

# Final Frontier: An Educational Game on Solar System Concepts Acquisition for Primary Schools

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**Abstract**— Science teachers and researchers believe that students' disengagement from STEM area can be overcome by using interactive and fun-based computer educational games in order to support knowledge acquisition through direct experience. This paper presents a research study on the effectiveness of a new interactive educational 3D video game called *Final Frontier*. The game supports delivery of scientific knowledge on the Solar system to primary school students. A comprehensive case study that involved 30 children was conducted to evaluate the game. The results confirmed that the game supports high learning achievements through an enjoyable and fun learning environment entirely appreciated by children. The vast majority of the students (93%) have expressed their interest in learning other subjects through such an interactive computer game.

**Keywords:** Technology enhanced Science Education, Educational Game, Primary Education, and Solar System

## I. INTRODUCTION

It is a recognized fact that most European countries are currently experiencing a crisis amongst their young generations in respect to training in relation to scientific vocations. The number of students specializing in scientific disciplines declines in many European countries, and Europe faces the concrete risk of a shortage of scientists. Children's disengagement from STEM is mainly due to the perception that scientific subjects are difficult. This perception is the consequence of the fact that children have faced difficulties in acquiring scientific concepts at primary school level and therefore they lack some scientific background information, which exacerbates the problem in their later education.

However, children's disengagement from STEM area can be overcome by using interactive and fun-based teaching methods that use technology in order to support knowledge acquisition through direct experience. The use of an educational computer game is one example of a fun-based teaching method.

Research work in the area of educational games has shown the positive impact of game-based teaching methods on students' motivation [1, 2], knowledge construction, learning performance [3], fostering students' science learning [4, 5]. Klich al. [6] found that science education

game was effective in increasing adolescents' knowledge about the science content presented in the game. The effectiveness of educational games on scientific concepts acquisition by the first grade students was also demonstrated in [7]. Furthermore, the results of research done by Bakker et al [4] and Lin et al. [5] indicated that the use of educational computer game is an effective mean of improving students' attitude towards Mathematics and increase their learning performance, by attracting students' attention and increase motivation and engagement.

Acknowledging the benefits of educational computer games and their suitability for teaching STEM topics, this paper presents a research study on the effectiveness of a new interactive educational 3D video game called *Final Frontier* developed by the authors. The game supports delivery of scientific knowledge of the planets from the solar system to primary school children. The research assessed the game through a case study that involved 30 children from Ireland that played the game in the class. Pre-test, post-test and a game review survey were run and data collected was analyzed.

The research presented in this paper is part of a large research EU Horizon 2020 project called NEWTON [8] in the area of technology-enhanced learning. NEWTON develops, integrates and disseminates innovative technology-enhanced learning (TEL) methods and tools, and creates new or inter-connects existing state-of-the art teaching labs. The NEWTON TEL methodologies include interconnected fab labs and virtual labs, multi-modal and multi-sensorial media distribution, augmented reality, gamification, game-based learning, and self-directed learning pedagogies (e.g., flipped classroom, online problem-based learning, and e-practice testing). *The Final Frontier* 3D interactive computer game introduced in this paper will be deployed on the NEWTON platform and tested in different European schools.

The rest of the paper is structured as follows. Section II briefly introduces the *Final Frontier* game. Section III presents the research methodology and the case study results. Section IV concludes the paper and indicates some further work directions.

## II. THE *FINAL FRONTIER* GAME

*Final Frontier* is an interactive 3D educational video game for children that supports knowledge acquisition about planets and their satellites. Children learn about Mercury, Venus, Moon and Mars through direct experience, challenges and fun. The topics covered by the game are part of the Geography curriculum, section “Planet Earth and Space”, defined for the 2<sup>nd</sup> class in Irish primary schools. The game rewards student achievements through points, keys collected which are used to open doors to next levels, and number of questions answered correctly.

During the game play the player interacts with a non-player character (NPC) Teacher that guides the player on the next tasks to be done and may provide hints when the player needs help in order to progress. Knowledge assessment quizzes that must be answered by the player are also embedded in the game and enables progression from one level to another.

The game starts with a cinematic visual sequence of a shuttle leaving the Earth to get to a spaceship. The player then assumes control and starts exploring the environment. The NPC Teacher communicates the player the task to be solved in the first level: collect 5 meteorites from the Mercury’s craters using the jetpack (Figure 1). Mercury is the closest planet to the Sun and the most cratered. This is illustrated in the game through an image of a large Sun and presence of many craters.

Once the player has collected 5 meteorites, they are teleported back to the spaceship. In order to access the next level, they need to complete correctly the first quiz. Successful completion of the quiz enables the player to collect a key and open a door to the next level, which is about Venus. If wrong answers are given, the player is allowed to try again.

Various Venus characteristics are experienced by the player in the second level of the game. For example, Venus has a dense gravity therefore the player cannot jump high, the clouds are also extremely thick on Venus and not much sunlight can get through, therefore the luminosity level in the game is very low. The aim of this level is to traverse the terrain and to explore the area that consists of dangerous active volcanos and igloo like structures, which are safe zones. When the player is located in a safe zone they can learn facts about Venus such as: it has an opposite rotation to that of Earth and is the hottest planet in the Solar System

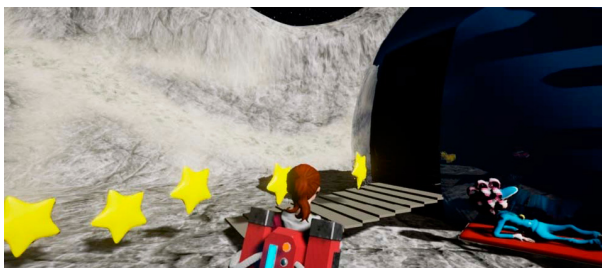


Figure 1 NPC, jetpack and collectable stars

due to its CO<sub>2</sub> clouds. When the level is completed the player is teleported back to the spaceship and asked to answer another quiz (see Figure 2). Success in the second quiz enables player access to game level three which is about Moon.

The Moon level involves jumping through a number of platforms to gain entry into the largest crater on the Moon. Knowledge regarding the Moon gravity is gained through interaction with the game. Because the gravity on the Moon is much lower than that on Earth, the jump is much higher and the player must anticipate this. As the player progresses, information about the role of the Moon in a solar eclipse is displayed and an animation demo of this event is provided. A third quiz success enables player access to level four of the game, which is about the furthest from Sun small planet, Mars.

The Mars level requires the player to take control of a dune rover and is assigned the mission to collect 10 meteorites in less than 5 minutes. This level has hoops and ramps and it was designed to finish the game on a fun note. If the player fails to collect the meteorites the level will restart. When the player completes the level and its associated quiz, they will have completed the entire game.

## III. CASE STUDY RESULTS

The research study investigated the effectiveness of the *Final Frontier* game when teaching scientific knowledge on the solar system to primary school students. The topics covered by the game conform to the primary school Geography curriculum approved by the Irish Department of Education for the first and second class.

A total of 30 children of age 8 (17 girls and 13 boys) from a primary school located in Dublin, Ireland took part in the case study. Parent/Guardian consent to have their children involved in the case study was obtained prior to starting the testing. The children were allowed to play the game as long as they needed in order to complete all the levels. All children have used computers of the same type and with the same environment settings which were provided by the school.

A paper-based pre-test assessed the children knowledge level on the topics covered by the game. Once the game was completed, the children filled in a paper-based post-test assessment and a game review survey. All children have completed the game and have answered the pre- and post-



Figure 2 Venus level assessment quiz

tests, as well as the survey. The style of the questions used in the pre- and post-tests were *multiple choice* with answers on a 1-5 Likert scale, *yes/no* questions and a normal *fill in blank* question. Most of the questions asked were of a closed question format. An analysis of the pre-test and post-test results, as well as the game survey answers was performed.

The results indicate that the children were in general not familiar with topics related to the four planets studied through the *Final Frontier* game and only a few of them were able to answer correctly the pre-test questions.

TABLE 1 presents the post-test questionnaire results, in terms of percentage distribution of right and wrong answers.

TABLE 1 PERCENTAGE OF CHILDREN VS NUMBER OF CORRECT ANSWERS IN THE POST TEST ASSESSMENT

Number of questions correct answered in the post test assessment	Number of students	Percentage of students
4 out of 4	21	70%
3 out of 4	7	23%
2 out of 4	2	7%
1 out of 4	0	0%
none	0	0%

Overall, the post-test results have shown that the children were able to acquire scientific knowledge regarding the four planets through the game play, 93% of the children have answered correctly at least 3 out of 4 questions from the post- test questionnaire. An analysis of pre-test vs post-test results has shown that the *Final Frontier* game supports high learning achievements and the vast majority of the children have scored high in the learning assessment done through the post-test questionnaire.

The children satisfaction with the game environment was assessed making use of the game review survey. 96.6% of the children confirmed that they really enjoyed playing the game. The most appreciated game features mentioned by the children were: jetpack (53.3%), traveling around the planets (13.3%) and collecting stars/meteorites (13.3%).

Over 93% of the children indicated they would like to learn other subjects through an interactive educational game. All children answered affirmative when they were asked if they would like to play again the game. Overall, the survey on the *Final Frontier* game clearly indicates that the game provides an enjoyable and fun learning environment for primary school students and has successfully transferred knowledge on the four planets from the solar system.

#### IV. CONCLUSION AND FURTHER WORK

The paper has introduced *Final Frontier* - a new 3D interactive educational video game for primary school children. The game supports knowledge acquisition about the Solar system planets and satellites Mercury, Venus, Moon and Mars through direct experience, challenges and fun. The research study has investigated the effectiveness of

the game when teaching scientific knowledge of the solar system in a primary school. Pre-test and post-test questionnaires and a game review survey were conducted on a class of 30 children.

Result analysis has shown that the *Final Frontier* educational game supports high learning achievements and the vast majority of the children have scored high in the post-game learning assessment. The children answers provided in the survey show that the game provides an enjoyable and fun learning environment entirely appreciated by children. The vast majority of the students (93%) have expressed their interest in learning other subjects through an interactive computer game.

Further research will assess game-based teaching methods using *Final Frontier* versus employing a traditional teaching method that requires listening to a teacher. The *Final Frontier* game will also be deployed on the NEWTON platform and new case studies in other European primary schools will be performed.

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