Water Cycle in Nature – An innovative Virtual Reality and Virtual Lab: Improving Learning Experience of Primary School Students

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Abstract: A technology-enhanced learning (TEL) application, "Water Cycle in Nature", that focuses on the physics phenomena part of the natural water cycle and precipitation formation was employed in a small-scale educational pilot carried out in a primary school in Ireland, as part of the European Horizon 2020 NEWTON project. This application contains 3D immersive computer-based virtual reality and experimental laboratory simulations. 58 primary school children took part in this pilot, split in two groups, one control and one experimental, with 29 students in each. The goal of the study presented in this paper was to assess the benefits of the Water Cycle in Nature application both in learner experience and usability and knowledge gain. The results show good outcomes in usability and learner experience. In terms of knowledge gain it has been shown that the excitement of the experimental group students towards the game might have created a barrier in terms of learning improvement and the NEWTON application will serve better as a revision tool.

1 INTRODUCTION

Subjects in science, technology and maths (STEM) are currently suffering an increased lack of interest from students starting from primary to third level institutions. It is very important to capture learners' attention to STEM subjects early on, starting in primary school, and encouraging them to pursue these subjects in future education. Numerous studies have been performed on this, such as investigating content and language integrated learning in OpenSimulator Project (CLILiOP), focusing on Geography by employing Virtual Reality (VR) (Fokides and Zamplouli, July 2017), showing better cognitive results for the experimental group of learners and a higher employment of geographical terms in knowledge post-tests, compared to the control class. VR is also employed in the field of primary school mathematics, investigating the benefits of OpenSimulator VR environment combined with game-based learning, showing significant improvement when using the combination between the two techniques (Kim and Ke, 2017).

Another TEL technique employed in STEM subjects is Augmented Reality (AR) showing much potential in attracting learners of all ages and levels to science-related education, such as in (Cuendet, et al., 2013), where three different AR systems, TinkerLamp, Tapcarp and Kaleidoscope, were employed for geometry teaching in a primary school setting, showing great usability and integration into the classroom. In (Sommerauer and Muller, 2014) AR was employed in an informal environment at a mathematics exhibition, where participants of various ages took part, including primary level students, showing that all AR-enhanced exhibits performed significantly better in terms of knowledge acquisition and retention compared to non-AR exhibits. The benefits of combining AR with game-based learning are investigated in (Pellas, et al., 2018) presenting multiple benefits on both knowledge gain and learning motivation, specifically in STEM education. The concept of game and technology-based primary level maths teaching is also investigated in (Misfeldt and Zacho, 2016), where its benefits are observed from the point of view of both teachers and learners.

Modern education is trying to stay in line with technology, such as iPads being employed in many schools for all subjects, including maths. For example, in (Hilton, 2018), where its effect on learners' attitude and motivation toward maths is investigated, showing a positive influence from both angles. The use of tablets in education is also investigated in (Fokides and Atsikpasi, 2017), specifically for teaching plants to primary level students, showing a positive impact on knowledge acquisition and improvement in both collaborative and independent learning for the experimental group. Mobile devices have also been combined with collaborative learning in (Iglesias Rodríguez, et al., 2017) presenting major benefits for primary school learners. The use of tablets in primary and secondary education, including for STEM subjects, has been investigated in (Haßler, et al., 2016), where most of the examined case studies showed positive learning outcomes. Such primary education benefits are also shown in (Domingo and Gargante, 2016), improving access to content and increasing engagement from pupils.

This paper describes the use of the Horizon 2020 NEWTON project computer-based application, *Water Cycle in Nature*, in a primary school in Dublin, Ireland, focusing on physics, specifically on precipitation formation. A research study on 5th primary school classes was carried out, one control and one experimental, examining the benefits of the *Water Cycle in Nature* application for knowledge gain, learner experience and usability. The next two sub-sections give a brief description of the Horizon 2020 NEWTON project and the *Water Cycle in Nature* application. The case study is described in Section 2, followed by the obtained results in Section 3. The summary of the paper and its conclusions are presented in Section 4.

1.1 European Horizon 2020 NEWTON Project

Horizon 2020 NEWTON project aims to design, develop and deploy innovative solutions for TEL including innovative pedagogies such as adaptive multimedia and multi-sensorial content delivery mechanisms (Zou, et al., 2018), (Bi, et al., 2018), personalisation and gamification solutions (Lynch and Ghergulescu, July 2017), Virtual Labs (VL) and fabrication labs (Togou, et al., July 2018), problem-based, game-oriented, and flipped-classroom-based learning (El Mawas, et al., 2018). All NEWTON project solutions are employed using the NEWTON project technology enhanced learning platform, NEWTELP, to be used by teachers for course creation and both knowledge and qualitative assessment, and by students with the primary focus on learning course material and completing knowledge tests and questionnaires (Montandon, et al., June 2018).

1.2 Water Cycle in Nature Application

The *Water Cycle in Nature* application was developed by NEWTON project consortium partner SIVECO in Romania and is one of many applications employed in small and large-scale technology enhanced educational pilots with the objective of assessing learner satisfaction and knowledge gain. The *Water Cycle in Nature* application is a VL combined with VR technology, where the content is explored by students though immersive multimedia 3D in two separate settings: Nature Environment for presenting and Experimental VL environment (Bogusevschi, et al., 2018), (Bogusevschi, et al., April 2018) for reinforcing the previously presented definitions, such as vaporisation, evaporation, boiling and condensation.

2. CASE STUDY DESCRIPTION

2.1 Evaluation Methodology

The *Water Cycle in Nature* application was employed in a primary school in Dublin, Ireland, St. Patrick's Boys' National School (BNS), where two 5th classes, with 29 pupils in each class aging from 10 to 11 years old, participated and randomly assigned as control and experimental group. Ethics approval was obtained from the DCU Ethics Committee and this evaluation meets all ethics requirements.

The experimental class took part in the NEWTON approach lesson, where the *Water Cycle in Nature* application was employed. The control class participated in a classic approach lesson, developed by the NEWTON Project team, ensuring that the educational content in both lessons, classic approach and NEWTON approach, were identical, and was provided by their usual teacher. Pre-tests were carried out in both classes before their respective lesson, assessing the participating pupils' knowledge level of the topic. Following each lesson, post-tests were provided to students, investigating knowledge gain.
Following all the compulsory steps of the small-scale study, pre-test, classic approach lesson, post-test, the control group also interacted with the *Water Cycle in*

Nature application, allowing the NEWTON project researchers to assess the comparison in terms of learner satisfaction between the classic approach and the NEWTON approach. Following the interaction with the application, both classes completed a Learner Satisfaction Questionnaire (LSQ), containing the following questions: Q1- The video game and the experiments that I did in the lab from the video (this is called a virtual lab!) helped me to better understand vaporisation and condensation processes; Q2- The video game and the experiments that I did in the virtual lab helped me to learn easier about the vaporisation and condensation processes; Q3-I enjoyed this lesson that included the video game and the experiments in the virtual lab; Q4-The experiments that I did in the virtual lab made the lesson more practical; Q5-The video game distracted me from learning; Q6-I would like to have more lessons that include video games and doing experiments in virtual labs; Q7-Comments/Suggestions (Bogusevschi, et al., April 2018).

2.2 Data Collection

For the experimental group, the *Water Cycle in Nature* application was uploaded on NEWTON Project lap-tops, as the school PCs did not have the necessary specifications to support the application. After the post-test knowledge assessment was performed, the control class also interacted with the application.

The DCU NEWTON Project researchers supervised the experimental approach, providing support and helping students when necessary, collecting all the paper-based knowledge tests and LSQs. The classic approach lesson was carried out simultaneously with the experimental approach lesson, by the usual control class teacher. Student IDs were employed for both groups, in order to ensure anonymization.

The knowledge pre-test and post-test contained seven and eight questions respectively, each with a maximum of 10 points (Bogusevschi, et al., 2018).

3. RESULTS

3.1 Learner Experience

The learner experience was assessed based on LSQ questions Q1 to Q6. The LSQ percentage results for the experimental and control classes are presented in Figure 1 and Figure 2. A 5-Likert scale was employed during the LSQ, with the following answers Strongly Agree (SA), Agree (A), Neutral (N), Disagree (D) and Strongly Disagree (SD). One control group student did not provide answers to questions Q4, Q5 and Q6.

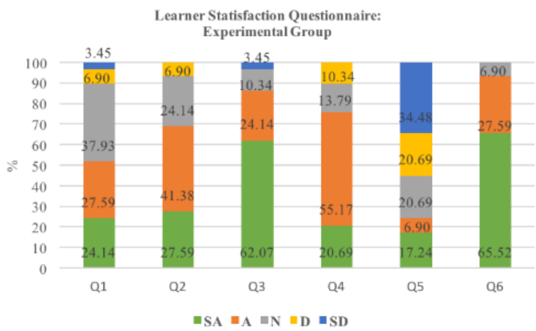

Figure 1: Experimental Group Learners' LSQ results

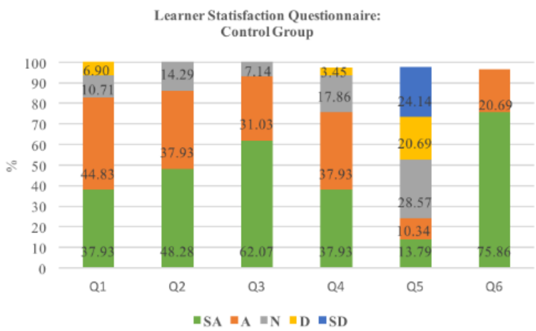

Figure 2: Control Group Learners' LSQ results

It can be observed that a much higher percentage of control group students agreed that the *Water Cycle in Nature* application VL helped them better understand vaporisation and condensation processes (Q1), at just under 83%, compared to ~52% for the experimental class. This might point to the fact that the NEWTON approach worked better as a revision tool for the control class, as the learners from this group were firstly presented the relevant physics topics during a classic approach lesson. A higher percentage of control group students considered that the video game and the experiments helped them to learn easier about the vaporisation and condensation processes (Q2), with over 86% compared to just under 69% of the experimental group students, which also points to a higher efficiency of the application as a revision tool, rather than an introduction tool. A similar percentage of learners in both classes enjoyed the application (Q3), with ~93% in the control class and ~86% in the experimental class. The same percentage of students (75.86%) in both classes thought that the *Water Cycle in Nature* application virtual experiments made the lesson more practical (Q4). Just over 24% of learners in each class thought that the application was distracting them from learning (Q5) and the vast majority of participating students would like to have more lessons that include video games and doing experiments in virtual labs (Q6), at 93% of experimental class and just over 96% of the control class learners.

3.2 Application Usability

The usability of the *Water Cycle in Nature* application was assessed using the provided LSQ Q7 answers. In each class, 11 students (37.9%) chose not to provide an answer to this question. The majority of the remaining 62.1% provided positive comments, such as *"Good lesson"*, "*I enjoyed it and I would do it again"*, *"Very fun and help me learn about vaporization and condensation"*, *"Very fun and easy to learn definitely want to learn more things like this as normal school is boring"* in the control class and *"It was Awesome"*, *"It was really fun it helped me to learn about vaporization and condensation"*, *"It was amazing and the best I love learning that way"*, *"I think was so cool thank you so much"* in the experimental class.

It appeared that the control class was somewhat more positive in their comments, as they used the application to review what was already presented to them in the classic approach lesson and they were using the NEWTON approach lesson more so as a revision tool. Some of the experimental class students perceived parts of the *Water Cycle in Nature* application slightly boring, expressing the hope to have a more gamified experience and to have more freedom in the VL, in terms of experiments to carry out. Some students provided commented on the audio track, suggesting having a more engaging voice-over.

3.3 Knowledge Acquisition Assessment

The learning impact assessment was investigated using the pre-tests provided to both classes prior the classic approach for control class and NEWTON approach for the experimental class and the post-tests employed after each lesson. The average grades for the pre-test and post-test are presented in Figure 3. It is seen that the experimental class had a slightly higher average pre-test grade. A t-test between the two pre-tests showed that the experimental group's higher average pre-test mark was of no statistical significance, at $\alpha = 0.05$ ($t(56) = 1.7423$, $p = 0.087$).

Following the classic and NEWTON approach lessons the average grades improved for both classes. The experimental class exhibited a 15.21% improvement, with 55% of students providing improved grades, whereas the control group had a much higher knowledge gain, at over 85%, with 82% of students having improved grades. The experimental group shows improvement of no statistical significance, at $\alpha = 0.05$ ($t(28) = 1.243$, $p = 0.2239$). The grades improvement for the control group is statistically significant, at $\alpha = 0.05$ ($t(28) = 5.0517$, $p = 0.0001$).

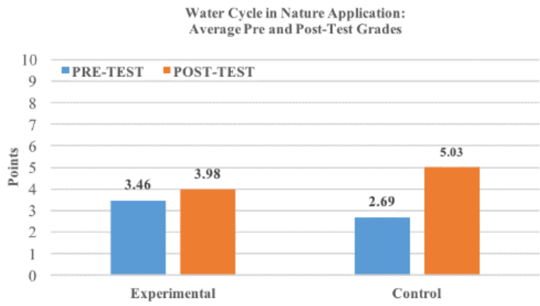

Figure 3: Average Pre and Post-test Mean grades for the experimental and control groups

4. CONCLUSIONS

The primary school small-scale TEL pilot described in this paper investigates the usability and learner experience, as well as knowledge gain assessment of the Horizon 2020 NEWTON Project *Water Cycle in Nature* application. A small-scale educational pilot was conducted in St. Patrick's BNS in Dublin, Ireland. Two classes of 29 students in each took part in the case study, one class exposed to the NEWTON project application as the experimental group and the other class, where the classic teacher-based approach was used, as the control group. Both participating groups where provided knowledge tests before and after the lessons, teacher-based or computer-based, in order to assess the learning outcomes for each teaching approach. Following the post-tests after the classic approach lesson, the control class was also exposed to the application. Both classes completed a LSQ, investigating Learner Experience and Application Usability. In terms of knowledge gain, both classes showed improvement, however it was observed that the control class performed much better compared to the experimental class. The experimental class appeared much more excited about the *Water Cycle in Nature* application which might have created a barrier to achieving significant knowledge gain, as they were more interested in the visual aspects of the application, rather than its educational content. The classic approach presentation was provided to the control group by their usual teacher, who allowed additional questions from students during the classic approach, which created an advantage for the control class. In the NEWTON approach lesson, the experimental class did not ask any questions, as they were very focused on the application's immersive multimedia 3D simulation and not on the actual educational content. It also has to be noted that during the experimental approach, the usual teacher was not present, which might have introduced a very high sense of freedom for the experimental group learners, enabling them to concentrate only on the game, which was a very new school experience for them, rather than on learning. This case study reinforced the perception that teachers' leadership is extremely valuable during TEL lessons (Bogusevschi, et al., n.d.).

Very good results were observed in terms of Learners Experience and Application Usability. The control class reported the application much more useful when learning about precipitation formation, compared to the experimental group. This might be due to the fact that, having been presented the topic in a classic approach manner first, the control group considered the NEWTON Project *Water Cycle in Nature* application as a revision tool. Following the LSQ comments provided by the two groups, the application was updated and localised, and it will be employed as part of a large-scale pilot in various European countries (Ireland, Slovakia and Romania) as part of the Earth Course (Bogusevschi, et al., 2018) that will be provided to students using multiple NEWTON project technologies, which, following the findings in the small-scale pilots presented in this paper, will also assess the NEWTON approach as both an introductory and as a revision tool.

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