Earth Course: Knowledge Acquisition in Technology Enhanced Learning STEM Education in Primary School

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Abstract: *Earth Course* is a Technology Enhanced Learning Large-Scale pilot carried out as part of the European Horizon 2020 NEWTON project focussing on science, technology, engineering and maths education, specifically on four main topics: Biosphere, Atmosphere/Physics, Astronomy and Geosphere. It was carried out in two Irish primary schools located in Dublin, St. Patrick's Boys National School (BNS) and Corpus Christi Girls National School (GNS), where two 5th classes with students of 10-11 years old were employed in each school. One class in each school employed NEWTON technology as an introductory tool to a particular *Earth Course* topic (30 boys and 30 girls) and one class as a revision tool (30 boys and 27 girls). 8 separate learning sessions were carried out during this pilot employing digital educational content developed as part of the NEWTON project. The focus of this paper is on the knowledge acquisition assessment for the two classes in each school showing that most NEWTON approach lessons benefited learners, with a slight advantage for its employment as a revision tool, rather than an introductory tool.

Introduction

Technology-Enhanced Learning (TEL) methods are currently one of the proposed teaching solutions for the increasing lack of interest in science, technology, engineering and maths (STEM) subjects seen globally (Henriksen, 2016). These subjects appear to be perceived as boring or more difficult and many students seem to become disengaged in such topics, especially if they are struggling to understand certain complex concepts leading to diminishing grades. TEL solutions offer various methodologies which can improve understanding STEM subjects, therefore increasing learners' interest. It has been observed in primary schools the majority of students are interested in STEM topics (Bogusevschi, Muntean, Gorji, & Muntean, 2018) and it is important to continue fostering students' interest in these throughout their education, from primary to secondary and third-level institutions.

Horizon 2020 NEWTON Project was set-up to design, develop and deploy a multitude of TEL solutions with the objective of increasing learner quality of experience at the same time maintaining or increasing the learning outcomes. NEWTON project employs multiple technologies and combinations of technologies in order to achieve its objectives. NEWTON Project approaches are validated in real-life Small and Large-Scale pilots across Europe (Bogusevschi, et al., 2018), (El Mawas, et al., 2018), (Bogusevschi, Muntean, Gorji, & Muntean, 2018), (Zhao, Muntean, Chis, & Muntean, 2018), (Zhao, Bogusevschi, & Muntean, Improving Future STEM Education with Innovative Learning Management System and Technology-Enhanced Learning Materials NEWTON Project and Large Scale Pilots , 2018). Its innovative approaches include adaptive multimedia (Bi, et al., 2018) and multiple sensorial media (Zou, et al., 2017), (Zou, Trestian, & Muntean, E3DOAS: Balancing QoE and Energy-Saving for Multi-Device Adaptation in Future Mobile Wireless Video Delivery, 2018), (Bi, et al., 2018), (Bi, Silva, Ghinea, & Muntean, 2018), personalisation (Lynch & Ghergulescu, 2018), gamification (Lynch, et al., 2018), Virtual Labs (VLs) (Ghergulescu, et al., STEM Education With Atomic Structure Virtual Lab For Learners With Special Education Needs, 2018), (Lynch & Ghergulescu, July 2017), (Lynch & Ghergulescu, Review of Virtual Labs as the Emerging Technologies for Teaching STEM Subjects, 2017), fabrication labs (Fab Labs) (Togou, Lorenzo, Lorenzo, Cornetta, & Muntean, 2018), Augmented Reality (AR) and Virtual Reality (VR) (Bogusevschi, et al., 2018), problem-based and game-based learning (El Mawas, et al., 2018), (Zhao, Chis, Muntean, & Muntean, 2018). NEWTON technologies and its gamification portal are embedded on the **NEW**TON **T**echnology-**E**nhanced **L**earning **P**latform (NEWTELP, newtelp.eu) developed by consortium Partner SIVECO from Bucharest, Romania (siveco.ro) (Bogusevschi, Muntean, Gorji, & Muntean, 2018).

This paper is structured as follows. Next section presents related works on knowledge gain during TEL educational pilots and case studies. Following this, the *Earth Course* Large-Scale pilot is presented, including its assessment procedure, evaluation methodology and description of participating schools and learners. The knowledge acquisition results are then presented for each individual topic finalised by the conclusion on learning improvement.

Related Work

Various TEL methods have been investigated regarding their benefits on learners' knowledge acquisition. For example in (Fokides & Zampouli, 2017) the topic of Geography was combined with second-language learning employing virtual space technology, where 105 primary school learners participated in a case study, showing that the experimental group which employed the Content and Language Integrated learning in OpenSimulator Project (CLILiOP) tool, composed of 35 learners, showed statistically significant higher knowledge gain compared to the two control groups with 35 students in each, one being conventionally taught under the scope of the CLIL and one just conventionally taught. VR is employed in (Yu, 2017) as part of Astronomy courses, where 973 students participated, 157 of which did not experience the VR visualisation, 306 viewed the VR content on a flat screen and the remaining 510 students were immersed in the VR content describing the Solar System relative distances and planets' size. The employment of immersive VR showed higher knowledge gain and knowledge retention. Mathematics is another area where VR has shown promising results. For example in (Şimşek, 2016) a 3D online virtual world (Second Life) is used in a maths course, enabling visualisation of 3D objects, where 28 secondary school students participated, finding significant knowledge improvement after employment of the Second Life application. Manipulative mathematics is employed in (Moyer-Packenham, et al., 2016) on 100 younger children with ages between 3 and 8, showing that this technology benefited students in their learning performance. In (Guerrero, Ayala, Mateu, Casades, & Alamán, 2016) virtual objects' manipulation with tangible devices are investigated when teaching geometry (FlyStick and PrimBox) with 60 students with and without special educational needs, half of which were assigned to the experimental group and half to the control group. This study resulted in more meaningful and more durable learning for the experimental group of students.

Virtual Lab (VL) is another TEL teaching approach, which was also employed in the NEWTON Project. It was previously shown in various research works to provide knowledge gain benefits to students, especially if they do not have access to an actual laboratory. In (Amirkhani & Nahvi, 2016) 30 Mechanical Engineering students participated in a study employing an interactive VL (IVCL), being separated in two groups, one control and one experimental. Similarly to other research works, the experimental groups exhibited higher knowledge gain compared to the control group.

AR is a very popular TEL approach, allowing visualisation of complex theories and objects and combined with the real world. In (Cai, Chiang, Sun, Lin, & Lee, 2017) AR-based motion-sensing software was employed in Physics learning, focusing on magnetic field induction, where 38 secondary-school students participated, helping them to better understand the scientific concepts presented. AR is also combined with other pedagogical approaches to amplify its benefits. For example in (Laine, Nygren, Dirin, & Suk, 2016) a geometry learning platform, Science Spots AR (SSAR) is employed, mixing gaming, storytelling and AR, focusing on children of 11 and 12 years of age. Game-based approaches show improved knowledge gain in (Ak & Kutlu, 2017), where 60 high-grade students participated in a case study, separated in three groups where the educational content was delivered by the classic approach to one group, as a 2D game to the second group and as a 3D game to the third group. The outcomes showed that both 2D and 3D games-based learning provided significantly higher knowledge gain, compared to the traditional approach.

Some of the NEWTON project Small and Large-Scale pilots have been finalised and, following data analysis, it was observed significant knowledge improvement for classes employing the NEWTON experimental approaches, such as multimedia (Bi, et al., 2018), mulsemedia (Bi, Silva, Ghinea, & Muntean, 2018), VLs (Ghergulescu, et al., STEM Education with Atomic Structure Virtual Lab for Learners with Special Educational Needs, 2018) and serious games (Dan Zhao, 2019). Many pilots were only finalised at the end of 2018 and the obtained results will be published at a later date. However, it has to be noted that the preliminary outcomes confirm the benefits of the NEWTON Project TEL approaches in terms of knowledge acquisition and improvement.

Earth Course Large-Scale Pilot

Pilot Structure and Applications

In this paper, the *Earth Course* Large-Scale pilot has the purpose of assessing the effect of NEWTON technologies, such as virtual environments, including computer-based VR, VLs, gamification, game-based learning, and of the NEWTON Project platform (NEWTELP) on knowledge acquisition, where two research questions are investigated:

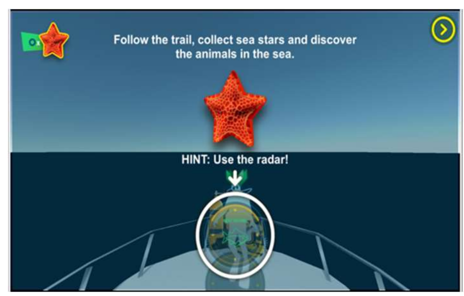
- *What is the impact of NEWTON Project Technologies and platform on knowledge gain when employed as an introductory tool?*
- *What is the impact of NEWTON Project Technologies and platform on knowledge gain when employed as a revision tool?*

This instance of the *Earth Course* contained 8 separate learning sessions: *Water Cycle in Nature* as part of the Atmosphere/Physics topic, *Wildlife I and Wildlife II, Sea-life I and Sea-life II* as part of the Biosphere topic, *Final Frontier I* and *Final Frontier II* as part of the Astronomy topic and *Geography* as part of the Geosphere topic.

a) *Water Cycle in Nature* application (Nature Environment)

b) *Water Cycle in Nature* application (Virtual Lab - Boiling Experiment)

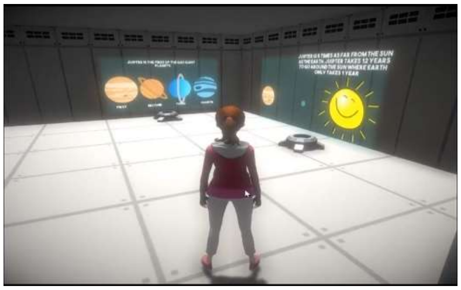
c) *Water Cycle in Nature* application (Virtual Lab - Condensation Experiment)



d) *Sea-life* Application – Nature Environment

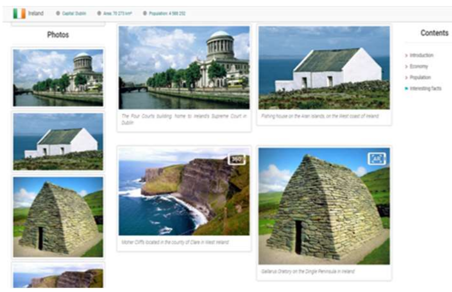
e) *Sea-life* application – Virtual Lab Environment – Clownfish

f) *Final Frontier I* application - Venus



g) Final Frontier II application – Virtual Library

h) Geography application – Educational Content



i) *Geography* application – Integrated Images with AR functionality

j) *Geography* application – Virtual Map

Figure 1. NEWTON Project *Earth Course* applications screen examples employed in St. Patrick's BNS and Corpus Christi GNS

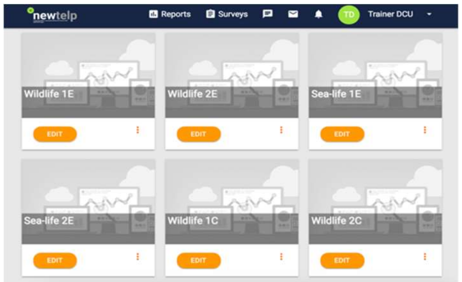
The *Water Cycle in Nature* application was developed by NEWTON Project consortium partner SIVECO from Bucharest, Romania and it combines computer-based VR with VL focusing on Physics phenomena participating in precipitation formation, such as vaporisation and condensation (Bogusevschi, et al., 2018). As part the *Water Cycle in Nature* application, the learner is immersed in a Nature environment (**Figure *1* (a)**) and a VL with separate experiments previously described in the Nature setting (**Figure *1* (b)** and **Figure *1* (c)**).

Applications *Wildlife I and II, Sea-life I and II* were also developed by SIVECO and employed interactive computer-based VR technology (**Figure *1* (d)**) with VL (**Figure *1* (e)**) combined with gamification providing educational content on various terrestrial and aquatic animals, including deer, moose, brown bears, wolfs, seahorses, dolphins, sharks and puffer fish (Bogusevschi, Muntean, Gorji, & Muntean, 2018).

Final Frontier is a game that starts on a spaceship and has two parts. Part *I* focuses on Rocky Planets and allows for an exploration of the virtual planets and employs gamification and game-based learning (El Mawas, et al., 2018). **Figure *1* (f)** illustrates a screenshot of the game. The *Final Frontier Part II* is set in a virtual library that exists on the spaceship and provides educational information about the giant Gas Planets (**Figure *1* (g)**) and the Rocky planets. The second part of the game can also be used as a revision tool. The *Final Frontier* game was developed by NEWTON Project consortium partner, National College of Ireland (NCI, ncirl.ie).

The *Geography* application was developed by consortium partner Slovak University of Technology in Bratislava (STUBA, stuba.sk) and is focused on United Kingdom and the Republic of Ireland. This application was at an early stage of development during the *Earth Course* pilot, whereby not all its technologies, such as AR and VR, were fully integrated. Example images are presented in **Figure *1*(h)** showing some of the reading material learners had to familiarise with; **Figure *1*** (i) with some of the AR functionality integrated later on. The Virtual Map application, shown in **Figure *1*** (j), was employed to assess students' geographical knowledge.

The *Earth Course* applications, user accounts for all participating students and assessment questionnaires and knowledge tests were located on the NEWTON Project platform, NEWTELP. An example of the *Earth Course* Sessions' list is seen in **Figure *2* (a)** with a view of a specific session from a learner's perspective is presented in **Figure 2 (b).**



a) NEWTELP Platform – *Earth Course* Sessions' list

b) NEWTELP Platform – Example of *Earth Course* Wildlife I screen (learner's perspective)

Figure 2. NEWTON Project *Earth Course* NEWTELP platform screen examples employed in St. Patrick's BNS and Corpus Christi GNS

Participants

Two schools from Dublin, Ireland have participated in the Horizon 2020 NEWTON Project *Earth Course* Large-Scale Pilot, Corpus Christi GNS and St. Patrick's BNS. In each school two 5th classes took part with learners of 10 – 11 years of age as seen most suitable by the teachers for the *Earth Course* educational content. Each school had the same set-up in terms of overall assessment, whereby one class was employing the NEWTON project approach as an introductory tool (class A in St. Patrick's BNS and class A' in Corpus Christi GNS). The other class employed the NEWTON Project approach as a revision tool (class B in St. Patrick's BNS and class B' in Corpus Christi GNS), whereby the students were initially presented the educational content in a classic teaching approach manner by their usual teacher, following which, 4 to 10 weeks later, the same content was revised using the NEWTON Project applications. 30 boys and 30 girls were part of classes A and A' respectively, and 30 boys and 27 girls were part of classes B and B' respectively.

Evaluation Methodology

Prior to carrying out the *Earth Course* Large-Scale Pilot ethics approval was obtained from the DCU Ethics Committee and this evaluation meets all ethics requirements. All parents were provided with Consent forms, Data Management Plan and Plain language statement. All participating children were provided with Assent forms. Knowledge acquisition was assessed for the two experimental classes in St. Patrick's BNS and two classes in Corpus Christi GNS, evaluating the use of NEWTON either as an introductory tool (class A and A') or as a revision tool (class B and B'). Knowledge pre and post-tests were employed for assessing the knowledge gain of the NEWTON approach. For experimental groups A and A' a knowledge pre-test was provided before the NEWTON lesson and a knowledge post-test after the NEWTON lesson. For experimental groups B and B' a knowledge pre-test was provided before the classic-approach lesson and a knowledge post-test after the NEWTON approach lesson.

Results

Learning Acquisition Assessment

The knowledge acquisition results were assessed for each *Earth Course* session separately, whereby relevant knowledge pre-tests were provided prior the employed educational activities, either before the classic approach lesson for classes B and B' or before the NEWTON approach lessons for classes A and A'. Relevant knowledge post-tests were then employed for each topic, following the NEWTON approach lessons, which was an introductory lesson for classes A and A' and a revision lesson for classes B and B'. It has to be noted that *Wildlife* and *Sea-life* lessons were performed in two separate sessions each, *Wildlife I* and *Wildlife II, Sea-life I* and *Sea-life II* respectively, in order to conform to the school timetable, as one session would be too lengthy for one regular primary school lesson. As both sessions had the same structure and technology employed, the knowledge assessment for *Wildlife I* and *Wildlife II* is combined into one overall report, with the same evaluation approach performed for *Sea-life I and Sea-life II*. The Astronomy topic was also delivered as part of two learning sessions, *Final Frontier I* and *Final Frontier II*. The Astronomy topic's knowledge assessment is performed separately for each session as the pedagogical and TEL approach for each of the two lessons was different. *Final Frontier I* is more focused on game-based learning and gamification with educational content regarding Rocky planets, whereas *Final Frontier II* is localised in a digital library setting where the game-based learning and gamification elements are removed and educational content focused on giant Gas Planets.

For each assessment, the following calculations were performed:

- Knowledge Pre-Test Average Grade Comparison;
- Knowledge Post-Test Average Comparison;
- Paired t-test at $\alpha = 0.05$ between the knowledge post-test average grades compared to knowledge pre-test average grades for each of the four classes, identifying which approach in each school exhibited a statistically significant difference in knowledge acquisition after students participated in the *Earth Course* pilot.

The obtained results for each point are presented in **Table 1** for St. Patrick's BNS and in **Table 2** for Corpus Christi GNS. The results differ between the two schools in terms of which setting was more beneficial, NEWTON approach as a revision tool or an introductory tool.

In St. Patrick's BNS the *Water Cycle in Nature* application provided post-test results of statistical significance for the revision approach lesson, with no statistical significant improvement for the introductory approach. The same was observed for the *Sea-life* lessons. The *Final Frontier II* lessons showed knowledge gain of statistical significance for both approaches, with a slightly increased improvement for the revision approach in class B. The *Wildlife* and *Final Frontier I* lessons however showed statistical significance for the introductory approach only. The *Geography* lesson displayed no knowledge gain.

In Corpus Christi GNS, the *Water Cycle in Nature* application performed similarly as in the boys' school, with statically significant benefit for the revision approach. The *Wildlife* lessons in Corpus Christi GNS displayed the same performance, being more beneficial as a revision tool in class B. The introductory approach displayed statistically significant benefits in the *Sea-life* and *Final Frontier I* lessons. Both approaches performed similarly in *Final Frontier II* lessons, displaying improvement of the same statistical significance. As in the boys' school, the *Geography* lesson did not provide any knowledge benefits.

Lessons	Pre-Test Average		Post-Test Average		t-test Post-Test vs. Pre-Test	
	A (%)	B (%)	A (%)	B (%)	A	B
Water Cycle in Nature	44.58	33.46	45.63	46.25	P = 0.8474	P = 0.0135
Wildlife	46.37	44.83	65.24	47.15	P = 0.0001	P = 0.6564
Sea-Life	48.89	31.03	53.70	57.86	P = 0.2207	P = 0.0001
Final Frontier I	57.76	72.4	84.48	62.50	P = 0.0001	P = 0.0975
Final Frontier II	57.41	47.92	76.85	87.5	P = 0.0087	P = 0.0001
Geography	59.18	47.62	42.73	32.44	P = 0.001	P= 0.0028

Table 1. St. Patrick's BNS *Earth Course* Knowledge acquisition assessment for classes A (where the NEWTON approach was employed as an introductory tool) and B (where the NEWTON approach was employed as a revision tool).

Lessons	Pre-Test Average		Post-Test Average		t-test Post-Test vs. Pre-Test	
	A'	B'	A'	B'	A'	B'
Water Cycle in Nature	40.37	39.50	44.35	54.38	P = 0.2931	P = 0.0084
Wildlife	47.25	57.89	56.87	69.33	P = 0.0781	P = 0.0382
Sea-Life	54.35	56.76	60.95	66.75	P = 0.0354	P = 0.0590
Final Frontier I	50	63.04	81.9	69.57	P = 0.0001	P = 0.1679
Final Frontier II	47.32	27.17	80.17	77.17	P = 0.0001	P = 0.0001
Geography	53.14	40.91	40.29	23.7	P = 0.319	P = 0.0001

Table 2. Corpus Christi GNS *Earth Course* Knowledge acquisition assessment for classes A' (where the NEWTON approach was employed as an introductory tool) and B' (where the NEWTON approach was employed as a revision tool).

Conclusions

This paper presents the learning outcomes of a Horizon 2020 NEWTON Project Large-Scale Pilot, *Earth Course*. The *Earth Course* is composed of four main topics: Biosphere, Atmosphere/Physics, Astronomy and Geosphere. The pilot was carried out in two primary schools from Dublin, Ireland, Corpus Christi GNS and St. Patrick's BNS with two 5th classes in each school. Eight separate learning sessions were carried out with each class from the two schools using the NEWTON approach either as an introductory tool or as a revision tool. Classes A and A' in St. Patrick's BNS and Corpus Christi GNS respectively were assigned as the experimental class employing the NEWTON approach as an introductory lesson on a particular *Earth Course* topic. Classes B and B' in St. Patrick's BNS and Corpus Christi GNS respectively were assigned as the experimental class to which the educational content was presented by their usual teacher, following which, 4 to 10 weeks later the NEWTON approach was employed in the same classes as a revision tool.

When assessing which class benefited more from the NEWTON approach lessons, it appears that, in Corpus Christi GNS it has the same benefits both as a revision and an introductory tool, whereas in St. Patrick's BNS the NEWTON approach seemed to provide slightly higher knowledge gain as a revision tool It should also be noticed that the first school had girls only where the second school had boys only.

A technology-based analysis shows that the computer-based VR technology combined with a VL in the *Water Cycle in Nature* application was more beneficial as a revision tool in both schools. Both *Wildlife* and *Sea-life* applications employed VR, VLs and gamification, and, if assessing the outcomes for both schools, these were beneficial as an introductory tool and as a revision tool as well. The outcome for the *Final Frontier I* application, employing gamification and game-based learning, provided a significant improvement for the class employing the NEWTON approach as an introductory tool. Students appeared very interested in the employed game-based learning approach, and it is recommended to make use of this approach in future TEL lessons. The *Final Frontier II* lesson, which employed a computer-based virtual library, provided benefits for both classes in the two schools.

Following the *Earth Course* Large-Scale Pilot it is recommended to modify the *Geography* application. However, it has to be noted that during this instance of the *Earth Course* Pilot, not all features of the application were finalised, such as the AR content, which might have benefited the students, increasing their interest in the presented content. Employing all innovative features of this application might increase knowledge gain. It must be emphasised that the excessive amount of reading present in this application was perceived as very boring and uninteresting by most students, which encouraged them to either not read the entire content or not pay attention to the read material. However, the *Final Frontier II* application also required reading educational content. Nevertheless, it did show knowledge gain benefits both as an introductory tool and as a revision tool. The difference is that the reading material in *Final Frontier II* was much shorter compared to the *Geography* application, leading to the conclusion that this educational approach in TEL lessons should be employed in a limited manner and combined with other methodologies, such as gamification and game-based learning, AR/VR and VL.

Following the first instance of the *Earth Course* Large-Scale Pilot, it is planned to provide the two schools access to the Horizon 2020 NEWTON Project NEWTELP Platform and the *Earth Course* applications and educational content as well as assessment questionnaires and knowledge tests to other teachers for their in-class or after-school activities.

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References

Ak, O., & Kutlu, B. (2017). Comparing 2D and 3D game-based learning environments in terms of learning gains and student perceptions. *British Journal of Education Technology*.

Amirkhani, S., & Nahvi, A. (2016, July). Design and implementation of an interactive virtual control laboratory using haptic interface for undergraduate engineering students. *Computer Applications in Engineering, 24*(4), 508-518.

Bi, T., Pichon, A., Zou, L., Chen, S., Ghinea, G., & Muntean, G.-M. (2018). A DASH-based Mulsemedia Adaptive Delivery Solution. *ACM Multimedia Systems Conference (MMSys), International Workshop on Immersive Mixed and Virtual Environment Systems (MMVE).* Amsterdam, The Netherlands.

Bi, T., Silva, F., Ghinea, G., & Muntean, G.-M. (2018). Improving Learning Experience by Employing DASH-based Mulsemedia Delivery. *IEEE Games, Entertainment, Media Conference (GEM).*

Bi, T., Simiscuka, A., Silva, F., Togou, M., Rozinaj, G., & Muntean, G.-M. (2018). A Study of Learning Experience with s DASH-based Multimedia Delivery System. *10th annual International Conference on Education and New Learning Technologies (EDULEARN).* Palma de Mallorca, Spain.

Bogusevschi, D., Muntean, C. H., Gorji, N. E., & Muntean, G. M. (2018). Earth Course: A Primary School Large-Scale Pilot on STEM Education. *10th annual International Conference on Education and New Learning Technologies (EDULEARN).* Palma de Mallorca, Spain,.

Bogusevschi, D., Tal, I., Bratu, M., Gornea, B., Caraman, D., Ghergulescu, I., . . . Muntean, G.-M. (2018). Water Cycle in Nature: Small-Scale STEM Education Pilot. *Proceedings of EdMedia: World Conference on Educational Media and Technology*, (pp. 1496-1505). Amsterdam, The Netherlands.

Cai, S., Chiang, F.-K., Sun, Y., Lin, C., & Lee, J. J. (2017). Applications of Augmented Reality-Based Natural Interactive Learning in Magnetic Field Instruction. *Interactive Learning Environments, 25*(6), 778-791.

Dan Zhao, C.-H. M.-M. (2019). The Restaurant game: A NEWTON Project Serious Game for C Prpogramming Courses. *30th annual conference of the Society for Information Technology and Teacher Education (SITE).* Las Vegas, USA, 2019.

El Mawas, N., Tal, I., Moldovan, A., Bogusevschi, D., Andrews, J., Muntean, G., & Muntean, C. H. (2018). Final Frontier Game: A Case Study on Learner Experience. *Proceedings of the 10th International Conference on Computer Supported Education (CSEDU), .* Madeira, Portugal.

Fokides, E., & Zampouli, C. (2017). Content and Language Integrated Learning in Opensimulator Project. Results of a Pilot Implementation in Greece. *Education and Information Technologies, 22*(4), 1479-1496.

Ghergulescu, I., Lynch, T., Bratu, M., Moldovan, A., Muntean, C. H., & Muntean, G.-M. (2018). STEM Education with Atomic Structure Virtual Lab for Learners with Special Educational Needs. *10th annual International Conference on Education and New Learning Technologies (EDULEARN18).* Palma de Mallorca, Spain.

Ghergulescu, I., Lynch, T., Bratu, M., Moldovan, A., Muntean, C., & Muntean, G.-M. (2018). STEM Education With Atomic Structure Virtual Lab For Learners With Special Education Needs. *International Conference on Education and New Learning Technologies (EduLearn).* Palma de Mallorca, Spain.

Guerrero, G., Ayala, A., Mateu, J., Casades, L., & Alamán, X. (2016, October). Integrating Virtual Worlds with Tangible User Interfaces for Teaching Mathematics: A Pilot Study. *Sensors, 16*(11).

Henriksen, E. (2016). *Understanding student participation and choice in science and technology education.* SPRINGER.

Laine, T. H., Nygren, E., Dirin, A., & Suk, H.-J. (2016). Science Spots AR: a platform for science learning games with augmented reality Authors Authors and affiliations. *Educational Technology Research and Development, 64*(3), 507–531.

Lynch, T., & Ghergulescu, I. (2017). Review of Virtual Labs as the Emerging Technologies for Teaching STEM Subjects. *International Technology, Education and Development Conference.* Valencia, Spain.

Lynch, T., & Ghergulescu, I. (2018). Innovative pedagogies and personalisation in STEM education with NEWTON Atomic Structure Virtual Lab. *AACE EDMEDIA Innovative Learning.* Amsterdam, The Netherlands.

Lynch, T., & Ghergulescu, I. (July 2017). NEWTON Virtual Labs: Introduction and Teacher Perspective. *IEEE International Conference on Advanced Learning Technologies (ICALT).* Timisoara, Romania.

Lynch, T., Playfoot, T., De Nicola, C., Guarino, G., Di Salvadore, F., & Ghergulescu, I. (2018). Gamification elements in STEM subjects – Lessons learned from NEWTON Project. *Ireland International Conference on Education, - IPETeL.* Dublin, Ireland.

Moyer-Packenham, P. S., Bullock, E., Shumway, J. F., Tucker, S. I., Watts, C., Westenskow, A., . . . Jordan, K. E. (2016). The role of affordances in children’s learning performance and efficiency when using virtual manipulative mathematics touch-screen apps . *Mathematics Education Research Journal, 28*(1), 79-105.

Şimşek, I. (2016). The Effect of 3D Virtual Learning Environment onSecondary School Third Grade Students’ Attitudes toward Mathematics. *The Turkish Online Journal of Educational Technology, 15*(3), 162-168.

Togou, A., Lorenzo, C., Lorenzo, E., Cornetta, G., & Muntean, G.-M. (2018). Raising Students’ Interest in STEM Education via Remote Digital Fabrication: An Irish Primary School Case Study. *10th annual International Conference on Education and New Learning Technologies (EDULEARN18)*, (pp. 2835-2840). Palma de Mallorca, Spain.

Yu, K. C. (2017). Learning about the scale of the solar system using digital planetarium visualizations. *85*(7), 550-556.

Zhao, D., Bogusevschi, D., & Muntean, G.-M. (2018). Improving Future STEM Education with Innovative Learning Management System and Technology-Enhanced Learning Materials NEWTON Project and Large Scale Pilots . *International Conference on Engaging Pedagogy.*

Zhao, D., Chis, A., Muntean, G. M., & Muntean, C. H. (2018). A Large-Scale Pilot Study on Game-Based Learning and Blended Learning Methodologies in Undergraduate Programming Courses. *International Conference on Education and New Learning Technologies (EduLearn).* Palma de Mallorca, Spain.

Zhao, D., Muntean, G., Chis, A., & Muntean, C. (2018). A large-scale Pilot Study on Game-based Learning and Blended Learning Methodologies in Programming Courses. *10th annual International Conference on Education and New Learning Technologies (EDULEARN).* Palma de Mallorca, Spain.

Zou, L., Tal, I., Covaci, A., Ibarrola, E., Ghinea, G., & Muntean, G.-M. (2017). Can Multisensorial Media Improve Learner Experience? *Proceedings of the 8th ACM on Multimedia Systems Conference (MMSys'17.* New York, NY, USA.

Zou, L., Trestian, R., & Muntean, G.-M. (2018). E3DOAS: Balancing QoE and Energy-Saving for Multi-Device Adaptation in Future Mobile Wireless Video Delivery. *IEEE Transactions on Broadcasting, 63*(1).