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► **To cite this version:**

Nour El Mawas, Marilena Bratu, Dorothea Caraman, Cristina Hava Muntean. Investigating the Learning Impact of Game-based Learning when Teaching Science to Children with Special Learning Needs. 30th annual conference of the Society for Information Technology and Teacher Education SITE, Mar 2019, Las Vegas, United States. hal-02251329

HAL Id: hal-02251329

<https://hal.science/hal-02251329>

Submitted on 1 Aug 2019

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Investigating the Learning Impact of Game-based Learning when Teaching Science to Children with Special Learning Needs

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Abstract: In an attempt to find solutions to the current challenges faced by children with special needs, new teaching and learning methodologies that make use of various technologies such as 3D computer based games, Augmented Reality, Virtual Reality enhanced learning have been proposed to be used in the classroom. The technology can enhance the lives of children with learning disabilities and gives them options of intervening in their various educational and cognitive problems. The paper presents a research study on learner experience when a new interactive educational 3D video game called Final Frontier, was used in a secondary school from Romania by children with hearing impairment. Pre- and Post- tests results analysis has shown that the game helped the children to acquire knowledge on the Solar system. It was also noticed that an interactive game-based learning approach is more suitable for children with disabilities than an interactive exploratory based digital library method.

Keywords: Geography education, Solar System, Game based learning, learners with disabilities

Introduction

There has been a vast process of transforming institutions, organizations, services, and even societies to ensure the protection, respect and promotion of the inalienable and non-negotiable rights of people with disabilities. Researches in the fields of psychology, special education and educational sciences (Brown 2016) have demonstrated the unmapped possibilities of developing the potential of a person with a certain disability, the possibilities of his/her integration and social affirmation under conditions of support services provided by society through educational, therapeutic, rehabilitation and functional compensation oriented activities.

Research work related to children with disabilities has shown that teenagers with disabilities have, in one form or another, more or less severely restricted access to information, as well as the ability to process and transmit it. They have a reduced drive for activity. They find it difficult to initiate spontaneously the activities specific to their age. It was also noticed that they have a limited interpersonal and group relationship due to society isolation and self-isolation.

In an attempt to find solutions to these challenges new teaching and learning methodologies that make use of technology have been proposed to be used in the classroom. The technology can enhance the lives of children with learning disabilities and gives them options of intervening in their various educational and cognitive problems. Children with disabilities often feel better about themselves as a result of using technology. For example, Virtual learning environments that use technologies such as Virtual Reality, Augment Reality, virtual Laboratory, interactive 3D educational games encourage interactive learning and provide a variety of opportunities for the learners with disabilities to have control over the learning process and learning preferences.

The research work presented in this paper is part of the EU Horizon 2020 NEWTON project¹ that focuses on design, development and deployment on NEWTON TEL Platform (NEWTELP) of technology based innovative educational solutions for all levels of education, starting from primary to third degree institutions, including learners with special needs. NEWTON Project's innovative technologies include Augmented Reality and Virtual Reality (Bogusevschi et al. 2018a) (Bogusevschi et al. 2018b), Virtual Teaching and Learning Laboratory (Ghergulescu et al. 2018b; Bogusevschi et al., 2019), Fabrication Labs (Fab Labs) (Togou et al., 2018), adaptive and personalised multimedia and multiple sensorial media (mulsemedia) (Bi, et al., 2018; Moldovan & Muntean, 2017; Moldovan et al. 2016), personalisation and gamification (El Mawas et al., 2018a) and interactive educational computer-based

¹ <http://www.newtonproject.eu/>.

video games (El Mawas et al., 2018b; El Mawas et al., 2018c). Different innovative pedagogical approaches are also deployed as part of the 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; El Mawas et al., 2018d; Zhao et al., 2019; Bradford et al., 2014; Chis et al., 2018).

The paper presents a research study on learner experience when a new interactive educational 3D video game called *Final Frontier*, was used in a secondary school from Romania by children with hearing impairment. The educational game delivers knowledge on 8 planets from the Solar system through 3D interactive game based learning and 3D interactive exploratory based digital library.

The paper is organized as follows. Next section introduces current research work on game based learning used for teaching STEM subjects to children with disabilities. This is followed an overview of the *Final Frontier* educational game including the overview of the case study and its results analysis. At the end conclusions are drawn regarding the research study performed and future perspectives are presented.

Using educational games in teaching STEM subjects for students with disabilities

STEM is a curricular area that has a major impact on the students' life skills, and it is important in the preparation of young people as future participants in the labour market. In the opinion of many specialists, the approach to STEM learning should be an interdisciplinary one (Tsupros et al. 2009) with the scientific concepts being related to real-world experiences so that students can apply science, technology, engineering, and mathematics in contexts that make connections between school, community, work, and the global economy. This approach enables the development of STEM literacy and supports students to be able to compete in the new economy (Bryant Davis 2014). Serious barriers appear for children with special needs to be full participants in STEM lessons. Although we find articles in the literature that show the difficulties of students with disabilities in STEM activities, there are also articles that highlight the progress made by them considering that the barriers stem from even inadequate work methodology and the fact that some teachers do not adequately adapt the curriculum (Marino et al. 2010).

Modern educational technology offers new opportunities for accessing STEM content for children with special needs from the early years of primary school, as more and more evidence-based practices demonstrate. Universal design for learning (UDL) applied by specialists using technology to enable learning in heterogeneous groups of students has demonstrated for many years how to improve the access of students with disabilities to STEM content.

Moreover, the use of gaming technology has positive valences both in learning and in educational-therapeutic intervention. Another example, computer-mediated communication (CMC) increases adaptive capacity as well as access to STEM. Such methods of assistive technology manage to improve the learning performance of students with special needs with benefits noted in terms of autonomy and independence. That is why we consider the opinion that the potential for participation of children with disabilities in STEM activities is often not capitalized on or encouraged enough (Bryant Davis 2014).

In the literature of the field, however, there are few experimental studies illustrating the benefits of these innovative technology-based strategies, methods and techniques in the classroom, which are very useful to increase the access of students with special needs to STEM activities. Here are some of these, as described in various research papers. We mention that they are used in a certain educational context, in order to achieve clearly defined objectives.

(Li et al., 2012) published a study in which is explored the effects of applying game-based learning to webcam motion sensor games and sensory integration training for autistic students. All the results show that by using sensory integration training, it is increased student sensory connections (including vision, hearing, motor senses), and coordination of limbs. Also, the use of game-based learning for training autistic students' sensory integration is significant and effective.

(Brown et al., 2013) published a study based on the research carried out within the RECALL Project through by which they demonstrated that Digital Games Based Learning (DGBL) can have a positive effect on some of the core development needs of people with intellectual disabilities and associated sensory impairments. The research is based on the evaluation of a novel route learning system for people with disabilities using location-based services that is using also a gamified version of the software. One of the conclusions of this research is that using the gamified version can help people with special needs to better understanding of map based representations.

In 2016, Orhan Simsek, published a study that aim to investigate the effectiveness of the game-based app Motion Math: Fraction to help students with Mathematics Learning Disabilities to gain fraction skills in an after school program. Participants in this study had to play Motion Math: Fraction 20 minutes daily for 2 weeks. The

results demonstrate that using this app in contribute to improve fractions skills for all the participants and the knowledge gained was maintained after no longer playing. Participants in this study received special education services under the following categories: Specific Learning Disabilities, Autism Spectrum Disorders and Language Impairment, Other Health Impairment including ADHD. Therefore, the conclusion does not refer to the usefulness of this game in working with other categories of children with disabilities such as sensory disabilities (visual or hearing impairment).

Final Frontier Game

Final Frontier is an interactive adventure based educational computer game for children about space and solar system. The game has a linear story and aims to immerse and motivate learners through direct experience, challenges and fun. Four small planets, four gas giant planets, the Moon satellite and the organization of the planets in the solar system are covered.

The game supports two learning modules: through game levels (**Erreur ! Source du renvoi introuvable.**), tasks/problems to be solved and quizzes per level to be completed; or through a virtual, interactive, library (**Erreur ! Source du renvoi introuvable.**) that exists on the spaceship describing the concepts to be learned about the planets and the solar system. Once the player completes the tasks for a given level, they must complete a puzzle that assesses the acquired knowledge. If they get it right they



Figure 2. The player on a surface of Venus (Final Frontier game part 1).

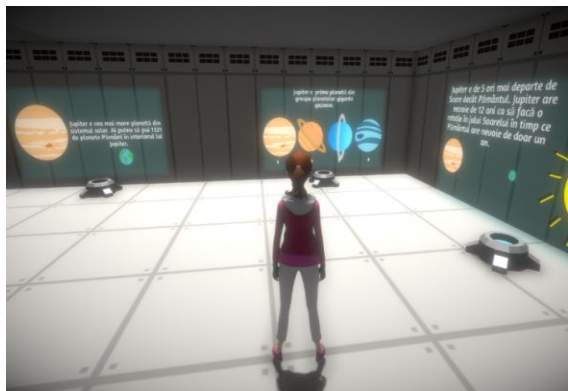


Figure 1, Jupiter room in the digital library (Final Frontier game part 2).

gain access to the next level.

The game is divided into two parts: Part 1 includes the Terrestrial Planets (Mercury, Venus, Earth and Mars) plus the Moon satellite and Part 2 contains the Giant Gas Planets (Jupiter, Saturn, Uranus and Neptune). The Part 2 has the digital library as a learning module.

When the Final Frontier game was designed, we ensured that its game objectives align with the Romanian curriculum objectives. In addition, learning outcomes achieved through computer games depend largely on how educators align learning (i.e., learning subject areas and learning purposes), learner characteristics, and game-based pedagogy with the design of an instructional game. That is why we included instructional support. Without instructional support children tend to learn how to play the game rather than learn the solar system knowledge embedded in the game. Games are more effective for learning when they actively engage children in learning - meaningful interactivity promotes learning. A detail description of the Final Frontier game and the game design methodology is provided in other papers published by the authors (El Mawas et al. 2018b, Muntean et al. 2018).

The game can be played in 5 different languages: English, Slovak, Check, Spanish, Italian, and Romanian. El Mawas et al. have presented a case study on using the game in an Irish primary school (El Mawas et al. 2018b) and in a Slovakian primary school (El Mawas et al. 2018c). This paper presents the results of a case study that involved the deployment of the game in a Romanian secondary school for children with disabilities.

In this case study the disability addressed is hearing impairment. Therefore, implicit visual support was added to the game, thus these children can benefit from using game based learning to learn new concepts. Gaming primarily generates a boost in motivation for learning. The game offers the opportunity to the learner to discover and practice problem-solving strategies in an attractive visual environment. Also, by using educational games, skills of

self-control, reflection, evaluation (through small quizzes) and re-evaluation of the results obtained and appropriate adjustment of their own actions in the game develop (Bratu et al. 2018).

Case Study Analysis

Methodology

The evaluation process consisted of several phases which cover collection of consent and assent forms, description of research study, knowledge post-test and other post-questionnaires. Note that in other evaluations of the game (i.e. Dublin and Slovakia) we use also surveys in order to evaluate the learning experience of the teenagers. We avoid the use of these surveys in this context in order to reduce the cognitive loads of the learners with disabilities. The learning process for Solar System subject taught by the Final Frontier game was divided into two parts: first one devoted to rocky planets (Final Frontier part 1) and other one to giant gas planets (Final Frontier part 2). The two parts were consecutive without any break. All learners did two knowledge tests one before (pre-test) being exposed to Final Frontier game and one after a learning phase (post-test).

In order to evaluate learners' level of knowledge on the subject prior the particular pedagogical approach all children 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 different children to analyze and evaluate level of acquired knowledge. (Table 1) shows questions of pre-test and post-test used during the evaluation. 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. More precisely, children have two single choice questions, one Yes/No question, and one open question in each test. However, regarding the open question, children can choose the option "I don't know" in the pre-tests but they need to give an answer in the post-tests because we presume that children may not know the answer before being exposed to the learning experience.

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:	5) Is Neptune the furthest planet from the Sun?	6) Which Planet is the largest planet in the Solar System?	7) How many moons Saturn has?	8) Which planet is the first planet discovered by a telescope?
a) Yes	a) Mercury	a) Craters	a) Type answer:	a) Yes	a) Neptune	a) 15	a) Type answer:
b) No	b) Venus	b) Mountains		b) No	b) Jupiter	b) 18	
c) I don't know	c) Mars	c) Water	b) I don't know	c) I don't know	c) Uranus	c) 20	b) I don't know
	d) I don't know	d) I don't know			d) I don't know	d) I don't know	
Post-test questions							
1) Which planet 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?	5) Which planet is famous for its rings made up of small lumps of ice and dust?	6) What planet is the furthest planet from the Sun?	7) Is Jupiter the largest planet in the Solar System?	8) What planet is tipped on its side, like a barrel?
a) Mercury	Type answer:	a) Yes	a) Very hot	Type answer:	a) Mercury	a) Yes	a) Uranus
b) Mars		b) No	b) Very cold		b) Neptune	b) No	b) Saturn
c) Venus		c) Like on Earth			c) Uranus		c) Earth

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

Note that the pre-test and post-test are composed of 8 questions each. The questions 1 to 4 evaluate the children learning related to part 1 of the game while questions 5 to 8 evaluate the children learning related to part 2 of the game.

The research (study was carried out at a secondary school located in Bucharest, Romania with children of a standard class of 9 pupils. The children were between 12-13 years old. The learning process took place during the normal hours of study thanks to cooperation of school teachers and members of “Universitatea din București”. The game and all the tests were accessed through the NEWTELP a platform developed within the NEWTON project and provided to learners on laptops.

Results Analysis

The results presented in this paper focus on the evaluation of knowledge acquisition based on pre- and post-tests results analysis that were completed by all learners. In this section, we analyze children answers of questions related to part 1 and part 2 of Final Frontier game.

The pre-test and post-test results related to part 1 are displayed in (Table 2 **Erreur ! Source du renvoi introuvable.**), were the percentage of correct answers and the corresponding number of children are provided. Regarding the pre-test related to part 1, no children answered correctly all pre-test questions and 22.3% of children provided correct answers to 3 questions out of 4 in the pre-test. 33.3% of children provided incorrect answers to 2 questions out of 4. 44.4% of children provided incorrect answers to either all questions or answered correctly only one question out of 4.

Regarding the post-test related to part 1, 44.4% of children answered correctly all post-test questions and 33.3% of children provided correct answers to 3 questions out of 4 in the post-test. 22.3% of children provided incorrect answers to 2 questions out of 4. 0% of children provided incorrect answers to either all questions or answered correctly only one question out of 4. An analysis of the results shows that Final Frontier part 1 increases the learning outcomes for the children. 77.7 % of children have answered correct at least 3 questions out of 4 in the post-test versus only 22.3% of children in the pre-test.

The pre-test and post-test results related to part 2 are displayed in (Table 3) and the percentage of correct answers and the corresponding number of children are provided. An analysis of the pre-test results for Part 2 show that no children succeeded to answer correct more than 50% of the questions (up to 2 out of 4 questions). all questions or 3 questions out of 4 in the pre-test. Regarding the post-test results, an improvement in their knowledge level was noticed, 22.2% of children provided correct answers to 3 questions out of 4 in the post-test. Based on Table 3, we can notice that the Final Frontier part 2 increases the learning outcomes for some children.

	Questions of the pre-test related to part 1 (Q1 to Q4)	Questions of the post-test related to part 1 (Q1 to Q4)	Variation (Δ)
4 out of 4	0 %	44.4 %	44.4 %
3 out of 4	22.3 %	33.3 %	11 %
2 out of 4	33.3 %	22.3 %	- 11 %
1 out of 4	33.3 %	0 %	- 33.3 %
None	11.1 %	0 %	- 11.1 %

Table 2. Number of questions related to part 1 (Q1 to Q4) (in percentage) correctly answered by children

	Questions of the pre-test related to part 2 (Q5 to Q8)	Questions of the post-test related to part 2 (Q5 to Q8)	Variation (Δ)
4 out of 4	0 %	0 %	0 %
3 out of 4	0 %	22.2 %	22.2 %
2 out of 4	55.6 %	11.1 %	- 44.5 %
1 out of 4	44.4 %	66.7 %	22.3 %
None	0 %	0 %	0 %

Table 3. Number of questions related to part 2 (Q5 to Q8) (in percentage) correctly answered by children

The overall average score of the students showing the level of acquired knowledge in percentage in the pre-test and post-test for each part (part 1 and part 2) is 41.67% in the pre-test 1 and 80.56% in the post-test 1. While this mean is the same, 38.89% in the pre-test 2 and post-test 2.

As we can notice, Final Frontier part 1 increases knowledge the level of learners by 38.89% and Final Frontier part 2 has no learning impact on the learners. This result was influenced by the fact that learners are exposed to two different learning modules. One using the game as a way to learn and the other using a digital library. We can conclude that the game is more suitable for the learners with disabilities than the digital library. Learners with disabilities learn better when they play and interact with different objects and non-player character in a gamified scenario. The reading activity in the digital library is not suitable for this kind of disabilities. This can justify why we start our evaluation with 12 children. All the children start our experimentation but 3 children decided to stop it when they start the Final Frontier part 2. They were very nervous about the reading activity in the

digital library. The teacher in the school justify this behaviour by the fact that children with special needs have concentration problem and they dislike to learn by themselves.

Conclusion

The paper presented a case study that investigated the learning experience of children with hearing impairment when a new interactive educational 3D video game called Final Frontier, was used in the classroom. a secondary school from Romania by children with hearing impairment. The educational game is about the Solar system and it has two parts, the first part teaches children about 4 rocky planets while the second part about 4 gas giant planets from the Solar system. Interactive game based learning methodology is used in Part 1, while Part 2 of the game allows for an exploration of an interactive, visual based digital library. Pre- and Post- tests results analysis has shown that the game helped the children to acquire knowledge on the Solar system. It was also noticed that an interactive game-based learning approach is more suitable for children with disabilities than an exploratory digital library based learning approach.

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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