (compatible with Android mobile devices) for pupils of the 1st, the 2nd and the 3rd grade for practicing their skills in the multiplication table. The game incorporates an adaptation mechanism that records player performance (correct and wrong answers) and adapts next level's questions to match the player's learning needs.

An adaptive model based on four main aspects of adaptive mechanical games: dynamic difficulty adaptation, adaptive flow, gameplay schemes and the use of frustration, is developed by [10]. Their serious game Number to Number Combat combines feedback based on the dynamic adaptation of difficulties, player performance and adaptive flow.

[11] presents an adaptive mobile learning system that provides learners with adaptive content according to their knowledge levels, learning styles, and heterogeneous learning devices. The system exploits Bayesian networks and content adaptation technologies to support both learner adaptation and device adaptation, allowing each learner to construct a personalized and adaptive learning environment.

[12] connects concepts of mobile learning and flipped classroom. [12] proposes an approach called Smart Enhanced Context-Aware for Flipped Mobile Learning "SECA-FML", implemented in Android mobile application,

aiming to provide learners with an adapted course content format (especially multimedia content) based on their context by taking into account the different context dimensions and the mobile device context.

[13] presents the new architecture of the educational learning game authoring tool "e-Adventure", generating an adaptive Ubiquitous learning game for multiple mobile platforms. Also [13] adds the learner model during the game design to create an interesting game for different learner profiles.

[14] proposes a game design approach, building context-adaptive games based on a model of the game structure and a generic adaptation model. Their method consists of designing different game scenarios involving different gameplay for the game then, game engine selects and proposes the appropriate one according to the context.

As part of the adaptive learning process is the adaptive assessment applied in Computerized Adaptive Tests (CAT), which adapts the complexity and number of test questions to the learner's level, to obtain greater accuracy in the assessment. For example, [15] presents the Adaptive Formative Assessment in Context-Aware Mobile Learning approach, where the goal of this approach is to provide learners with an adaptive and personalized formative assessment taking into account the learner context based on the CAT theory.

The more complicated approach is presented in [16] where learning and assessment in the system are adaptable based on knowledge, competencies, preferences and needs of the learner. In [17], an example of electronic adaptive assessment of students has been constructed on the basis of a generalized net model with intuitionistic fuzzy estimations.

Microlearning is becoming a very popular learning trend. It can be defined as very short and bite sized lessons lasting no more than 5 minutes [18]. As [19] mentions, microlearning has advantages as improved knowledge retention, is perfect for mobile learning, more cost efficient, rapidly fills performance gaps and boosts learner's motivation. [20] points that "young people are not nowadays interested in spending time by listening to the lectures" and that " they select the knowledge and skills, which usefulness they can imagine or prove in a short time".

With the expansion of popularity and widespread use of mobile devices in recent years, research on the applicability of the concept of microlearning is growing. Authors as [21] believe that mobile microlearning applications are more effective, flexible and enjoyable.

We believe that a mobile educational game with built in micro-lessons can be a successful learning tool especially for primary school students because it does not require very long attention from students and micro-lessons have small learning objectives, suitable for this age group.

DESIGN WITH ADAPTATION OF THE CONTENT AND LEARNING PROCESS IN A MICROLEARNING-BASED MOBILE GAME

We propose a design of a microlearning-based mobile game with adaptability suitable for children in primary school. The design offers an adaptation of the learning process and the learning content to improve the learners' experience and learning outcomes. The design is based on game **levels with tasks** for learners that they have to solve during the game, taking into account the success/failure and time of solving the tasks, task difficulty and task type.

Because the game is for small children, only 3 **types of difficulty** (1, 2 and 3) are used. The game starts with medium difficulty (2) and target time for each level.

If the **time** for solving the task is less than half of the set target time, then the learners at the next level will receive a task of greater difficulty (if any, after 3 the difficulty does not increase). Also, if learners solve a task in less than the set target time, they collect the remaining unused time and can use it to solve the next tasks.

The game-based learning is designed to support students in **failure**. If the students cannot solve the task at any level, they will receive the new similar task of the same task type, for the same level, but with less difficulty (if any, after 1 the difficulty does not decrease). In case of failure, the learners also receive **adaptive help**: a hint at the first mistake and supportive learning material (micro-lesson) at the second mistake. If students wish, they can repeat the level they did not cope with or continue to the next level with 0 points. The game always continues with the current difficulty and the new target time of the upcoming level, increased by the time collected so far, no matter where the game will continue – forward to the next level or backward to repeat the same level.

The game design is based on **rewarding** students with success to motivate them, through these incentives, to continue to play (learn and/or practice). For each successfully solved task, the players receive points, which are equal to the current difficulty. When the players collect 6 points, they are exchanged for the virtual object. The player's goal is to collect maximum virtual objects for a maximum collected time (i. e. for minimum time to solve tasks).

Figure 1 shows the pseudocode implementing the proposed game-based learning with adaptability.

```
Function start_level
Pass in: level, difficulty, points_for_level, points_for_all_levels, awards, collected_time
DISPLAY task1(difficulty)
IF Call answer_is_correct (task1, level_time + collected_time)
THEN
IF level_spent_time < level_time / 2
THEN
Call increment (difficulty)
points_for_level := points_for_level + difficulty
                        points_for_all_levels := points_for_all_levels + difficulty
ELSE
                        points_for_level := points_for_level + difficulty
                        points_for_all_levels := points_for_all_levels + difficulty
ENDIF
ELSE
                Call decrement(difficulty)
                DISPLAY task2(difficulty)
                SHOW hint
IF Call answer_is_correct (task2, level_time + collected_time)
THEN
                        points_for_level := points_for_level + difficulty
                        points_for_all_levels := points_for_all_levels +difficulty
                        Call increment (difficulty)
ELSE
                        Call decrement(difficulty)
                        points_for_level := 0
                        SHOW supporting_learning_material (micro-lesson)
                        SHOW correct_answer(task2)
                ENDIF
        ENDIF
IF coins_for_all_levels > 6
THEN
        awards := awards + 1
        points_for_all_levels := points_for_all_levels - 6
        ENDIF
collected_time := collected_time + level_time - level_spent_time
SHOW level, points_for_level, points_for_all_levels, awards, collected_time
IF not want to repeat level
THEN
        level := level +1
        ENDIF
        Call start_level(level, difficulty, points_for_level, points_for_all_levels, awards, collected_time)
Endfunction
```

FIGURE 1. Game-based learning with adaptability (pseudocode).

PROTOTYPE FOR ADAPTIVE MOBILE GAME

The proposed design is applied and tested in a prototype game for learning mathematics for children from 3rd grade. The game is designed on the basis of 13 game types, presented in [17] – 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.

The developed game supports learning on the topic "Addition and subtraction of numbers up to 1000 without passing". The game contains 8 levels of different game types suitable for this math topic.

Students have to solve math problems, randomly generated and ordered in levels – 1 math problem per 1 level for a target time of 5 min (for this experimental game). If the students cannot solve the problems at any level, they will receive help: in the first failure – a hint on how to solve the problem and in the second failure - a video example and a correct answer to the last mathematical problem.

This game prototype allows students to collect coins depending on the difficulty of the math problem – 2 coins for medium, 3 coins for high, 1 coin for low and 0 coins for level failure. Every 6 coins are exchanged to 1 gold bar. The main game goal is to collect the maximum number of gold bars for the minimum time.

If the learners interrupt the game at an intermediate level, when revisiting the game, they continue to where they have reached.

If more than one player is registered on one mobile device, the game also generates a ranking showing the collected coins and bars for each player.

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 the preferred operating system over iOS based on statistics on mobile operating systems used worldwide and in Bulgaria [17].

All of the vector images in the game are used under a standard license allowing for royalty-free use in design. 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 conditions.

To store players' profiles and show current progress and achievements and final ranking, the SQLite database is used.

FIGURE 2. Example of the mobile math game.

CONCLUSION

The paper presented a design for adapting the learning path and content of an educational game suitable for primary school, which is experimented in a specific mathematical mobile game. As a main advantage of adaptability, it can be noted that the realized game is suitable for all groups of students, regardless of the level of knowledge. Adaptability protects against demotivation, both the stronger students, who receive more difficult tasks and the weaker students - with easier tasks and support in case of failure.

The game aims to increase the level of knowledge of learners, not just to assess it. In case of failure, the game prototype offers support on two levels – through a hint and a micro-lesson, followed by visualization of the correctly solved math problems.

The game also maintains the interest of learners by entertaining them, providing them with game rewards to strive for and that is closely linked to the progress made in learning. Through the mobile game, students discover a new visually expressive, educationally impacting and interesting way to study, which can be used for self-study at home or school if the teacher wishes to use the new technologies in the classroom.

Future work will be dedicated to automating the process of creating games from the developed set of game templates, which teachers will be able to organize and set various specific tasks.

REFERENCES

1. S. Sani, T. Aris, N. Mustapha and N. Sulaiman, "Student Modeling: An Overview" in International Journal of Advances in Computer Science & Its Applications– IJCSIA (2015),Vol. 5, Issue 2, ISSN: 2250-3765.
2. R. K. Koedinger and T. A. Corbett, "Cognitive tutors: technology bringing learning sciences to the classroom", edited by R. K. Sawyer, The Cambridge handbook of the learning sciences, New York (2006): Cambridge University Press, pp. 61–78.
3. L. Velsen, "User-centered evaluation of adaptive and adaptable systems: a literature review", The Knowledge Engineering Review Journal, Cambridge University Press (2008), Vol. 23:3, pp. 261–281.
4. P. Brusilovsky, "Efficient Techniques for Adaptive Hypermedia", Intelligent hypertext: Advanced techniques for the World Wide Web, Lecture Notes in Computer Science, Vol. 1326, Berlin 1997: Springer-Verlag, pp. 12-30.
5. L. Qing, Z. Shaochun, W. Peng, G. Xiaozhuo and Q. Xiaolin "Learner Model in Adaptive Learning System", Journal of Information & Computational Science (2010), 7: 5, pp. 1137–1145.
6. P. Brusilovsky and C. Peylo, "Adaptive and intelligent Web-based educational systems", International Journal of Artificial Intelligence in Education 13 (2-4), (2003) Special Issue on Adaptive and Intelligent Web-based Educational Systems, pp. 159-172.
7. A. I. Alshalabi, S. Hamada, K. Elleithy, I. Badara and S. Moslehpour, "Automated Adaptive Mobile Learning System using Shortest Path Algorithm and Learning Style", International Journal of Interactive Mobile Technologies (iJIM) 12(5):4, (2018). DOI: 10.3991/ijim.v12i5.8186.
8. O. Gaggi, F. Ciraulo and M. Casagrande, "Eating Pizza to learn fractions" in ACM International Conference Proceeding Series, (2018), pp. 220-225.
9. A. Leonardou and M. Rigou, "An adaptive mobile casual game for practicing multiplication", Proceedings of the 20th Pan-Hellenic Conference on Informatics, (2016), DOI:10.1145/3003733.3003798
10. J. Tremblay, B. Bouchard and A. Bouzouane, "Adaptive game mechanics for learning purposes: making serious games playable and fun", LIARA laboratory, Université du Québec à Chicoutimi, Québec, Canada (2003).
11. Ho-Chuan Huanga, Tsui-Ying Wangb and Fu-Ming Hsieha, "Constructing an Adaptive Mobile Learning System for the Support of Personalized Learning and Device Adaptation" in International educational technology conference (ietc2012).
12. E. F. Louhab, A. Bahnasse and M. Talea "Considering mobile device constraints and context-awareness in adaptive mobile learning for flipped classroom", Educ Inf Technol 23, (2018), pp. 2607–2632. https://doi.org/10.1007/s10639-018-9733-3
13. L. Bennis, S. Amali and N. El Faddouli, "Generating Adaptive Learning Games to Multiple Mobile Platforms", In book: Advanced Intelligent Systems for Sustainable Development (AI2SD'2019), DOI: 10.1007/978-3-030-36653-7_13.

14. A. Gouaich, L. Abrouk and Y. Francillette, “Adaptive gameplay for mobile gaming”, IEEE Conference on Computational Intelligence and Games (CIG), New York, USA, 22-25 Aug. 2017, eISSN: 2325-4289.
15. E. F. Louhab, A. Bahnasse and M. Talea, “Towards an Adaptive Formative Assessment in Context-Aware Mobile Learning”,in 3rd International Conference on Computer Science and Computational Intelligence, Procedia Computer Science 135 (2018), pp. 441–448.
16. L. Nacheva-Skopalik and S. Green, “Adaptable personal e-assessment”, International Journal of Web-Based Learning and Teaching Technologies (IJWLTT 2012) (4), pp. 29–39.
17. A. Shannon, D. Langova-Orozova, E. Sotivora, K. Atanassov, P. Melo-Pinto and T. Kim, “Generalized net model for adaptive electronic assessment, using intuitionistic fuzzy estimations”, Advances in Soft Computing Vol. 33 (2006), pp. 291-297, ISSN:16153871, ISBN: 3540228071; 978-354022807-3.
18. I. Janke, “Unpacking the Inherent Design Principles of Mobile Microlearning, Technology, Knowledge and Learning” (25), (2020), pp. 585–619. https://doi.org/10.1007/s10758-019-09413-w
19. C. Pappas, “Microlearning In Online Training: 5 Advantages And 3 Disadvantages”,(2016), https://elearningindustry.com/microlearning-in-online-training-5-advantages-and-3-disadvantages
20. J. Skalka and M. Drlík, “Conceptual Framework of Microlearning-Based Training Mobile Application for Improving Programming Skills”. Interactive Mobile Communication Technologies and Learning IMCL 2017. Advances in Intelligent Systems and Computing, Vol. 725, pp. 213-224, Springer, Cham. https://doi.org/10.1007/978-3-319-75175-7_22
21. S. Cates et al., “MobiLearn go: mobile microlearning as an active, location-aware game”, Proceedings of the 19th International Conference on Human-Computer Interaction with Mobile Devices and Services. Association for Computing Machinery, USA, New York (2017),103, pp. 1–7. DOI:https://doi.org/10.1145/3098279.3122146
22. M. Gocheva, E. Somova, V. Angelova and N. Kasakliev, ”Types of mobile educational games for children in primary school”, INTED2020, 14th annual International Technology, Education and Development Conference, 2-4 March, 2020, Valencia, Spain, pp. 2291-2300, ISBN: 978-84-09-17939-8, ISSN: 2340-1079, DOI: 10.21125/inted.2020.0698.