Investigating the Learning Impact of Final Frontier Educational Game in a Slovakian Primary School

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Abstract. To better prepare our young generation for the rapid economic, scientific and technological developments ahead, STEM topics must be introduced at an earlier educational stage such as at primary school level. This paper investigates the learning impact of using an immersive educational video game called Final Frontier in a Slovak primary school for teaching concepts related to the solar system. 44 students divided in two groups, a control and an experimental group, took part in a case study that investigated the learning outcome of the children when the game was used.
The results show that Final Frontier game based learning brought better knowledge gain values. Moreover, majority of children saw learning more entertaining and the game helped them to learn better by a direct experience with planets environment.

Keywords: Geography education, Solar System, Game based learning, primary school education

1 Introduction

To inspire the next generation of engineers and scientists, STEM topics must be introduced at a young age and 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.

A number of projects performed research on suitable pedagogies to be used when introducing STEM topics to young children. hands-on projects, lab experiments, inquiry-based learning and educational games have been proposed as suitable methods to be used in primary education when teaching STEM. Among those the team of researchers, scientists, engineers, educators, psychologists and developers part of NEWTON

[1] project have instigated innovative technologies to be used in primary schools, secondary schools and Universities for teaching STEM topics.

In the context of NEWTON project this paper presents a case study that involved the use of an educational immersive video 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 classical learning approach (a teacher with presentation) and even higher level when we concentrate on a knowledge gain.

The paper is organized as follows. Section 2 introduces existing games related to the Solar System and different game methodologies. Section 3 gives an overview of the Final Frontier game. Section 4 presents research methodology of the case study and its results. 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. Titans of Space (http://www.titansofspacevr.com/) is a free educational game that provides to 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 goal of the game is to learn about the planets in 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.

Space Rift [2] is an educational game that teaches children about the solar system. Players explore 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 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.

Odyssey [3] 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.

In this context, our research contributions are as follows: (i) development of the *Final Frontier* educational game for teaching Solar system planets-related concepts, a

topic that was not thoroughly covered by previous research studies, and (ii) evaluation of the learning impact of the game when deployed to target primary school students.

3 The Final Frontier Game

3.1 NEWTON Project

NEWTON [1] is a large-scale EU Horizon 2020 project that aims to develop, integrate and disseminate innovative technology-enhanced learning (TEL) methods, tools and STEM related educational content that make use of virtual reality, augment reality, multimedia, mulsemedia, self-directed learning pedagogies [4,5] (e.g., flipped classroom, problem-based learning and game based learning), inter-connected fabrication labs [6] and virtual lab technologies [7]. The project has developed and deployed the NEWTELP platform that integrates and deploys these novel and emerging mechanisms and TEL methodologies.

The personalisation and adaptation perform at content level and platform level by using a Learner Model implemented by the NEWTELP platform [8] and aims to address the individual learner needs including their physical disabilities, to improve the learning process, and to increase the learning outcomes and learner quality of experience.

The Final Frontier immersive and interactive computer based educational game introduced in this paper was developed as part of the Earth Science Large scale NEWTON pilot [9] and used through the NEWTELP platform in three European schools by children of age 10-13 years old.

Different case studies have investigated the benefits of the educational game in different European schools and results are currently analyzed and cross countries analysis will be performed.

3.2 Game overview

Final Frontier is an interactive educational video game about space for children up to 13 years old. The game supports knowledge acquisition on Solar system planets (i.e. Mercury (**Fig. 1**) and Venus (**Fig. 2**) were targeted in this study) through direct experience, challenges and fun. The topics coved by the game are part of the Geography curriculum, section “Planet Earth and Space”, defined for the primary school in Ireland. The game has different levels, each level containing different models and landscapes. In each level, the game requires meeting a game objective (i.e. mission), collection of stars and meteorites and has constrains e.g. coolant time. Information regarding the number of stars and meteorites collected, coolant time and game level mission is displayed on the screen.

Once a level is completed, the player must answer correctly a multi-choice question in order to be able 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

Fig. 1. The player on a surface of Venus.

Fig. 2. The player with jetpack on Mercury.

For more information about the Final Frontier game description and the game design methodology please read our previous research paper [10, 11].

The game can be played in 6 different languages: English, Slovak, Czech, Spanish, Italian, and Romanian. Nour et al. [10], have presented a case study on using the game in an Irish primary school. This paper presents the results of new case study that involved the use of the Final Frontier game in a Slovakian primary school.

4 Case Study

This research study is focused on knowledge acquisition aspect of game based learning realized in a STEM subject. The Final Frontier game developed to teach children basic information about Solar system planets was deployed in pedagogical process to analyze its impact on a level of acquired knowledge in comparison with standard (classical) learning process.

4.1 Research Methodology

The evaluation process consisted of several phases which cover collection of consent and assent forms, description of research study, special pre-questionnaires, knowledge pre-test, learning experience, knowledge post-test and other post-questionnaires. We will call a group of children (learners) which were involved in this evaluation process as the experimental group (EG). In order to compare a level of knowledge acquisition we also selected a group of learners (class) taught in a classical way referred to as the control group (CG).

Fig. 3 shows a simple draft of our evaluation process where only phases relating to 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): first one devoted to rocky planets and other one to 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 a learning phase (post-test). The learning phase depends on a

group the learner belongs to. It means learners of the experimental group played the Final Frontier game (part 1 during the 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 room but a teacher didn't answer any question relating to the subject. The control group of learners was presented with a Classical approach of the same content using Power Point 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. Representatives of the Newton project (pilot leader/local researcher) took part of both approaches for observational purposes.

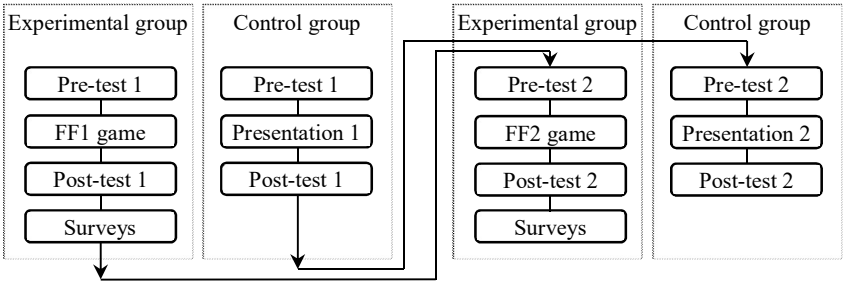

Fig. 3. The evaluation process scenario (FF1/2 – Final Frontier game part 1/2).

Table 1. The pre-test and post-test questions used in Final Frontier part 1 evaluation.

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

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 to both groups to analyze and evaluate level of acquired knowledge. **Table 1** shows questions of pre-test 1 and post-test 1 used during the Lesson 1. The pre- and post-tests creation followed requirements such as they should last max. 10 minutes, both tests are to be

similar in content and identical in the temporal extent. Single choice and simple answer questions have been included.

The research (case) study was carried out at a primary school located in Bratislava – Lamač, Slovakia with learners of two standard classes. One class (a total of 19 children of age 12-13 years[1]) went through the Newton approach (EG) and other class of 25 children (of same age) was presented with a classical approach (CG). The learning process took place during the normal hours of study thanks to cooperation of school teachers and members of Slovak University of Technology. For the experimental group all tests were implemented in a platform developed within the Newton project and provided to learners online. The control group was provided with a printed version of all tests.

4.2 Results Analysis

As was mentioned above in this paper we concentrate on evaluation of knowledge acquisition based on two different pedagogical approaches (a classical learning and game based learning). The evaluation is based on results of pre- and post-tests which are done by all learners.

Final results showing the level of acquired knowledge in percentage for both groups of learners, both types of tests and both lessons of the Final Frontier subject are depicted in **Fig. 4**. As can be seen both pedagogical approaches increased knowledge level of learners. The highest average (pre- as well as post-test) scores were achieved for the Lesson 1 and a classical approach (CG). 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 a knowledge gain which achieves values: 13.16% in case of EG and 8.33% in case of CG we can see benefit of the Newton approach based on game-based learning. Results for the Lesson 2 (FF2) show almost the same average pre-test score for both groups (about 70%), i.e. in this case all learners have the same level of knowledge in 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 these results, we can see that learning using the Final Frontier game (in both lessons) brought better knowledge gain values. During learning process (hours) the Newton project representatives have been looking after learners' behavior and comments. Moreover, after the learning process special interviews with learners and teachers were realized. 8 learners from the experimental group took part interviews (some arranged in group and other individually). Based on these activities and their results we can summarize that majority of learners saw learning more entertaining and the game helped them to learn better by a direct experience with planets environment.

[1] Primary schools in Slovakia are based on 9 years' education with children between 6 to 14/15 years old.

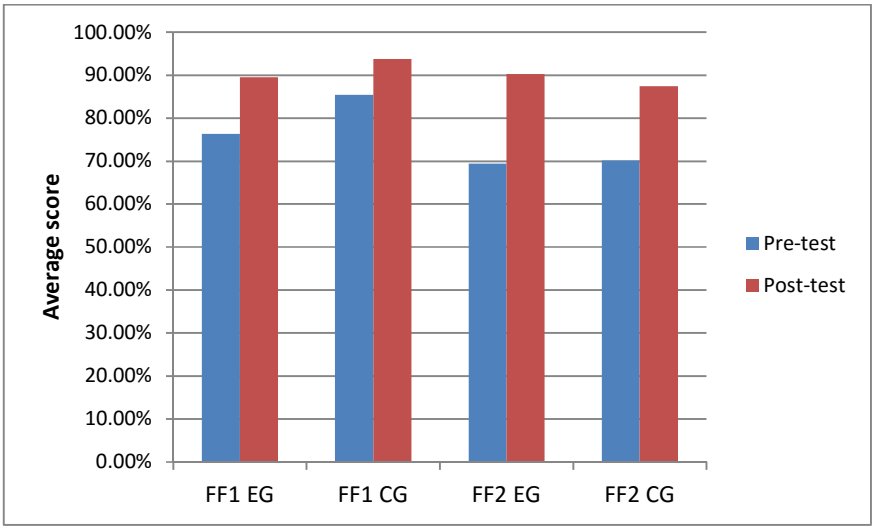

Fig. 4. Average pre- and post-test scores for learners of experimental group (EG) and control group (CG) and for Lesson 1 and 2 (Final Frontier part 1 and 2).

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

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	42.11 %	62.5 %	53.49 %	63.16 %	79.17 %	72.09 %
3 out of 4	36.84 %	20.83 %	27.91 %	31.58 %	16.67 %	23.26 %
2 out of 4	5.26 %	12.5 %	9.3 %	5.26 %	4.17 %	4.65 %
1 out of 4	15.79 %	4.17 %	9.3 %	0 %	0 %	0 %
none	0 %	0 %	0 %	0 %	0 %	0 %

5 Conclusion

The research study presented in this paper concentrates on an impact of game-based learning on students' knowledge acquisition level. For this purpose, the interactive educational video game about the Solar system (Final Frontier game) was developed and used within Newton project. The learning process realized using this game was divided into two teaching hours (lessons) and each one evaluated separately. Two school classes

of learners from a primary school took part in this pilot testing. Student sample consisted of 44 learners (12-13 years old). In order to evaluate and compare results one class was taught using this game and other one was presented with a classical approach. The evaluation process was based on knowledge pre- and post-tests.

Evaluation results for the first lesson (rocky planets of the Solar system) showed that students of the control group (presented by classical learning approach, i.e. by a teacher with PowerPoint presentation) achieved higher average (pre- as well as post-test) scores than learners of the experimental group (taught by the Final Frontier game). However, the knowledge gain was higher for learners of the experimental group. In 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 a same level of knowledge from analyzed subject the learning activity using the Final Frontier game (against a classical approach) provides higher knowledge gain (approximately 4.2% in average) and learners feel more entertained during learning (study).

After the learning process we also discussed with some learners from the experimental group to acquire and evaluate their experiences and feelings. Some students think that they learned more using our game, they liked 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, they missed direct contact with teacher. Some students would like to combine both approaches together, i.e. game with interactivity with teacher answering questions and explaining other facts.

Future work will aim to expand the research study to include 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 Final Frontier game will also be deployed on the NEWTON platform and the benefits investigation of the educational game in different European schools will be analyzed. The game will also be used in schools with special needs' students in order to evaluate the game usability and the learning outcomes for children with hearing disabilities.

Acknowledgements

This research is supported by the NEWTON project (http://www.newtonproject.eu/) funded under the European Union's Horizon 2020 Research and Innovation programme, Grant Agreement no.688503.

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