Teachers' Impact and Feedback Related to Technology Enhanced Learning in STEM Education in Primary and Secondary Schools

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Abstract

STEM education is currently suffering from lack of interest from students and the number of people pursuing STEM-related careers has decreased rapidly. One of the reasons is the perception that such subjects are boring and various approaches have been proposed to solve this issue. The European Horizon 2020 NEWTON Project is tackling this problem by creating a pan-European learning management platform, NEWTELP, and developing multiple TEL application employing various technologies and approaches such as Virtual Reality, Augmented Reality, Virtual Labs, fabrication labs, gamification, multimedia, mulsemedia, game-based learning, problem-based learning and self-directed learning. Educational pilots focused on STEM topics have been carried out as part of NEWTON project assessing various aspects, such as knowledge gain, affective state and usability. Extensive feedback and observational analysis was performed in order to investigate the benefits of NEWTON TEL approaches to both teachers and learners. This paper presents the importance of teachers and discusses their role in TEL lessons and teacher feedback following NEWTON project pilots.

1. Introduction

TEL is one of the approaches currently viewed as a solution for the increasing lack of interest from students in STEM subjects. Various TEL techniques have been employed in order to increase students' motivation and knowledge acquisition. However, it is important not to forget about teachers as their full engagement in TEL approaches is vital to effective educational scenarios employing technology enhanced techniques [1], [2]. It has been shown that teachers' familiarity with technology and TEL approaches benefit students [3]. The importance of lesson structures assigned by teachers has been shown to result in better results in classes employing TEL approaches, such as tablets in [4]. In [5] it has been shown that teachers' active participation in supporting students during TEL lessons is benefiting not only in knowledge acquisition but in learner motivation as well.

As students are becoming more aware of various digital techniques it is important for teachers to be fully comfortable with using these as part of their TEL lessons [6], to be able to efficiently lead the class and employ these as tools for increasing knowledge acquisition and learner motivation. Collaborative learning for example is a method employed in enhancing teachers' capabilities in employing TEL approaches [7], [8]. Encouraging teachers to employ the "design for learning" approach in order to foster innovation as part of the TEL solution has also been emphasized in [9]. Various other methodologies for TEL design have been proposed [10] and it is of critical importance to accustom teachers with these techniques and to support them in employing various TEL methodologies [11], which have already been shown to be effective, as teachers' leadership role in the classroom is of high significance.

This paper presents the employment of TEL approaches as part of the Horizon 2020 NEWTON Project and teachers' feedback on these. This paper focuses on the importance of teachers' engagement in TEL activities in order to ensure efficient and effective outcomes and is organized as follows: the next section provides a brief description of the NEWTON project, following which the assessed TEL small and large-scale pilots are described. Three results sub-sections are then provided: the first one discussing teachers' feedback obtained from questionnaires, the second sub-section focusing on the feedback received from teacher interviews and the third sub-section presenting the two smalls-scale pilots and the importance of teachers and educators and how they affected the knowledge acquisition outcomes of these pilots.

2. NEWTON Project

Horizon 2020 NEWTON Project is focusing on designing, developing and deploying various TEL solutions for increasing learner quality of experience and increasing knowledge acquisition. NEWTON Project approaches have been tested and validated in

small and large-scale pilots across Europe [12], [13], [14], [15], [16].

NEWTON Project's innovative approaches include adaptive multimedia [17] and multiple sensorial media [18], [19], [20], [21], personalisation [22], gamification [23] and serious games [24], Virtual Labs (VLs) [25], [26], [27], fabrication labs (Fab Labs) [28], Augmented Reality (AR) and Virtual Reality (VR) [12], problem-based and game-based learning [13], [29]. NEWTON technologies and its gamification portal are embedded on the **NEW**TON **T**echnology-**E**nhanced **L**earning **P**latform (NEWTELP, newtelp.eu) [14].

3. NEWTON Project Pilots

This paper is focusing on a set of small and large-scale pilots carried out in Dublin, Ireland. Two small-scale pilots were carried out in the second semester of the 2016/2017 academic year in a primary school, St. Patrick's Boys National School (BNS) [30], and a secondary school, Belvedere College [12], [31]. Both small-scale pilots have employed the NEWTON project application *Water Cycle in Nature*, where knowledge acquisition and Learner Satisfaction were assessed. These pilots employed two classes in each instance, where the experimental class employed the NEWTON approach and the control class was taught the same content by their usual teacher in a classic approach manner. 52 students, 27 in the experimental group and 25 in the control group, participated in Belvedere College and 58 students in St. Patrick's BNS, with 29 students in each class. The experimental approach employed the school PCs in Belvedere College and the NEWTON project laptops in St. Patrick's BNS, as this school's PCs did not have the necessary specifications for the employed applications.

Two large-scale pilots, Earth Course [14], were carried out in two primary schools, St. Patrick's BNS and Corpus Christi Girls National School (GNS) during the second semester of the 2017/2018 academic year, employing the NEWTON project platform, NEWTELP, and eight separate sessions over eight weeks using NEWTON project developed applications:

- *Water Cycle in Nature*, providing educational content on precipitation formation and relevant physics phenomena, which employed VLs and computer-based VR;
- *Wildlife I & II*, focusing on a set of terrestrial animals, which employed VLs, computer-based VR and gamification;
- *Sea-life I & II*, focusing on asset of aquatic animals, which employed VLs, computer-based VR and gamification;
- *Final Frontier I & II*, focusing on the solar system planets and astronomic objects, which employed gamification and game-based learning;
- *Geography*, focusing on educational content regarding UK and the Republic of Ireland and employed computer-based VR.

These large-scale pilots were focused on the following assessments:

- Learner Motivation and Affective State.
- Usability of the NEWTON approach and NEWTELP platform.
- Knowledge acquisition.
- Feedback from teachers and students.

Each of the two schools employed two classes in the large-scale pilots. Experimental class A and A' in St. Patrick's BNS and Corpus Christi GNS respectively were employing the NEWTON approach as an introductory tool to a topic. Experimental class B and B' in St. Patrick's BNS and Corpus Christi GNS respectively employed the NEWTON approach as a revision tool, whereby they were firstly presented the educational content by their usual teacher 4 to 10 weeks before the NEWTON approach. St. Patrick's BNS classes A and B had 30 boys in each. In Corpus Christi GNS, there were 30 girls in class A' and 27 girls in class B'. Both schools employed the NEWTON project lap-tops as Corpus Christi did not have a computer room and only tablets were available, which were not suitable for the NEWTON Project applications and St. Patrick's BNS PCs had the previously reported drawbacks. All NEWTON approach lessons and student assessments were carried out using the NEWTON Project platform, NEWTELP.

4. Results

4.1 Large-Scale Pilots: Teachers' Questionnaires

During the two Large-Scale pilots in St. Patrick's BNS and Corpus Christi GNS questionnaires were provided to all participating teachers of the two classes in each school before and after the pilot. The teachers' familiarity and day to day use of TEL was assessed. It was identified that all teachers use their own PCs or lap-tops but that during most classes students do not use such equipment. Students might have some occasional sessions with tablets or in a computer room encouraging students to perform team and collaborative work. Teachers reported employing collaborative learning, problem-based learning (PBL) and self-directed learning (SDL) approaches. Only one teacher agreed that it is sometimes difficult to motivate students during STEM classes. Two teachers

reported their students are always fully engaged as part of their classes, whereas the other two were neutral. All teachers disagreed to the perspective that it might be difficult to motivate students in STEM classes. Only one teacher was neutral in terms of students' enjoyment during STEM classes with the other three feeling that their students enjoy these classes.

Following the completion of the two Large-Scale pilots, another questionnaire was provided to all participating teachers. The teachers in Corpus Christi GNS noted that the availability of NEWTON would change the way they use technology in their classroom. The experimental class B and B' teachers agreed that using technologies helps engage students and the experimental class A and A' teachers reported liking using technology and would want to use it more often. None of the teachers reported major changes in their usual teaching practice in terms of pedagogical approaches, such as PBL and SDL as they were employing these before the pilot.

Most teachers agree that NEWTON helped motivate students, and one teacher was neutral. Two teachers also agree that NEWTON engaged students throughout every lesson. The same teachers also agreed that NEWTON made it easier to motivate students. The other two teachers were neutral on the latter two points.

4.2 Large-Scale Pilots: Interviews with Teachers

During the interviews carried out with the teachers in St. Patrick's BNS and Corpus Christi GNS it was confirmed that most students enjoyed the NEWTON approach classes. As these pilots were mostly carried out by the NEWTON Project research teams, teachers were less involved in the process, except for the classic approach lessons required as part of the experimental groups' B and B' assessment procedure. Nevertheless, especially in Corpus Christi GNS, where teachers were present during the NEWTON sessions, they did notice how engaged students were during these sessions. All teachers noted the excitement expressed by children in anticipation of each session, throughout the entire duration of the Earth Course large-scale pilot. Teachers in both schools were open to using novel technologies in their classrooms and they did see the benefits on the NEWTON approach. However, the limitations of the school PCs or the lack of a computer room prohibits teachers to fully employ all the functionalities of the NEWTON novel approaches. Teachers also noted that it is imperative to have a more established communication between TEL designers and teachers, which again emphasizes the need to improve teachers' familiarity and involvement with TEL approaches.

4.3 Small-Scale Pilots: Case Studies

As part of NEWTON Project, two small-scale pilots were carried out as test sessions, before establishing the overall set-up of its large-scale pilots. The two small-scale pilots employed the same NEWTON application, *Water Cycle in Nature*. The NEWTON project platform, NEWTELP, was not employed at that stage as it was still under development. One pilot was carried out in the Dublin secondary school Belvedere College where two classes of 1st year students of ages from 12 to 13 years old participated, one control and one experimental. During this pilot both knowledge gain and learner satisfaction were assessed [12], [31]. The second pilot was carried out in a Dublin primary school St. Patrick's BNS, where two 5th classes with students of 10 to 11 years of age took part. The same set-up was employed, whereby one class was experimental and one was control. As in Belvedere College, the same assessments were carried out [30], [32].

It was notable that in terms of Learner Satisfaction, both schools' experimental classes exhibited very positive results. Over 74% of students in Belvedere and over 67% in St. Patrick's BNS found the *Water Cycle in Nature* application helpful in better understanding the physics phenomena which participate in precipitation formation. Approximately 67% of students in Belvedere and 77% in St. Patrick's BNS believed the application helped them to learn easier about the topics at hand. Over 74% of students in Belvedere and just under 90% of students in St. Patrick's BNS enjoyed the NEWTON project approach. Over 55% of students in Belvedere College also reported that the *Water Cycle in Nature* application made the lesson more practical and 75% of St. Patrick's BNS students reported the same. The majority of students in both schools would like to have more lessons using the NEWTON project approach, with over 70% of Belvedere College students and just under 95% of the St. Patrick's BNS students. So it can be seen that overall the participating students were very happy with the NEWTON approach.

However, the outcomes differ in terms of knowledge gain. It can be noted that in terms of Learner Satisfaction, the Belvedere College experimental class students provided somewhat less positive feedbacks compared to St. Patrick's BNS. However, in terms of knowledge acquisition, the Belvedere College students surpassed the St. Patrick's BNS students. The same pre-tests and post-tests were employed in both schools and the same grading approach was used. The major difference between the two lessons were that in Belvedere College their usual teacher carried out the NEWTON TEL approach lesson, whereas in St. Patrick's BNS the students' usual teacher was not present during the NEWTON session, which was supervised and led by the

NEWTON Project research team. Both classes did show increased knowledge after the *Water Cycle in Nature* pilot. However, the statistical significance of the knowledge acquisition was only present in Belvedere College, where students reported a 5.52 score in their pre-test and a 6.7 score in their post-test, with a paired t-test at $\alpha = 0.05$ resulted in ($t(26) = 2.865$, $p = 0.008$). On the other hand, in St. Patrick's BNS, students reported a score of 3.46 in their pre-test and a score of 3.98 in their post-test, where a paired t-test at $\alpha = 0.05$ ($t(56) = 1.7423$, $p = 0.087$) showed no statistical significance. During the experimental lesson in St. Patrick's BNS the students appeared a lot more excited compared to the Belvedere College students and they also seemed to focus more on the visual aspects of the application rather than on the knowledge gain. This might be due to the fact that they did not have their usual teacher present, which introduced a high sense of freedom allowing them to focus more on the game aspect of the application rather than on its educational content.

5. Conclusion

This paper reports on findings following the NEWTON Project small and large-scale TEL STEM pilots focusing on the importance of teachers' presence and guidance during these innovative sessions and their feedback.

Two small-scale pilots were carried out in St. Patrick's BNS and Belvedere College, Dublin – Ireland, employing the *Water Cycle in Nature* application and assessing knowledge gain and learner satisfaction. One small-scale pilot NEWTON approach session was carried out in each school.

Two large-scale pilots were carried out in Corpus Christi GNS and St. Patrick's BNS, Dublin –Ireland, where eight NEWTON approach sessions took place in each class, focusing on educational content about Earth, specifically Physics, Astronomy, Biosphere and Geosphere. Two classes participated in each school in the large-scale pilots, one class employing the NEWTON approach as an introductory tool and one as a revision tool. During the large-scale pilots, feedback from teachers was collected through questionnaires pre and post pilots and interviews after the pilot was finished.

It was reported that teachers are open to using technology in the classroom and it is important to make them aware of the possible TEL approaches and TEL design. Teachers need to become a more integral part of devising TEL sessions. Another impediment to teachers using effective TEL methodologies more often is the availability of necessary equipment in schools, which was noted in the two primary schools which participated in the NEWTON Project pilots.

The difference in the knowledge acquisition outcomes of the two small-scale pilots, which employed the same approach and application, highlighted the importance of teachers' guidance and leadership in ensuring a structure to all lessons, including TEL sessions. In Belvedere College, where their usual teacher was leading the TEL NEWTON approach session and was ensuring a discipline and structure, the experimental class students reported a high knowledge gain of statistical significance. Whereas in St. Patrick's BNS, where the experimental class usual teacher was not present during the TEL NEWTON session which was led by the NEWTON research team, the knowledge gain was of no statistical significance, even though the learner satisfaction outcome was better than in Belvedere College. This confirms findings in other studies which emphasized the importance of teachers' leadership in all TEL approach lessons.

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