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Toby the explorer – an interactive educational game for primary school pupils

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***Abstract*—Technology enhanced education has been recently established as a new approach for all stages of education in developing countries, especially in Macedonia. Although computer games are often given little attention we believe that within the vast amount of technologies and instruments used to achieve the needed improvements it is computer games that are playing the central role in delivering the desired effects, in particular to children and teenagers. In this paper we present the "Toby the Explorer", an interactive educational game for primary school students. We show in depth the engineering behind the game, its design and structure. We also give an insight and evaluation of the importance of the game in enhancing the educational process. Our results show that the learning process is regarded as more easy and fun by the students that learned by playing, but also it increased their interest in learning other subjects not included explicitly in the game.**

Keywords—Educational games; Game-based learning; e-Learning; Desktop games; Games for kids

I. INTRODUCTION

Technology usage in the 21-st century is no longer an exception, but a rule, especially in domains close to and intertwining with computer science and engineering. People are trying to ease their lives, prominently by using a plethora of mobile applications in many, if not all, aspects of their daily life. Education and learning, as an example of the previous, has been under great influence of these technological processes, and the rise of computer-based learning applications and educational games is more evident than ever. Traditional teaching, usually based on lectures and tutorials fosters the idea of instruction-driven learning model [1] where students are passive listeners. However, the technology aided learning paradigm follow the constructivism learning theory, where learning from real-world situations is put on the first place. According to this "student centered" strategy [2][3], students collect in-deeper knowledge when they directly experience the situation. One such approach is the project based learning [4] that improves professional skills related to a particular project and specialized knowledge, provides an interdisciplinary insight to a problem, and improves the overall socio-technical skills of the students. Project based learning can be a very useful tool in learning for higher education, however it is very difficult to keep secondary, and even more so primary, school students engaged in such a process. The "fun-based" approach using games as a tool for learning is better suited for such students. Numerous fields of learning, some being: languages, mathematics, programming, science, history, geography, art and many other, are enhanced by wide range of educational games [5]. Such applications are especially useful in improving, and even enabling, the learning process in youngsters since they tend to keep children mentally active, can be used as an addition to the classroom work and as after school fun activities that extend the learning process.

Adults may make up the majority of game players, but video games are more popular than ever among kids, new research shows. According to NPD [6], 91 percent of U.S. children ages 2-17 play video games (64 million). More interesting, these numbers are up nearly 13 percent from a 2009 study. The number of kids in the U.S. has increased by 1.54 percent in that time, but not nearly enough to make up for the massive increase in game playing. Gaming among kids ages 2-5 has increased the most.

"Year-to-date through August 2011, kids comprised 44 percent of new physical software dollar sales, representing a vitally important consumer segment for the games industry," said Anita Frazier, industry analyst, The NPD Group. "Knowing how kids are spending their gaming time and dollars in both traditional and non-traditional outlets is key to staying relevant to this highly engaged audience."

Educational games are application software that helps students to learn the lesson subjects and to develop their problem solving skills by using their desire and enthusiasm to play [7]. Such games can be observed as free fun activities that provide students with the opportunity to reinforce their knowledge by repeating it in a more comfortable environment.

Prensky in [8] distinguishes between six structural factors that define an application as a game: *Rules* to impose limits which force us to take specific paths to reach goals and ensure that all the players take the same paths; *Goals or objectives* which create a sense of duty, so we play the game voluntarily and spend time and make an effort for it. *Outcomes and Feedback* that give a measure of progress towards the goals. Feedback comes when something in the game changes in response to an action a player takes; *Conflict, Competition, Challenge and Opposition* are the problems in a game that the

player tries to solve. *Interaction* can be viewed both as a player – computer interaction, and an interaction amongst multiple players playing the game; and finally *Representation* which refers to the essence of the game play, i.e. what the game stands for.

Most researchers believe that educational games have a positive impact on children and those children using educational games in the learning process have a greater chance of success as compared to children that use the traditional way of learning. Ritzhaupt at al. [9] noted several advantages of educational games over the traditional learning: children use action instead of explanation, create personal motivation and satisfaction, they are able to accommodate various learning styles and skills, they reinforce mastery, impose making decisions and collaboration with other learners. Divjak and Tomic [10] analysis of different research about the influence of educational games suggests that playing a digital computer game improves the spatial skills of the students and reduces the difference in spatial skills between boys and girls. This approach helps students in learning and improving skills for social problems solving and new/unfamiliar situations. However, it must be noted that in order to have a positive impact on students a good computer game must meet pedagogical criteria, be educational, but also interesting [11].

All of the before mentioned advantages of game based learning motivated us to create an interactive game that combines the processes of gaming and learning and produces a gain greater than the sum of the two.

Taking into account that the use of tablets and mobile phones is common for the children of today [12] and that they tend to use such mobile devices instead of desktop computers, we developed our game for both platforms. The game is designed as a three dimensional (3D) adventure game, since we believe that such a game will have greater appeal and will keep our targeted users, i.e. children, interested. The game is intended for primary school students aiming at extending their knowledge in different disciplines, like biology, geography and science.

The main advantages of "Toby the Explorer" are (but not limited to): the easy learning process, the development of the visual skills of the users, and the imperceptible transformation of fun into productive brain activity. These goals are enabled through the usage of highly visible performances and photographs that augment the learning by adding visual stimuli that accompany the written information. Additionally, the environment has a very realistic representation and is complemented with catchy music and special effects, and finally information within the game is represented in a very simple and reasonable way so it can be understood by everyone, and is amended with interesting facts.

The rest of this paper is organized as follows. The second section describes the game plot and scenario. The third section provides implementation details. Section four evaluates the game. This paper is concluded in section five.

II. GAME PLOT AND SCENARIO

The main character of this game is a little boy named Toby who is very ambitious and curious. He wants to know more about his surroundings and environment (Fig. 1). Toby lives in a small house near the lake. Near his house there is a small wood and a mountain abound with lots of animals and vegetation. There is a small village nearby and a farm where the player can learn more about the animals and nature. There are also a lot of hidden geographical spots which are harder to be found, but they discover more about some Earth phenomena. Very interesting thing is that the game has a lot of environmental sounds who make the game much more realistic. For example, if the player comes near water, splashes and stuff can be heard.

Fig. 1. Toby and his home

Since Toby is a very curious boy, he starts sniffing around the area. His mission is to find out as much as he can about the environment by collecting hidden scrolls and photos. On each of the scrolls he finds, there is a content describing the area, together with some facts about it. Photos show up very different places as well, containing graphical perspective of the area. But one thing Toby can't do is swimming, so the player must be careful to avoid deep waters. The player starts with three lives. Once they are lost, the game starts over again and the player needs to find the scrolls and photos again.

The game has a lot of detailed graphics and is made to perfection to the smallest object. We tried to compress as much as we can for the game to be easier to open on more devices. Each time the game is started, an options window pops up and prompts the player to choose graphics, controls etc. to match pc performances (Fig. 2).

The user interface of the game is very friendly and easy to navigate. It is separated on two parts:

- Main Menu User Interface
- In-game User Interface

The Main Menu User Interface consists of 4 buttons: Play, About, Scores, Quit (Fig. 3). The "Play" button starts the game and takes us to the main scene. The "About" button opens up a new popup which has a brief description of the game. The "Scores" button loads up all the scores the user has on his record. These scores are loaded from the database so an internet connection is be required for this option. The "Quit" button shuts down the game.

The In-Game User Interface is separated into four parts, and each fills a corner on the screen (Fig. 4). On the bottom left

corner there is a compass which allows the player to orientate during the play. The compass has a mini-map arrow which displays the player's direction of movement. In the top left corner there is an icon with a number on its right side which counts the lives left. Each time it hits zero, the game starts all over again. On the top right side of the screen there is a pause button used to stop the game and returns the control to the main menu. On the bottom right side of the screen there are two counters, dedicated to count the scrolls and the photos collected.

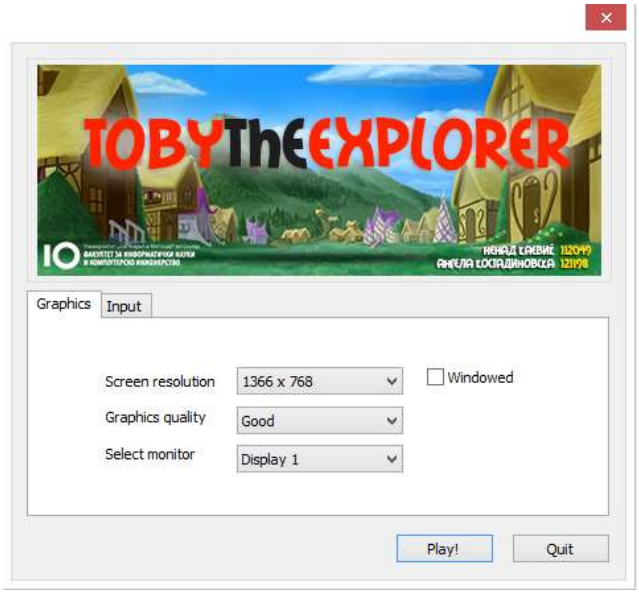

Fig. 2. Configuration Window

Fig. 3. Main Menu UI

The player's mission is to collect all the scrolls and photos in the area. They will serve as a way to learn more about the environment. When the player collects a scroll, a paper-like pop-up shows up with description about the current location. The same happens with the photos. When the player collects a photo it swirls up and pops at the screen with an imagery of the current area. Fig. 5 shows it visually.

There is quite a lot to be discovered by the player. The game abounds with actions and lots of excitement and is made for the player to go deeper in the story and to explore more and more.

Fig. 4. In-Game UI

Fig. 5. Photo Popup

III. Implementation of "Toby the Explorer"

A. Used technology

"Toby the explorer" is an interactive learning game targeting kids from age 7 to age 12. Since there are a lot of technologies allowing us to implement 3D game, we decided to use the latest game engine "Unity" [13]. Unity is a cross-platform game engine developed by Unity Technologies and used to develop video games for PC, consoles, mobile devices and websites. First announced only for OS X, at Apple's Worldwide Developers Conference in 2005, it has since been extended to target more than fifteen platforms.

The reason we decided to use this engine is its clear and simply written documentation which helped us to understand the whole framework of the engine. Unity understands two programming languages: C# and JavaScript. Mainly we used C#, but there are a few scripts that are written in JavaScript. The engine gives us a chance to easily scale the game for later expansions. For example, the market is already thriving with various platforms who occupy a lot of devices. Each of those devices requires different optimizations and specifications, which can be easily achieved with Unity.

Since this game has a lot of models used in it, we had to use modeling software which helped us to import modeled objects in the game. For that purpose we used Cinema 4D [14], developed by MAXON Computer GmbH. It is a modeling program based on xyz modeling axis and modeling rigs. Our main character is designed exactly in this editor using rigs and

bones to make it more realistic and acting as a real person. It totally combined all the parts of the body, connecting them with joints to act as ankles. On the top of it, we added animations on the character which brought it to life.

Another technology we used but is less adapted and is used in very little ranges is PHP and MySQL. We used these technologies for data storage. The idea came because this game needed competitiveness, so we decided to use databases to store the scores of the player.

B. Developing the game

Unity engine was used for both front and back end of the development. We used a lot of built in tools who helped us develop the environment of the game, but we also used a lot of external software.

The terrain of the game was made with the built in Terrain Editor in Unity. It consists of brushes and terrain shifters. The helpful tool in this terrain editor is the Height Map which allows importing of black and white bitmap and converts them into terrain; depending on the blacks and whites on the bitmap, i.e. white parts make higher terrain, while black parts lower terrain. As we mentioned above, we used Cinema 4D for the modeling part. All the models were easy to import and all the textures attached to them were easy to compress and attach. The engine provides shaders, which allow us to make the surface of the models much more realistic. All the lightings and specular blooms are part of the engine. We used a lot of lightning objects to make the ambient look real. In addition to the lightning, we used a lot of ambient sounds to bring the world alive and give a full sense of the surroundings.

Apart from the frontend development and all the things visible, we implemented a lot of backend scripts. Since the game consists of many movements and physics, we had to develop all objects, starting from the floating objects on the water like the boat, to flickering leaves in the woods and waves in the water.

Most of the scripts are attached to the boy, as it is the center of everything that is triggered. In the desktop version, the motion script for the boy uses the typical system input (Keyboard) and is controlled by the “arrow” buttons or the “w”,“a”,“s”,“d” buttons. The “space” button makes the boy jump. Since the physics had big impact on this game, we had to make sure that everything will move and act properly. For that purpose, we used Unity’s Colliders and Rigid Bodies who attach Physical parameters to the objects, allowing them to bump on each other depending on their surface.

In order to store the player scores, we had to use PHP and local server to test all of the storing process. For that purpose we installed "Windows, Apache, MySQL, and PHP" (WAMP) server [15] locally and wrote two PHP scripts (display.php, addscore.php). Using the myPHPAdmin panel on the WAMP server we created an empty database and filled it with three columns using a simple query. The second stage in this process is writing a C# script in Unity where we pass the variables between the PHP and the C# script. Fig. 6 describes the communication between the database and the game.

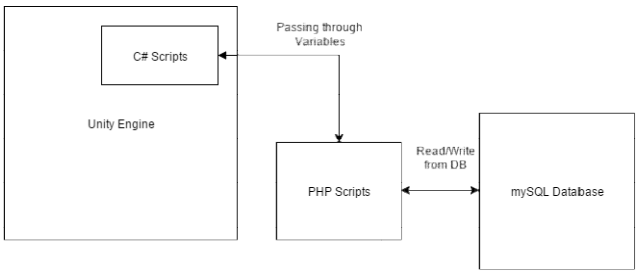

Fig. 6. Communication between the Database and the Game

This is why we found PHP very useful in this project as a mediator who handles the variables from the C# script to the MySQL Database and vice versa. Thus, it has a simple implementation and is easy to edit. The UML Class Diagram on Fig. 7 shows all the classes used to make all the communication works.

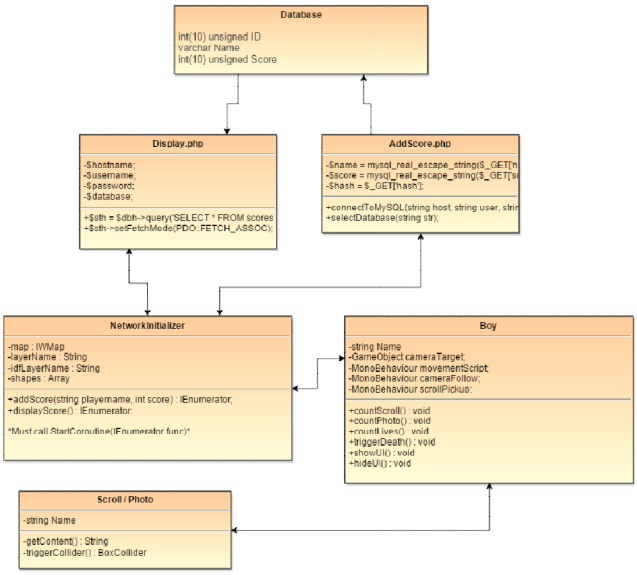

Fig. 7. UML Class Diagram

Creating the database requires installing WAMP which can be downloaded from internet for free. It will install a virtual server on the local computer with a phpMyAdmin panel. Since our implementation is based on a local server, we need to do this procedure on each device we run the game in order to save player’s scores.

IV. Evaluation

According to [16], 74% of the teachers in primary schools use digital games in the classroom. The instructors report that video games increase motivation and engagement in their students. 4 out of 5 of video game-implementing teachers use games created exclusively for educational purposes.

It’s not just teachers who are using games to assist in educating the youth of today. 56% of parents say video games positively affect their children [17].

The statistics of these studies show that interactive education might be very popular and effective in the future. This is why we think this type of games will bring the new age of education. We conducted our own small researches on how kids would react on the game. We tested 34 children between the age of 5 and 14. The research showed the following:

- 28 out of 34 children liked the game and were very attracted by it.
- 7 out of 34 (age 12 and above) think that the game could be a distraction to the kids during the classes.
- 9 out of 34 were unable to understand the plot of the game.
- 23 out of 34 think that the game can be expanded a lot more than it is now.
- 21 out of 34 think that the game should include other topics from different subjects covered at school.
- 15 out of 34 think that the game can be modified by means of covering not only science subjects, but also a society subjects.

Following the results of our research, we realized that the game was not equally accepted by all children. The reason is that this game was not in accordance with particular teaching material from particular grade. For example, children age 5 and 6 can not read, hence they found it difficult to answer the quiz. On the other side, older children (age 13 and 14), did not find anything unknown in the game, so they were a little bit bored.

Also, our team that developed the game consists only of computer engineers. Developing a game is a serious process and requires different professionals to be included in it, where computer scientists are only one small fraction of it.

Still, we believe that this kind of games could fit into the education system easily and could bring more effort into studying, but only if they are made in accordance with teaching curriculum, and if different professionals are included. Certainly this game could be used only for classes like Geography, Biology, Environments and Nature, but it could be expanded to be used for classes like Math, Physics, as well as for Society subjects. Hereafter, our game needs a couple of improvements to make it more solid for operating but mainly it is very scalable and easy to expand for further purposes. We hope that "Toby the explorer" will have positive impact to the children and in best way will increase their environmental knowledge.

V. CONCLUSIONS

In this paper, we describe the process of designing and implementing a 3D educational game that is very useful, and it for sure will develop the cognitive skills of the children. Because we incorporated learning material from primary school there is big chance of implementing this type of educational games in the normal learning process of the schools.

Developing learning games is a complex task, which requires many professionals to be included, like teachers, educators, psychologist, sociologist, computer scientist, etc. This makes educational games development an expensive complement to the traditional learning. In big countries, this opens new possibilities for third parties to develop new on-line services that can be used in the learning process. Nevertheless, in small countries, like Macedonia, there will be no interests for such a third party investments. Hence, small countries governments should make bigger investments into this kind of projects.

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