# Game-Based Learning: How to Make Math More Attractive by Using of Serious Game

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**Abstract.** The dynamics of change in the field of information technology open the doors to use of new methods of education. Communication bandwidth (networks), computers, laptops, tablets and mobiles (hardware) and new generation of operating systems, program languages and game engines (software) offer new possibilities. Devices and networks are still improved, getting faster and prices fall. These attributes started a new area: game-based learning. In our paper we discuss how to make math more attractive by serious game. Math is subject which is essential in many fields, including natural science, engineering, medicine etc. Generally, math is not very popular with pupils. Question is: how could we change it, but answer is actually not easy, but one of the possibilities is serious games for math. This is the reason why we have decided design and development a serious game focused on math - for reader's attention and math word problems. A multiplatform game engine Unity 3D was used for development of the game and Blender's tool for real time projects for simulations. We describe steps of design and development from graphical environment, design of the buildings to music and sounds.

**Keywords:** Design · Programming · Science education · 3D serious game · Game-based learning

## 1 Introduction

Serious games are not just developed and employed exclusively for entertainment purposes, but have successfully being incorporated as learning and training tools for a broad range of different areas [1, 2]. Following the rise of digitalisation, games can be composed with the help of the computer, or can even be adopted for and with the computer, in order to "learn by playing" [3].

Serious games present themselves as one of the more interesting and also promising means of improving cognitive abilities, particularly with pupils [4]. Recently, research has consistently shown that several aspects in cognition such as visual short-memory, multitasking and spatial cognition can be enhanced by game play [5–7]. Substantial research on the design and effects of digital educational games [8–10] has been carried out. In order to utilize educational games, it seems necessary to include instructional

features that foster appropriate cognitive processing while at the same time not decreasing players' intrinsic motivation [11].

Given the obvious appeal of computer-based games more generally – the computer game industry is growing much faster than the U.S. economy as a whole and 97% of students aged 12 through 17 play video games regularly – it is easy to understand and embrace the enthusiasm about and promise of computer games as a way to engage kids and lead to meaningful learning [12].

The body of academic literature on web-based games dedicated to increasing mathematical knowledge is still in its infancy compared with other well-developed research streams in education [13].

Unlike traditional learning, where the teacher gives students just theoretical knowledges, by using of problem-solving learning a teacher becomes students some problem tasks. Teacher motivates pupils or students, directs the search for new ways of solving the tasks which pupils acquire new knowledge and new methods of operation. Student discovers itself solve the problem. There is a team of investigators composed of two to five members. This kind of education supports thinking skills and students can apply theoretical knowledges into practical plane.

Problem-based learning as a method of instruction stands firm within the rationalist and, hence, is strongly influenced by cognitive psychology [14]. Another definition of problematic teaching says: "teacher not convey pupils in the final form of knowledge, places for pupils tasks containing unfamiliar to them knowledge and methods of operation, motivates them, directs the search for ways and means to solve problems [15].

Research shows that students in problem-based curricula are indeed learning facts and concepts and the skills needed for critical problem solving and self-learning [14–16]. Other research shows that students participating in these kinds of learning activities are more motivated to learn, that what they learn is more usable than the knowledge learned by students carrying out rote activities, and that they tend to better learn higher order thinking skills than do students in other learning situations [16–18].

Problem solving education should be one of the main goal how to develop this kind of learning, how to support analytical and critical skills. It is important to integrate a game to learning process but very important what kind of a game. A game should be effective beneficial for a students. In last twenty year is very untypical to integrate a game to learning. But in every age of pupils or students is important develop the specific skills.

According to the author Richard Rouse when drafting the game it is important to focus on three main areas that may seem unrelated at the first sight. They are:

- technology,
- gameplay,
- story.

## 2   Background of the Serious Game

The main goal of our interest was to create a serious game focused on support math skills for pupils of second level of primary schools. Serious game is focused on math word problems - primary goal and the reader's attention – secondary goal. It was

necessary to apply the taxonomy of education, which is often suitable for building cognitive tasks – Niemierko's taxonomy in our country (in Slovakia). Niemierko's taxonomy consists of four levels:

- *Remembering* – recognize or recall information, similar to knowledge in Bloom's taxonomy.
- *Understanding* – demonstrate that the student has sufficient understanding to organize and arrange material mentally, similar to comprehension in Bloom's taxonomy.
- *Specific transfer* – application of acquired information according presented patterns.
- *Non-specific transfer* – creative application of acquired information.

Our game called "The Young Seeker" is based on the single player adventure. Adventure is characterized by the solution of partial tasks during the action. After starting the game the player is shown tip, which is based on the way of commanding figure of the boy. After becoming aware of the keyboard shortcuts, the player starts the game. The beginning of the game takes place in front of the orphanage. It is surrounded by the tree alleys, rocky peaks, and by the fence around the building. The player can look through the orphanage and its surrounding area, as well as, the building itself. The player can move on the pavements and paths that are modeled in the surrounding area.

The plot starts with the player standing in front of the building (orphanage). After figure of boy enters the building he asks the player for his help. The story begins. The boy tells a player the beginning of the story. He finds out that there are paranormal phenomena in the orphanage and the goal is to solve the various subtasks so that the player gets four parts of the diamond. After they are obtained paranormal phenomena in the orphanage ends and the player gets to the next level. During the dialogues with the characters in the orphanage (boy, director of the orphanage, other children), the player must carefully read and consequently solve tasks. The game is quite difficult to find not only particular parts of diamonds, but also to answer the various puzzles that the player gets during the game. If the player does not answer at least half of the questions correctly, the player gets at the beginning of the game, in order to be able to answer individual questions. In the game there are also various Slovak proverbs, the player has to react in accordance with their sense. It strengthens not only the national awareness and national sayings and proverbs, but also the ability to solve various independent tasks (so called Property connectedness).

Overall, the story takes place in the recent past, partly to induce a sense of retro style. Therefore, the individual rooms of the orphanage and an environment are adapted to this period (typical character walls from 60's, 70's, wallpapers, pictures, curtains, chandeliers, staircases, tiles in the bathroom). Throughout the game playing music typical of this period is playing in the background.

During each part of the game, the player has available a list of individual tasks, respectively the task that has to be done right now. Helpdesk is activated via the key "J". Dialogues that are conducted with various people during the level are activated by running the "E" key.

## 3    "The Young Seeker" – Anatomy of the Serious Game

When designing serious game we remembered the target group that is pupils of Slovak's primary schools. It was necessary to adjust not only to the game as such, but also its design, playfulness, as well as graphic elements of the game and also the player.

### 3.1    Stage Creation

*The first stage* was to choose the genre of the game. At this stage, we have set the goal to choose the genre for the game, at the same time, to choose the way in which our story would be interpreted to the player (pupil). Among the fundamental objectives that were set was also the robustness of the game. We have therefore chosen that the game will be designed in 3D and at the same time we want to use the maximum of its potential. That is why we chose that the player will be able to move along the whole area without restrictions, thereby achieving the maximum impact of the environment and stronger overall impression of playing the game. Our goals and requirements were the biggest factor in choosing the genre of our game. With respect to the primary aspects of the game, we could only focus on a few genres that were dominated by adventures. It seemed to be the most favorable choice for our work. At the same time, however, during the game design we decided not to proceed in stereotypical manner and expand the genre of adventure game with elements from other genres, which would contribute to better impression of the game. Among the elements that would support the intended atmosphere of the story are the possibility of moving across the whole stage and a free camera. Our game can be characterized as a single player adventure, in which the player as the main hero of the story overcomes obstacles created by the environment and by the enemy. Here are the elements of the adventure, as the player is forced through interaction with the environment to solve tasks that divide him from further advancement in the game. These tasks usually involve finding hidden objects, solving puzzles and knowledge tasks etc.

*The second stage* was the game proposal. On that basis, there is following goal in the game: consistent solving of problems that are brought by the game based on interviews and "keys" to achieve further progress of the level story line. More detailed characteristics and description of the game objective can be found in Subsect. 3.2.

*The third stage* was the design of the structure of the game. After launching the game, player has the option to choose "New Game". The game can be stopped at any time, saved, temporarily stopped and continued. It depends on the decision of the player. More detailed characteristics of the design structure such as models, game interface and sound are described in the following subsection. Each of these attributes was designed so that they together constitute an integrated part and the structure of the game itself.

### 3.2    Structure of the Design

When we were creating design of the game we had to think especially about the impression that the game will leave. Since the game takes place in recent past, we had to adapt the entire visage of scenes and objects.

**Models**

Creating objects is among the most basic activities in any development environment and its definition is largely unchanged, although in each area it might look different. In the game engine the object is any object at the scene that can be handled, modified its appearance and behavior towards surrounding or another object.

Unity offers several possibilities to create objects that are the equivalent in practical use and their utilization depends on the user's habits. One way is through the button GameObject on the toolbar that displays the offer of the objects types that can be created. The basic types of objects are 3D objects, 2D objects, Audio, User interface and Light. The other way is to use the Create button at the object Hierarchy. Created objects are visible on the Scene and it is possible to work with them right away.

In terms of the time potential we decided that the proposal of the models design will be combined with the way of their creation. We modeled some models of the objects by ourselves (building, paintings, lamps). The reason was that we had special requirements for objects and it was necessary to model them according our perception. The second option was that we took the opportunity of free models that are available at Assets store. These were adapted according to the scene. There were less realistic, realistic but also fairytale animated models of objects, that allowed us to select from a wide range offer, but we had to take into account the intended dramatic impression of the story, so we chose the most realistic models. Assets store offers in addition to models also other content such as: animations, sounds, or scripts etc. Some of these attributes were also used and adjusted to our needs.

**Gaming interface**

Gaming interface or Graphic User Interface (GUI) plays an important role in presenting the various elements of the game to the user through images, text and animations; by their interactivity and imagination simplify orientation in propagated opportunities. Unity offers several alternatives for processing the interface that can be used not only as a variety of menu still defined on the screen, as well as interactive tools deployed on the playing area. GUI design elements were created with help of external software for editing 2D graphics. We used mainly freely available programs like Inkscape and Gimp in which we drew pictures to GUI representing key objects in the game.

When creating the menu, we have used a new system of Unit 5, which allows intuitive editing of individual windows and modifying their appearance and functionality by adding components. In this way it is thus possible menu item, which normally acts as a text, adjust so that the component of the button is added. Using this principle, we have compiled a minimalistic main menu, as well as other windows (Figs. 1 and 2).
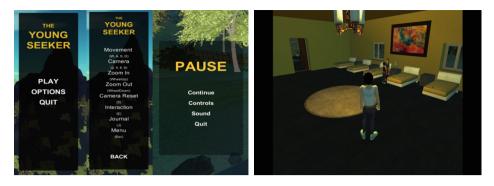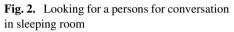
**Fig. 1.** Introduction view of the "Young Seeker"

**Fig. 2.** Looking for a persons for conversation in sleeping room

**Sound**

In the next section we applied the soundtrack to particular parts of the game. The basis was to find the appropriate music in order to create the desired atmosphere of the game. In the Unity the work with sound is very intuitive, since the use of sound reflects its perception from the real world. It is therefore necessary to determine the source of the sound and the object that it hears, the audience. The sound source can be any object in the scene and the audience is mostly camera, which is essentially our eyes and ears. Unity has functions to convert the sound intensity according to the distance of the source from the listener, which effectively simulates the perception of 3D area. Individual sounds can be assigned their priority in order not to mix together and not to create meaningless noise. This feature can be used to separate less important sounds, such as background music, wind, etc., from more significant sounds, such as the voice of the character during dialogue, collection of the key objects etc.

### 3.3    Development Tools

Currently the developer of the games, who decides to design a game on any platform, can choose from several engines from different producers, based on the popularity of the game or by the offer that engine has to offer. Among the most famous and at the same time most used game engines belong Unreal Engine 4, Unity 3D, Source 2, CryEngine 3 and Frostbite 3.

*Unity 3D* - A suitable tool for game development after analyzing software options was the Unity 3D. The reason why we have decided to implement in our game just Unity 3D, is its ease of operation and compatibility with a wide variety of formats for different types of media such as graphics, audio, video and text. In addition, the "Unity Technologies carried out a coup in the gaming industry through Unity, advanced and emerging platform for creating games and interactive 3D and 2D experiences such as learning simulations and medical and architectural views through different platforms such as mobile, PC, web, console and other" [19]. Unity 3D like most of today's software WYSIWYG (What You See Is What You Get) has its own environment divided into several working windows that can be adapted to suit our needs by their enlargement,

reduction, or changing location in order to be most natural during working. Other reasons for our choice is that the software has been around for several years and it is connected to plenty of means that serve to educate users about working in this environment, whether there are training videos or entire online documentation of scripts and programming methods useful in the creation of any content. Furthermore, we are interested in the possibility of downloading different content from Assets store intended for further development, which clearly ease the development of the game itself.

*Programming languages* - Unity generally supports several programming languages that are used in programming scripts. These scripts contain encoded logic of objects' behavior that are present in the game. Among the programming languages that are supported by Unity are:

- C#;
- Java Script;
- Boo;

For C# and Java Script exists online documentation of all programming methods, in which there can be found their methods of using, properties, and parameters used when working with them. Each programming script can be saved to a separate file and managed in the Project window like any other file.

Furthermore, it is necessary to assign it to the object, but usually to the object for which the script was dedicated and whose behavior is to modify. This is not a requirement, since it is possible for the objects and their components to be referenced directly in the programming script.

### 3.4   Math Example of Word-Solving Task

Our game is focused on math word problems and logical thinking. While playing the game, pupil proceeded by first completed several interviews with specific characters in the game. Always it is necessary the rank ok interview with the persons (boys, girls, teacher…). Therefore, if a pupil-player wrong order came to the person or the right one in order to display the messages, "You cannot start a conversation, please find another person". After completing the interviews followed the search objects in the game such: diamond, gold, shields, etc. The game stops and then displays the question at each object. The question always was related to interviews before. Pupils should answer for this question. Questions are focused on simple verbal math problems. We choose as example one specific math problem: Player completes talks with two girls (sisters). Bianca & Mary saved a different amount of money: Bianca has got 60 €, Mary 140 €. Pupil should remember these amounts. After that shows a question: "How many euro saved sisters together?" If a student answered correctly, got a second question, if a student answered incorrectly, game player goes back to the conversation with the first sister and read the conversation again. Second question is: "Bianca and Mary have saved 200 € together. Bianca wants to go on a trip and wants to take a fifth of their savings and Mary quarter. They will have a total of 50 € on a trip. How many euro saved Mary and how many Bianca?"

In this case we are watching two factors:

- readers' attention;
- math word problems.

The answer is unlimited in time. Pupil can choose the correct answer from one of the five options. It was always the only one correct answer. On the first question a student has got three choices (easier question), in the second questions student has got a five options. The game is designed for fixing phase of the learning process. The aim is to fix the curriculum after completion of the exposure part of the learning process. The first level of the game contains 10 mathematical word problems for pupils of 5th year of primary schools. A choice word problem has consulted with the sixth primary school mathematics teachers.

Among the most frequently detected shortcomings of logical character are wrongly activated triggers whose presence on the scene meant that players were able to skip part of the story. This did not meet certain prior conditions for progress in the story line, which meant that the story could not be further completed. Such errors were easy to locate and eliminate because their activation was mentioned in the script, but they had to be switched off by that time. It was enough to deactivate them; thereby we prevented skipping the story.

It seemed to some players that commanding of the character was clumsy. In order to contribute to a better gameplay rotation of the character should accelerate, but the rate of movement of the character should slow down. By modifying these parameters, we met their criteria, but such adjustments usually depend on individuals and adjusting these figures can disadvantage other players. However, we can say that after gaining certain amount of experience in working with Unity, it could be possible to make other solutions to movement of the character that would be universal and would not create any more problems.

## 4    Conclusions and Future Work

In the theoretical part we dealt with the characteristics of computer games, serious game. We were creating a didactic computer game (serious game) for fix math skills in fifth level of primary schools.

In practical part, we have created simple and funny game that meets the didactic aim of mastering the curriculum. Testing showed the justness of that argument. After analyzing theoretical documents of computer graphics, we were able to create 3D models of objects in the environment, which we then used in constructing scenes of the game. That preceded the drafting of games, specifying its attributes based on our choice, and determination of the genre that would be suitable for such purposes. Analysis of freely available game engines followed, which purpose was to compare the functional characteristics of the engines and choose the best for our work.

Nowadays, with the spread of information and communication technologies, these games should be implemented into school curriculum even more. Pupils would be involved more into the process of education. The game is designed so that it can be

further developed for objects and settings. The game could offer number of illustrative examples focused on various topics of problem-solving education. Very important will be obtain some results about impact of communication and opinions among pupils and teachers during use of the game. It will be important to find out what kind of role or activities will have a teacher and how games can help to pupils in finding employment [20–23, 26].

In addition there is possible to integrate to the serious game a special kind of technical movement as motion capture technology [24] which can improve movements and graphics of serious games. Besides that it would be great if the grid or cloud systems can be used to dynamically allocate resources during the game design in order to minimize total maintenance costs [25].

At the end of this paper we want to say:

- Learning with the game, is possible to obtain a higher cognitive results of pupils with support of appropriate methodological-didactic approaches;
- Higher motivation and interest;
- Development problem-solving;
- Friendly atmosphere during class.

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