The Effect of Educational Game on Children Learning Experience in a Slovakian School

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Abstract: Preparing our children for the rapid economic, scientific and technological developments ahead is a top research aspect for many research communities and state institutions. In this context, STEM topics have an important role in the earlier educational stage and more specifically at primary school level. This paper investigates the learning impact of using Final Frontier, an immersive educational video game in a Slovak school for teaching concepts related to the solar system. The experimental study involved 44 children divided in two groups, a control group and an experimental group. The aim of this paper is to present an investigation on the effect of educational game on the learning outcome of the children when the Final Frontier game is used. The results show that Final Frontier game based learning brought better knowledge gain values. In addition, the majority of children perceived learning more entertaining and they believed that the game helped them to learn through problem solving tasks and interactive exploration of the planets virtual environment.

1 INTRODUCTION

STEM education is very important nowadays as the entire economy and our general well-being rely heavily on by science, technology, engineering, and math. In order to motivate the young generation to follow an engineer or scientist career path, STEM topics must be introduced at primary school level to show to the children what an engineer or scientist can do. Research has proved that STEM subjects should be highlighted long before students begin to choose their specialisms at secondary school, high school or university. The young people are already aware that STEM is all around in their daily lives and they are curious to know how they can better use their STEM knowledge to solve problems in the world. Teachers have also recognized the need to equip our young people with a strong STEM foundation and they are willing to participate in hands-on professional learning activities that prepare them on how to introduce STEM topics to children.

Interactive computer-based educational games have gained wide recognition as an effective way to create interactive and constructivist learning environments through the use of technology. Game-based learning teaching approach has been introduced in both formal and informal education worldwide for teaching STEM related subjects. Recent studies that proposed and/or evaluated educational games for teaching concepts related to the solar system are presented in the next section.

A part of game based learning other approaches such as hands-on projects, lab experiments, inquiry-based learning, use of Virtual Reality (VR) and Augmented Reality (AR) have been investigated by researchers and applied when introducing STEM topics to young children. Gamification can provide another means of promoting students' active participation and investment into something beyond the academic expectations of a lesson (Papadakis and Kalogiannakis, 2017). Digital games are gaining wide recognition as an effective way to create socially interactive and constructivist learning environments (Papadakis, 2018).

The team of researchers, scientists, engineers, educators, psychologists and developers part of NEWTON project[1] have instigated innovative technologies to be used in primary schools, secondary schools and Universities for teaching

[1] NEWTON Project - http://newtonproject.eu

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STEM topics. NEWTON Project's innovative technologies include Augmented Reality and Virtual Reality (Bogusevschi et al. 2018a) (Bogusevschi et al. 2018b), Virtual Teaching and Learning Laboratory (Bogusevschi et al., 2019), adaptive and personalised multimedia and multiple sensorial media (Bi, et al., 2018; Moldovan & Muntean, 2017; Moldovan et al. 2016), personalisation and gamification (El Mawas et al., 2018a) and interactive educational computer-based video games (El Mawas et al., 2018b). Different innovative pedagogical approaches are also deployed as part of the STEM teaching and learning process such as flipped classroom, game-based and problem-based learning (Muntean et al., 2018; Muntean et al., 2017; Zhao et al., 2018; Zhao et al., 2019; El Mawas et al., 2018c; Zhao et al., 2019; Bradford et al., 2014; Chis et al., 2018).

In the context of NEWTON project this paper presents a case study that involved the use of an educational immersive game to teach concepts related to the Solar System in a Slovak primary school. The most important findings include the fact that game based learning brings a comparable level of knowledge acquisition over a teacher based learning approach and even higher level when we concentrate on a knowledge gain.

The paper is organized as follows. Section 2 presents research work done in the area of education games, focusing on solar system related games. Section 3 introduces the research methodology of the case study and a description of the Final Frontier game. Section 4 presents the results of the case study. Section 5 summarizes the conclusion of this paper and presents its perspectives.

2 RELATED WORK

Few studies have proposed and/or evaluated educational games related to planets or the solar system and they are presented next.

Titans of Space[2] is a free educational game that offers to the learners a guided virtual tour of the solar system. The player travels through the planets and stars inside a small spacecraft. There are many tour stops where the player can look around, read the information panel and proceed to the next destination when he feels ready. Note that the number and the duration of stops can be configured by the player. The learning objective of the game is to learn about the planets from the solar system. The game is designed to look inside the solar system with the following route: Earth, Mercury, Venus, Mars, Jupiter, Saturn, Uranus, Neptune and Pluto. However, the game was either not evaluated or the results were not published. The game does not provide planet exploration though problem solving tasks and therefore it does not support development of problem solving skills.

Odyssey[3] (Chakraborty, 2015) is an interactive simulation game to learn concepts of the solar system. The game consists of navigation menus to look at various objects from different vantage points. Many topics can be studied like Lunar Phases, Seasons of Earth etc. Setting a particular date in the date picker shows the state of the Solar System on that particular date. Odyssey serves as a medium for the teachers to explain various phenomena like phases of moon, apparent retrograde motion of planets, and path of the Halley's Comet. Students are expected to read from their textbooks and then test out their understanding through Odyssey. They can also explain various concepts like the changing of seasons due to the earth's tilt through Odyssey. However, there are no research papers that evaluate this game.

(Majgaard et al., 2017) introduces the design of a learning application about the Solar System suitable for 6th graders. Students participated in the design phase to increase their motivation and help them to overcome difficulties related to the understanding of the Solar System. The students learn via the application the distances between the Sun and the planets and their proportions relative to each other, as well as planetary motion through space. The application is based on augmented reality design in order to make unobservable objects visible in a learning context. Moreover, the authors of the paper (Majgaard et al., 2017) consider that the application promotes an engaging learning experience but there is no research that proves that.

Space Rift[4] (Peña and Tobias, 2014) is an educational game that teaches children concepts about the solar system. The player explores planets in a virtual environment. In this game, the player is free to navigate around the solar system with full control rather than just be fixed with the tour stops. Information about planets is visible when the player hovers close to a planet. Space Rift was tested with fifth-grade students. The students described the game as enjoyable and immersive, although they had

[2]Titans of Space - http://www.titansofspacevr.com/

[3] http://coffeeandjunk.github.io/odyssey/

[4]https://store.steampowered.com/app/437080/Space_Rift__Episode_1/

problems distinguishing some of the images due to lack of sharpness. However, the game evaluation involved only 5 students and was mostly focused on usability rather than educational aspects.

(Ranka et al., 2018) proposes Space Invaders, an educational game in a virtual reality mode that allows users to discover facts about the planets that exist in the Solar System. Each planet constitutes a level in the game, while the player tries simultaneously to evade and defeat aliens that are encountered. Initially, the main screen is displayed, which consists of all the planets, along with the Sun. Then the learner has to select Mercury as his first level and clear it by combatting the aliens. Once all the aliens on this level are killed, before the time runs out, the player will be able to attempt a quiz, otherwise the player loses. Once the level is completed the player will be taken to the next level. And in the similar way the player has to invade the space by capturing all the planets. Several experiments have been conducted to illustrate that the game can work effectively on any personal system and smartphone but there is no study on the learning impact of the game.

SolarSystemGO (Patricio et al., 2018) is an augmented reality based game with astronomical concepts. The game's aim is to provide awareness of the vastness and proportionality of the Solar System objects, such as the Sun and the planets. The player embarks on a voyage through the Solar System and its planets. He collects points as he reaches each planet. The planets are augmented objects placed on a scale with the Sun position, in a real outdoor space. The work reported in (Patricio et al., 2018) presents an evaluation of the game performance, especially on low-end devices and discusses the need to include other objects types such as satellites and asteroids.

The Final Frontier educational game that supports learning through problem solving, direct experience, challenges and fun interactive tasks. This paper in particular analyses the impact of the educational game on the learning process when the Final Frontier game was deployed in a primary school from Slovakia.

3 CASE STUDY

This research study is focused on knowledge acquisition of students when an educational game is incorporated in pedagogical process.

3.1 Final Frontier Game Description

The Final Frontier, immersive and interactive computer-based educational game investigated in this paper, was developed as a part of the Earth Science Large scale NEWTON pilot (Bogusevschi et al., 2018) and it was used through the NEWTELP platform by 10-13 years old children in three European schools.

The Final Frontier game supports knowledge acquisition on 4 rocky planets and 4 giant gas planets from the Solar system, e.g. Mercury (Figure 1) and Venus (Figure 2). A game level corresponds to each planet to be explored. For each level, game objective (i.e. mission to collection stars or meteorites) and constrains (e.g. coolant time) are defined. The stars, meteorites, jetpack and coolant time are ludic elements in the game; they are very important to ensure the balance between the gamification and the learning scenario. Once a level is completed, the player must answer correctly a multi-choice question in order to progress to the next level. The player is allowed to try to answer the question multiple times if a wrong answer is provided and extra information is provided.

Figure 1: The player on the Venus surface.

Figure 2: The player with jetpack on Mercury.

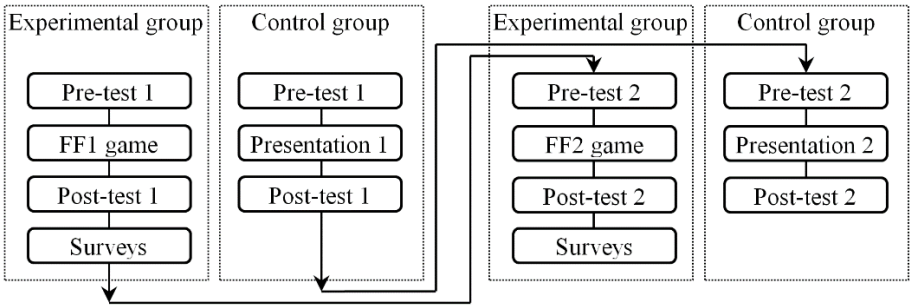

Figure 3: The evaluation process scenario (FF1/2 – Final Frontier game part 1/2).

Details on Final Frontier game description and the game design methodology are presented in (El Mawas et al., 2018b; Muntean and Andrews, 2017).

The game can be played in 6 different languages: English, Slovak, Czech, Spanish, Italian, and Romanian. The paper (El Mawas et al., 2018b) presents a case study on using the game in Irish primary school. This research paper investigates the use of the game in the Slovak school.

The game was deployed in pedagogical process to analyse its impact on a state of acquired experience and knowledge compared to the standard (classical) educational process.

3.2 Research Methodology

As this research study is focused on knowledge acquisition aspect of game-based learning in a STEM-related topic, pre- and post-test assessments were run before and after the use of the game.

The research methodology applied in this case study involved a random distribution of the children that took part in the case study into two groups: a control group (CG) and the experimental group (EG). The experimental group learned about the planets by playing the educational game. The control group was exposed to the classic teacher-based learning. The case study consisted of several phases which cover the collection of assent and consent forms, description of the realised course, special pre-questionnaires, knowledge pre-test, learning experience, knowledge post-test, and other post-questionnaires. Figure 3 shows a simple draft of the case study process where only phases related to the knowledge acquisition and evaluation are depicted.

The learning process for Solar System subject taught by the Final Frontier game was divided into two parts (lessons): the first one devoted to rocky planets and the second one to giant gas planets. Each one lasted one teaching hour. All learners from both groups (EG and CG) did two knowledge tests one before (pre-test) and one after each lesson (post-test). The learning process depends on a group the learner belongs to. It means learners of the experimental group played the Final Frontier game (part 1 during Lesson 1 and part 2 during Lesson 2) – NEWTON approach. Each learner played the game individually in the computer room with a teacher present in the room, but the teacher did not answer any question related to the subject. The control group was presented with a classical approach of the same content using PowerPoint presentations created by the NEWTON team members and presented by a school teacher. The information content of the game and presentations had to be the same. NEWTON representatives (pilot leader and local researchers) took part in both approaches for observational purposes.

In order to evaluate learners' level of knowledge on the subject prior the particular pedagogical approach both groups did the same pre-test 1 (within Lesson 1) and the same pre-test 2 (within Lesson 2). Similarly, the same post-tests were provided in both groups to analyse and evaluate level of acquired knowledge. Table 1 shows questions of pre- and post-test 1 applied during the Lesson 1. The pre- and post-tests creation followed requirements such as they should last max. 10 minutes, both (pre- and post-) tests should have very similar content and identical concept. These tests consist of a single choice and simple answer questions.

Based on knowledge tests results an average score can be calculated for both groups of students, both knowledge tests and for both lessons. By comparing average pre-test and post-test scores a knowledge gain can be calculated. And by comparing knowledge gains for particular lessons and groups it is possible to evaluate which pedagogical approach provides better results with respect to knowledge acquisition.

In addition to knowledge tests evaluation the implemented research methodology is also based on results acquired from several questionnaires learners of the experimental group took before and after

Table 1: The pre-test and post-test questions deployed in Final Frontier Part 1 (Lesson 1).

Pre-test questions			
1) Is Venus similar in size to the Earth?	2) Which Planet has a liquid water on it?	3) What does Mercury have a lot of?	4) Neil Armstrong is the first person on:
a) Yes	a) Mercury	a) Craters	a) Type answer:
b) No	b) Venus	b) Mountains	
c) I don't know	c) Mars	c) Water	b) I don't know
	d) I don't know	d) I don't know	
Post-test questions			
1) Which planed is called the Red Planet?	2) Which Planet is closest to the Sun?	3) Can you jump much higher on Moon then on the Earth?	4) What is the temperature on Venus?
a) Mercury	Type answer:	a) Yes	a) Very hot
b) Mars		b) No	b) Very cold
c) Venus			c) Like on Earth

lessons, observations carried out during lessons as well as interviews and discussions with learners.

The research study was carried out at the school located in Bratislava – Lamač, Slovakia with children from two standard classes. One class (the total of 19 children at the age of 12-13) went through the NEWTON approach (EG) and another class of 25 children (of the same age) was exposed to the classic teaching approach (CG). It is necessary to note that grades 5-8/9 are considered in Slovakia as basic/primary second stage schools (education) whereas in most school systems these grades are considered to be lower secondary schools. The learning process took place during the school study hours in the presence of the NEWTON team from the Slovak University of Technology and the teachers from the school. For the experimental group

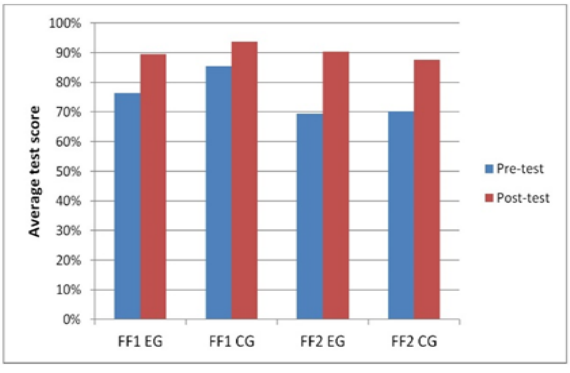

Figure 4: Average pre- and post- test scores for experimental group (EG) and control group (CG), for Final Frontier part 1 (FF1) and Final Frontier part 2 (FF2).

all the tests were implemented in NEWTELP platform developed within the NEWTON project and provided to learners online. The control group was provided with a printed version of all tests.

4 CASE STUDY RESULTS

The research focuses on the knowledge acquisition based on two different pedagogical approaches (traditional learning and game based learning). The evaluation was based on the results of knowledge tests (i.e. pre- and post-tests) as well as questionnaires which were taken by all learners.

4.1 Knowledge Assessment Results

Final results showing the level of learner' knowledge in percentage for all groups of learners, both types of tests and both lessons of the Final Frontier subject are depicted in Figure 4. It is noticeable that both pedagogical approaches increased knowledge level of learners. The highest average (pre- as well as post-test) scores were achieved by the control group (CG) in Lesson 1. This result was influenced by the fact that learners of this class/group already had some initial knowledge in the subject what is also confirmed by the highest pre-test score (85.42%). In this case (Lesson 1), learners of the experimental group (using FF1 game) achieved a lower value of the average pre- and post-test scores. However, if we concentrate on the analysis of the gained knowledge we can notice an increase of 13.16% in the case of EG and only 8.33% in the case of CG. Therefore, the benefit of game based learning can be observed.

Results for the Lesson 2 (FF2) show almost the same average pre-test score for both groups (about 70%), i.e. all children have the same level of knowledge in the researched subject prior the learning activity. After the learning activity, the level of their knowledge increased by 20.83% and 17.31% in the case of EG and CG, respectively.

To summarize the above analysis, we can see that learning using the Final Frontier game (in both lessons) brought better values of knowledge gain. During the learning process (hours) representatives of the NEWTON project have been observing how learners behave and what they ask and say. Moreover, we conducted special individual and group interviews with students and teachers after the learning process. Eight learners (from EG) took part in these interviews (four arranged in a group and others individually). Based on these activities and

their results, we can summarize that the majority of learners consider learning more entertaining and the game helped them to learn better by direct experience with planets environment.

4.2 Percentage of Correct Answers

Using the pre- and post-test results we also evaluated learner tests based on the number of correctly answered questions for Lesson 1 in both groups (Table 2). There is nobody in the used sample of learners who answered all questions incorrectly for this lesson and all learners answered correctly at least two questions in the post-tests. We can also see an increase by ca. 20% in a number of learner post-tests with all four correct answers.

4.3 Questionnaires Results

Children of the experimental group completed two types of questionnaires (motivation and usability) after each lesson. Figure 5 shows results for both questionnaires completed after the Final Frontier part 1 and 2 lessons. From these results we see that

- only 5% of learners would like to learn without NEWTON technology (i.e. in a standard way with a teacher),
- only 5% of learners think lesson was boring,
- 77% of learners consider learning with the game (Final Frontier) was really interesting
- Bu using the game 46% of learners became more interested in this STEM topic.

Table 2: Number of questions (in percentage) correctly answered by students in Lesson 1.

	Pre-tests			**Post-tests**		
	EG	**CG**	**Both**	**EG**	**CG**	**Both**
4 out of 4	42 %	63 %	54 %	63 %	79 %	72 %
3 out of 4	37 %	21 %	28 %	32 %	17 %	23 %
2 out of 4	5 %	12 %	9 %	5 %	4 %	5 %
1 out of 4	16 %	4 %	9 %	0 %	0 %	0 %
none	0 %	0 %	0 %	0 %	0 %	0 %

It can be seen that the most of learners liked the game-based learning approach. They liked the Final Frontier game, its environment, style, freedom, and interactivity. If we focus on results of the usability oriented questionnaires (other six questions in Figure 5), we can summarise that

- 73% of learners agreed that it is easy to use (play) the game,
- 77% understood all parts and 86% of learners said it is easy to learn to play the game,
- only 5% disagreed that this game helped them to learn better, and for example
- 64% thought the game saved their learning time (27% felt neutral).

5 DISCUSSION

As was mentioned in Section 2 there are already some educational games oriented to the Solar system concepts but research studies were only performed in one of them and only mainly from usability point of view and on very small student sample (Peña and Tobias, 2014). Our goal was to analyse developed game from usability, motivation and knowledge acquisition point of view and show its benefits.

The Final Frontier game was developed to be easily played, understood and learned to play. Analysis of questionnaire results confirmed these aspects of the game and showed that it is one of the key characteristics leading to successful learning process. Complex games with difficult control and low quality graphics can negatively influence learners' motivation (to play/learn), playfulness (to have fun) and learning experience and reception (Ranka et al., 2018). Standard hardware and software requirements of the game also simplify its deployment in the educational process and students enjoy learning in a computer room.

By comparing pedagogical approaches: standard teacher-based and game-based (using our game) for Solar system subject the analysis of knowledge test results showed a statistically significant increase in the knowledge gain in both approaches and confirmed that learning based on our game can provide comparable knowledge acquisition. We assume that the game benefits from a balance between amount of textual information and information transformed into visual and motional experiences. It also helps learners to understand and imagine abstract concepts (Zhao et al., 2018).

After the learning process, we also discussed with some learners from the experimental group to hear and evaluate their experiences and feelings. Some students think that they learned more using our game, they liked the game and they would prefer to have more subjects available in this way. On the other hand, two students (girls) would prefer (more) the classical approach with teachers because they missed a direct contact with a teacher. Some students would like to combine both approaches together, i.e. the game with interactivity with teacher answering questions and explaining other facts.

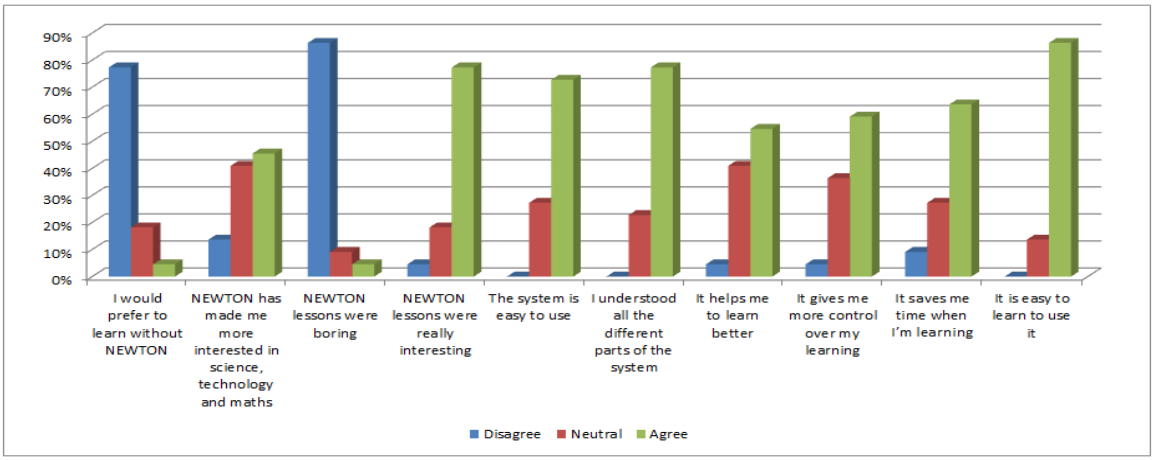

Figure 5: Distribution of the learners answer for the questionnaires.

6 CONCLUSIONS

The research paper investigates the impact of game-based learning on students' knowledge acquisition level. An educational video game about the Solar system (Final Frontier) was developed and used within NEWTON project. The learning process consisted of two sessions that were assessed separately. Two classes consisting of 44 children (12-13 years old) from primary school took part in this pilot testing. The sample consisted of 44 learners (12-13 years old). In order to evaluate and compare results, one class was taught using this game (experimental group) and other one used a classical approach (control group), i.e. a teacher with PowerPoint presentation. The evaluation process was based on knowledge pre- and post-tests.

Evaluation results for the first lesson showed that students of the control group achieved higher average (pre- and post-test) scores than learners of the experimental group. However, the knowledge gain was higher for learners of the experimental group. In the case of the second lesson (gas planets), learners of the experimental group achieved higher average post-test scores as well as the knowledge gain. We can summarize that if all learners (of both groups) start with the same level of knowledge from the analysed subject the learning activity using the Final Frontier game (in comparison to classical approach) provides the higher knowledge gain (approximately 4.2% in average) and learners feel more entertained during learning (study). Questionnaires showed that most of the learners liked the Final Frontier game, they considered it interesting and not boring and it was easy to play it.

This case study demonstrated that game-based learning can achieve comparable results in terms of the knowledge gain as classical learning with a teacher. Games must be easy to control, understand and learn to use with good picture quality. They need a balance between amount of textual and non-textual information. Students need freedom and problems to solve in them. And they should be easy to deploy in practise. These aspects greatly improve learners' motivation to play and learn via own experience. It appears (in this level of Slovakia schools) that combination of classical and game-based learning is viable solution to improve the knowledge acquisition but other studies are needed.

Future work will aim to expand the research study to include a deeper statistical analysis of the usability, the satisfaction, and the motivation of the learners through the game. We are also working on a personalized version of the game in order to address the problem of learners' diversity, their difference in terms of prior knowledge and learning experience. The game will also be used in schools with children with special needs in order to evaluate the game usability and learning outcomes for these children.

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