https://doi.org/10.53656/math2023-5-4-eva

Educational Technologies
Образователни технологии

EVALUATION OF CHILDREN'S BEHAVIOUR IN THE CONTEXT OF AN EDUCATIONAL MOBILE GAME

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Abstract. The paper presents a study aiming to propose a model and system for mobile game-based learning in which the behaviour of the learner during the game is taken into account, considering characteristics such as noise level, movements of the mobile device, switching between applications and the availability of Wi-Fi network and Internet connection. Behavioural profiles and behavioural templates are suggested implementation techniques to assist the teacher in evaluating learner's progress and curriculum efficiency. The learning model also applies adaptive, micro lesson and game-based approaches. An implementation of a software system prototype has been tested with real learners. The results of a survey of students' and teachers' opinions on the proposed approach are presented.

Keywords: behavioural learning model; game-based learning; m-learning; learner profile

1. Introduction

Games have a fundamental and leading role in the growth of the child as a person, along with upbringing, living environment, education, and communication. It is possible anywhere and at any time (Lawrence 2012). Games and learning are inextricably linked during a child's childhood as it grows and matures. It is an undeniable fact that people play for the rest of their lives or engage in game scenarios (e.g., in the gamification of non-game activities). Games are especially inherent during childhood when one is more subject to training and education. Therefore, the game approach is basic in the methodology of teaching preschoolers and primary school children. Pedagogy, as well as didactics, have long emphasized the role of games in learning and education. Educational games incorporate elements that make them a powerful motivational tool for learning, with many having a competitive motif and/or techniques that encourage creativity and the use of imagination.

The modern generation of children has a different approach to learning – they are active, searching and demanding. Students want fast, attractive, quality and effective learning through the latest technologies and tools they already use, such as the Internet and mobile devices. That's why, modern education must change or adapt pedagogical methods, approaches and strategies and use new and modern

technologies. One of the critical techniques is observation (e.g. of behaviour) of learners throughout the learning process. Unlike traditional classroom learning, when learning takes place in an online environment, this monitoring is difficult, and here the capabilities of modern devices and technologies can be used to help.

The purpose of the work is to present an approach for evaluation of the children's behaviour in a game-based learning model. A behavioural model of the learner is proposed. The explained ideas are experimented in a mobile game-based system for math education in primary school.

In Section 2, research related to children's behaviour during the game is presented. Section 3 gives a summary of a general model for mobile game-based learning in elementary school, based on which the learner's behavioural model described in Section 4 was designed. Section 5 presents the practical implementation of the prototype of the mathematics learning system in the elementary school stage, Section 6 shows the idea of behavioural templates based on the analysis and summarization of the collected data on the behaviour of the players. Section 7 highlights the contributions and perspectives of the study.

2. The child's behaviour during the game

The game is the natural way through which young children learn and develop. It is important for all aspects of growth, including emotional growth. Children have strong emotions and do not always know the words to express them. The game gives them the opportunity to uncover them. This is helpful for the behaviour, self-awareness, self-control, and relationships the child creates.

The concept of emotion is often used as a synonym for the concept of feeling, but in terms of psychology, they are well distinguished. Emotion is a high-intensity state of intense, short-lived arousal, which is a temporary and short-lived mental state, while feeling can be a continuous and long-lasting mental subjective-evaluative attitude towards a certain object (Leontev 1971).

It is extremely difficult to capture a child's emotions, feelings, moods, thinking, attitudes, and reactions. When using games and game situations, strong and vivid emotional impressions should be properly dosed. Otherwise, they can disorganize the child's activity. Game balancing can be defined as the process of providing an adequate level of game challenge. Several studies are researching the child's behaviour and emotions during games mainly focused on computer games. Some of the skills that computer games could develop are highlighted, namely problem solving, logical thinking, quick analysis, decision making, and memorization. (Bringula 2015) argue that participants in a computer game experience mixed emotions that can be both positive and negative. They reject the hypothesis that

there is no relationship between a participant's gaming behaviour and their emotions during the game.

In (McCain 2018), computer games are seen as a way of providing a virtual reality in which behaviour change can be both intentional and unintentional. Emphasis is placed on the fact that games and game elements can have a beneficial effect, rediscovering and showing hidden or suppressed qualities in the participant.

The paper (Bakaoukas 2016) investigated brain activity during engagement with different genres of computer games to take a first step towards understanding the player and compiling behavioural models. The results were obtained from the analysis of the rhythmic activity of the brain in the frequency range of 2–45 Hz, focusing on the alpha and beta rhythm waves. These waves reflect levels of relaxation (alpha rhythm) and concentration (beta rhythm). The main contribution of their analysis is the confirmation of the hypothesis that there is a link between brain activities and different categories of computer games.

There are few studies in the field of mobile gaming that analyze child behaviour during play. (Larche 2020) consider the balance between skill and challenge, in the flow (progression) of a mobile game, and the emotions that accompany the flow (e.g. boredom, frustration, and excitement). The balance between the skills and the challenge is analyzed through increasing game speed and changing game complexity. One of the main goals of studying players in games is to understand their cognitive, emotional, and behavioural patterns (Yannakakis 2013).

3. A model for mobile game-based learning in the primary school stage

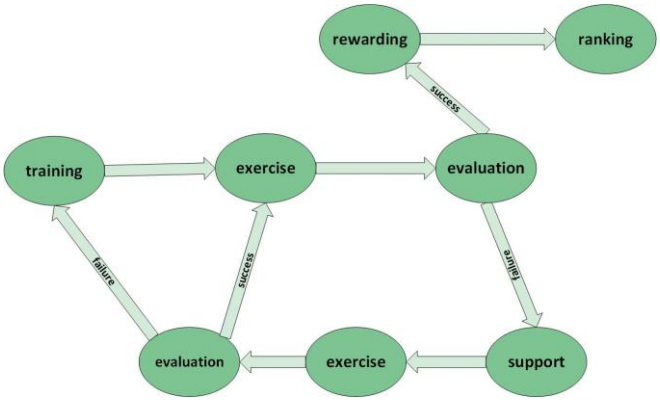

Figure 1. A generic cyclic model of mobile game-based learning for primary school children

A common model of mobile game-based learning suitable for primary school children is created. The conceptual model includes instructional, play, and behavioural models. A cyclic learning model is proposed (figure 1).

The approaches that have been chosen to be applied in the implementation of mobile learning for the primary stage are **game-based learning, adaptive learning, micro-lesson learning and active learning through behaviour monitoring**.

The behavioural model, the focus of this work, is presented in detail in the next section. The game model (Gocheva 2022b) is based on in-game achievements and includes the following elements: rewards received of different types (bonus, reward, combo, and badge), time saved from completed activities, level achieved, place on the leaderboard, and avatar used.

A classification (Gocheva 2020) of game tasks suitable for mobile implementation and for the corresponding age group of learners is made. A player (learner) model is proposed based on the following approaches: game-based learning, adaptivity (Gocheva 2022), and microlearning. Appropriate game elements and techniques are selected for use in the model. Didactic, behavioural, and functional models are proposed that can be used to create both a stand-alone game application and a mobile game platform.

4. Behavioural model

In the learning process, the learner's behaviour and emotions can be an indicator of the effectiveness of the curriculum, performance, knowledge and skills acquired or deficits, thus helping to evaluate the process.

In studies such as (Steenbeek 2018), the learning process is defined theoretically as a complex dynamic system – a network of interacting components (e.g., cognitive, emotional, and behavioural) of a subject (the learner) and components of the learning process on the part of the instructor. The authors conclude that for assessment to be adequate, it needs to be comprehensive, including a study of all components, and they propose a web-based program for assessing student learning and a video feedback coaching program for faculty.

Even if one does not follow a strict theoretical model, there are many examples in life that, through simple observation, show the relationship between certain human behaviours and the occurrence of specific events, such as the kinds of emotions students experience when they succeed or fail on a school test. Data is needed to analyze a child's emotions and behaviour during or after a learning game. For this purpose, three approaches can be applied to collecting these data: **by observation, by self-reporting the data or by automatic data collection**.

Observation of the learner is an important daily activity carried out by the teacher to ascertain the effectiveness of the learning process as a whole.

Self-reported data uses interviews, surveys, or questionnaires that learners must complete. This approach has a number of limitations, depending mainly on the fact that young children are involved. First of all, and given that children's attention is lost very quickly, the number of questions should not be large (8–10 questions). Next is the choice of question types (multiple choice, rating scale, ranking, open-ended).

The third approach uses automatic data collection during the learning itself. This approach is more popular as it reports and collects data during learning, which is implemented automatically with the appropriate software.

Table 1. Interpretation of learner behaviour data

Noise level	
low	high
• concentration • attention • focus	• prompt • distraction • fatigue • irritation • joy
Movements of the mobile device	
little	lots of
• concentration • interest • restraint	• strong emotions (in case of success or failure) • uncontrolled emotions
Number of switches to other applications	
unavailable	available
• individual work • concentration • focus • infatuation	• cheating • communication with other students • use of other applications • dissipation
Connection to WiFi network and Internet	
unavailable	available
• individual work • focus • attention	• cheating • communication with other students • use of other applications • dissipation

In this work, the third approach has been chosen to be experimented with. The aim is to collect data from the learner's actions and/or interactions with the environment, based on which various conclusions can be drawn related to the child's emotional state, the child's independence of work, etc. Possible data that can be collected automatically are, for example, **the 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 Wi-Fi network and the Internet (Table 1).

There are studies such as (Yang 2016) that show the importance of concentration when learning in virtual environments with mobile devices. One of the main findings of the study is that interest in conceptual knowledge acquisition is significantly related to concentration. The difficulty comes from how to automate using mobile device data to determine the child's concentration level. An indicator of this level of concentration may be the number of switches to other applications or the level of ambient noise around him, high values of which indicate that the learner is probably not concentrating sufficiently and is distracted by the environment or other software applications.

Different combinations of behavioural characteristic values can define different behavioural profiles. Examples of such profiles are presented in Figure 2. The behavioural data collected can help the teacher in forming an assessment or analyzing students' behaviour. Such data, in addition to educators, can be useful to researchers in other professional fields who study the behavioural patterns of learners.

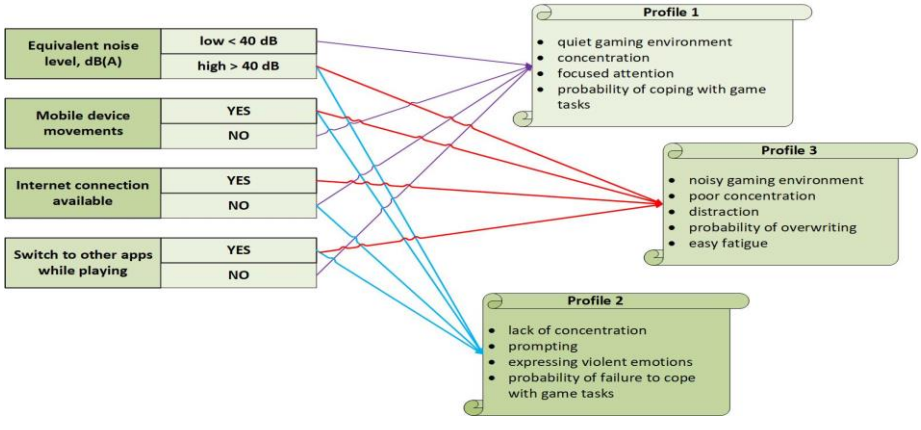

Figure 2. Sample of behavioural profiles

The authors present the educational model, based on three submodels: learning model (based on the student's learning achievements), game model (related to the player's achievements in the game), and behavioural model (based on the data about the behaviour of the student, recorded during the game). The educational model is represented by the triple $M = \{Me, Mg, Mp\}$, where *Me* is the student's learning model, *Mg* is the learner's game model, and *Mp* is the behavioural model. 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.

5. Implementation of a prototype

Based on the conducted research and the identified need for such applications, the age group for which to create a mobile game application was selected – primary school stage and specifically third grade. The mobile educational game should have a potential practical application in Math classes as a supplementary learning resource or for students to practice during their free time at home.

The architecture used for the mobile game-based learning system is based on the modules "Game Environment,", "Synchronization", and "Reports". The interface design of the mobile game is proposed based on templates. A number of modern software tools were used to implement the mobile application. A SQLite database is used to store the data locally, and a web server and a server database are used to synchronize the data. Functionality has been developed to report certain metrics during gameplay: noise level, number of switches to other apps, mobile device movements, wireless network, and Internet access. The reported data is sent to a remote DB, and from there this data is used by a web application upon request (query) by the teacher in the form of reports. The goal is to track the player's performance and some indicators of his behaviour from which the teacher can draw conclusions from the learner's learning path and assign a grade. From all this data, a so-called player behavioural model, which tracks not only the game's performance from a pedagogical perspective but also some indicators of the child's behaviour. A lot of research and analysis could be done and conclusions could be synthesized in this direction, but it is necessary to accumulate enough data from many players.

In a real-world learning environment, an experiment was carried out with 17 third-grade students from Yane Sandanski Primary School, Plovdiv, Bulgaria and 10 primary teachers to implement mobile game-based learning for primary school students. The aim is to develop a mobile educational game in mathematics to complement traditional classroom learning and to be used at home. All the intended functional features of the developed game were tested. A questionnaire survey was also conducted with the students and teachers participating in the experiment, which explored attitudes towards the use of mobile game-based learning in mathematics in terms of practicality, motivation, design, accessibility, support and feedback.

The "Practical Applicability" category is made up of 3 questions showing the learners' opinions of how useful they find this game. The results show 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 category “Motivation” is composed of 2 questions, examining students' motivation and the influence of the incentives they receive. 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. As can be seen from popular opinion – the role of game elements is essential in motivating and awakening the interest of learners.

The survey of teachers shows the following results. The category “Practical applicability” is composed of 7 statements, exploring teachers' opinions on how applicable they find game-based learning to traditional learning. 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 strongly agree and 20% just agree), which is one of the key objectives of the study, to show how effective and flexible adaptive learning can be. A detailed description of the conducted survey and analysis of the results is made in (Gocheva 2022a).

6. Behavioural patterns

As a natural development of the model and its practical application, the collected behavioural data from the player profiles can be analysed and summarised. Based on the identified profiles, behavioural templates can be (automatically) formed to facilitate the trainer in monitoring the learning progress of different learners. Data templates can greatly facilitate this process, as the data reported is a large amount and analyzing single data points for each learner would be time-consuming. On the other hand, the interpretation of this data may be different among different educators.

The templates are formed by examining the values of the reported indicative characteristics at each level, and the automated guess of the template type is made at the end of the game according to the rule that these characteristics are reported at least 6 levels of the game.

Based on direct observations, albeit with a small number of children, the authors' hypothesis is that four **behavioural patterns** can be derived (Table 2), which can be an indicator of the child's emotional state during play.

The first two patterns show rather positive emotions. Positive emotions can enhance the learning process through games by showing students the opportunity to pursue goals, seek alternatives, persevere, and respond effectively to criticism and error.

Table 2. Sample of behavioural patterns

Behavioural patterns	Indicative characteristics
concentrated/interested	• < 3 high noise detections • < 5 instances of sudden movements • 0 switches to other applications • the Internet connection is turned off
calm	• < 5 high noise detections • < 10 instances of sudden movements • 0 switches to other applications • the Internet connection is turned off
stressed/confused	• < 10 high noise detections • < 10 instances of sudden movements • 3 switches to other applications • the Internet connection is turned on
overexcited/overactive	• > 10 high noise detections • > 10 instances of sudden movements • > 5 switches to other applications • the Internet connection is turned on

The second two patterns show rather negative emotions that hinder or even impede the learning process. They can significantly reduce motivation, shift focus away from learning, impair the relationship between the student and the teacher or other students, and degrade performance.

7. Conclusion

This study attempts to propose an automated way of collecting and assessing child behaviour data in the context of game for educational purposes. It has been found that there is very little research specifically on mobile games, but like other

games they can improve a child's problem solving, logical thinking, quick analysis, decision making, and memorization abilities. A general model for mobile game-based learning in primary school is proposed. The conceptual model includes instructional, game-based, and behavioural models. The paper focuses on the behavioural model. The basis of the model is the hypothesis that in the process of learning the learner's behaviour and emotions can be an indicator of the effectiveness of the curriculum, the success rate, the acquired knowledge and skills or deficits, thus helping to evaluate the process. A prototype of a game-based learning system on the basis of the model has been implemented. The prototype allows for automated collection of child's behaviour data, taking into account certain characteristics from the mobile device. As a result, behavioural profiles and templates can be formed which, after analysis and evaluation, assist the teacher in evaluation of the learning process.

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