EARTH COURSE: A PRIMARY SCHOOL LARGE-SCALE PILOT ON STEM EDUCATION

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Abstract

This paper describes the set-up and assessment of the *Earth Course* Large-Scale Technology Enhanced Learning (TEL) STEM education pilot, which is part of the European NEWTON Horizon 2020 project (www.newtonproject.eu). The pilot is carried out in two separate primary schools in Dublin, Ireland: Saint Patrick's Boys' National School and Corpus Christi Girls' National School. The *Earth Course* Large-Scale Pilot (LSP) includes a set of educational applications, developed as part of the NEWTON project in an effort to attract students to STEM subjects, which cover a set of topics as part of four main areas: Atmosphere, Geosphere, Biosphere and Astronomy. The developed applications use various technologies and innovative pedagogical methods to achieve the learning objectives of the course and improve user learning satisfaction, including Augmented and Virtual Reality, gamification, game-based learning and problem-based learning. The modules are also suitable for students with disabilities, specifically hearing impairment. This paper describes the set-up for the *Earth Course* LSP, its assessment procedure and results on Demographics and Motivation and Affective State of participating learners.

Keywords: STEM, TEL, Augmented Reality, Virtual Reality, gamification, game-based learning.

1 INTRODUCTION

Important efforts have been put in order to make progress and first devise different innovative TEL solutions and then introduce them in students' and educators' daily life. Among those who are contributing fundamentally in this space are the team of researchers, scientists, engineers, educators, psychologists and developers part of the European Union-funded Horizon 2020 project NEWTON [1]. NEWTON Project proposes and integrates diverse novel technologies in education including adaptive multimedia and multi-sensorial content delivery mechanisms [2], [3], [4] personalisation and gamification solutions [5], [6], introduces virtual labs and fabrication labs [7], [8] and employs problem-based, game-oriented, and flipped-classroom-based learning [9].

In the context of the NEWTON project, this paper describes the overall principle and presents some deployment details of the *Earth Course LSP,* one of NEWTON project's large-scale STEM education pilot. The *Earth Course* is performed in two different Dublin-based Irish primary schools: Saint Patrick's Boys' National School (BNS) and Corpus Christi Girls' National School (GNS). This LSP includes several educational applications, which employ NEWTON innovative technologies and were developed to introduce students to four topics from the general subject of Earth science: Atmosphere, Geosphere, Biosphere and Astronomy. NEWTON project applications use various technologies and innovative pedagogical methods to achieve both course learning objectives and improve user learning satisfaction. The TEL solutions employed include Augmented and Virtual Reality (AR/VR), game-based learning and problem-based learning. This paper also describes the *Earth Course* LSP assessment procedure and an initial set of results.

1.1 Related Work

STEM education has become an important part of basic literacy in today's knowledge economy. This is due to the fact that only STEM knowledge citizens are able to create and develop technologies and use them to find solutions for societal issues such as poverty, healthcare, water supply, environment and climate change.

However, the number of science graduates in Europe is decreasing and there is an alarming lack of engagement of females to STEM careers. Therefore, Europe is facing a shortage of scientists. Previous research has reported that disengagement from science starts very early, at primary school level as

students become demotivated to study STEM subjects. Considering these facts, there is a need to attract children and students to STEM education as early as possible.

Nowadays young people are familiar with digital interaction as technology is part of their everyday activities. They use smart devices to search for information, to share information among themselves, to chat and to connect to various resources. Thus, the latest technologies should be integrated in the education system to engage and motivate learners. 3D educational games boost learners' confidence in STEM subjects, increases their interest in complex topics and helps teachers to deal with disengagement of young people from STEM. Currently increasing number of students are exposed to game-based learning [10], [11], [12] in their formal, non-formal and in-formal education and this trend is expected to continue.

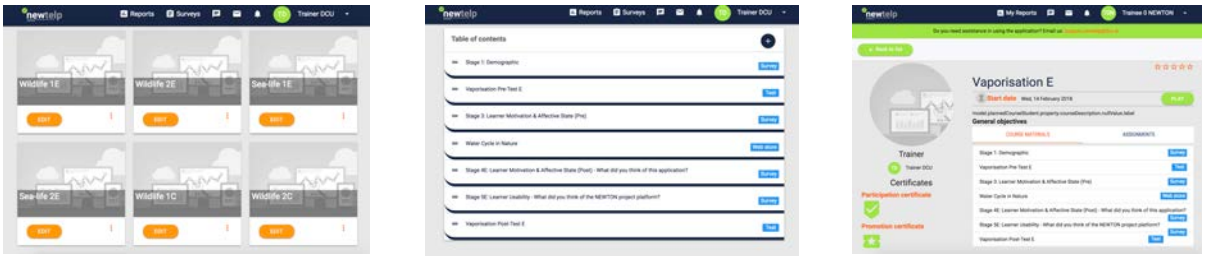
There are various endeavours to tackle various issues in STEM education. Next-Lab [13] is a European research project that focuses on introducing inquiry-based science education in **primary and secondary schools** across Europe, aiming to support a positive attitude towards science and technology. The Next-Lab platform provides access to virtual and remote science laboratories, inquiry learning applications and Inquiry Learning Spaces.

UMI-Sci-Ed [14], a Horizon 2020 project, aims at enhancing the attractiveness of science education and careers for young people via the use of latest technologies such as ubiquitous mobile computing and the Internet of Things. Students through a mentoring mechanism are provided with training material, IoT hardware kits and software tools to explore technologies through hands-on activities. They build applications relevant to the subject they study and participate in group based activities. Thus, the practical experiences provide them a rich context to grasp scientific knowledge [15].

The majority of research projects for STEM education make use of only one technology in the teaching and learning process and cover only one STEM topic. This paper introduces the NEWTON Project *Earth Course* LSP, a complex course that covers a large set of STEM topics using various technologies and innovative pedagogical methods such as AR and VR, 3D games and virtual labs to engage learners and to increase the learning outcome.

1.2 NEWTON Project Platform - NEWTELP

NEWTON Project's developed applications are part of Small-Scale Pilots (SSP) and LSPs and are supported on its platform - NEWTELP (NEWTON Technology Enhanced Learning Platform). NEWTELP provides the courses, containing the developed applications for each pilot as well as its assessment from multiple angles, such as knowledge gain, usability and affective state.



a) Courses' List *b) Course Structure* *c) Learner View*

Figure 1 Example of the NEWTON Project Platform – NEWTELP

An example of the courses' set-up on NEWTELP for an educator is presented in Figure 1a, presenting some of courses that are part of the *Earth Course* and an example of one of the courses, employing the *Water Cycle in Nature* application and its assessment procedure is seen in Figure 1b. Its view from a NEWTON Project Learner's perspective is presented in Figure 1c.

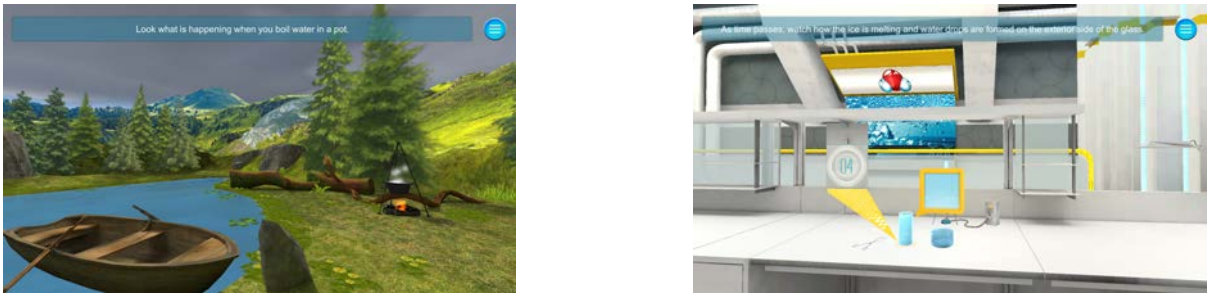
2 EARTH COURSE

The *Earth Course* is one of the three NEWTON Project LSPs: *Earth Course*, *GAM LAB* and *Programming*, which are taking place in multiple countries, including Ireland, Italy, Slovakia and Romania and in schools of different levels, from primary to third level institutions. The *Earth Course* is firstly taking place in Ireland, followed by schools in Slovakia and Romania. This LSP is focused on four main areas: Atmosphere, Geosphere, Biosphere and Astronomy. The sections below provide a brief description of each application.

2.1 *Earth Course* Modules Description

2.1.1 Water Cycle in Nature Application

The *Water Cycle in Nature* application was developed by one of the NEWTON project consortium partners - SIVECO, Romania and is part of the *Earth Course* Atmosphere module. This application was initially employed in NEWTON Project SSPs in two schools, one primary [16] and one secondary [17], where a different set of learners interacted with the application, focusing on assessing its usability, learner experience and knowledge gain and providing good results in each of these assessments. It was updated following learners' comments and suggestions and the new version of the *Water Cycle in Nature* application is employed in both schools participating in the *Earth Course* LSP, requiring one session per class.

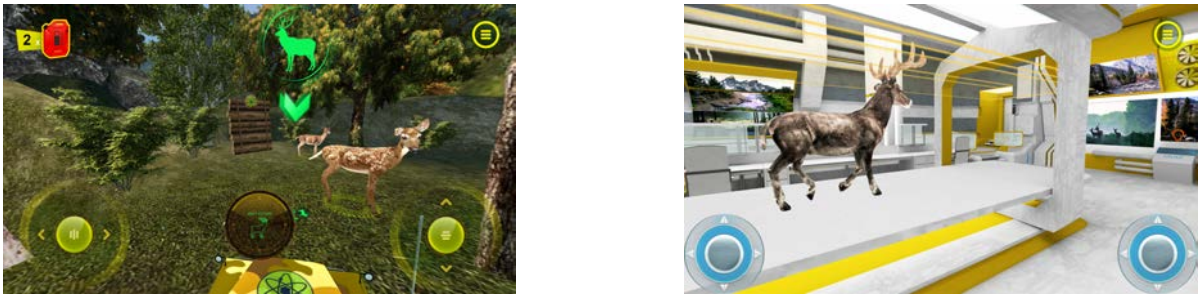


a) Nature VR Environment b) VL Environment

Figure 2 NEWTON Project Water Cycle in Nature application

2.1.2 Wildlife

The *Wildlife* application is developed by the NEWTON project consortium partner, SIVECO, Romania and is part of the *Earth Course* Biosphere Module. It involves 3D immersive computer-based VR and experimental laboratory simulation and it provides educational content on a set of animals, including deer, wolf, wild boar, fox, moose, brown bear, hare and lynx.



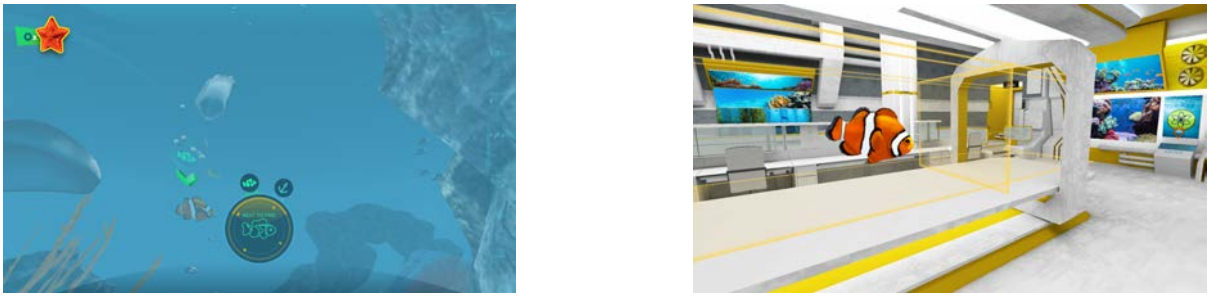
a) Deer in Nature VR Environment b) Deer in VL Environment

Figure 3 NEWTON Project Wildlife Application

Two separate environments are present for each animal: Nature VR Environment, where the participating learners need to find it and learn about it and Virtual Laboratory (VL) Environment, where a closer view of each animal is presented as well as additional educational information relating to it. This application requires two sessions per class, in order to comply with the regular timetable in both participating schools.

2.1.3 Sea-life

The *Sea-Life* application was also developed by the NEWTON Project consortium partner, SIVECO, Romania and is focused on the aquatic world as part of the *Earth Course* Biosphere Module. It presents educational content on various water animals, including dolphin, jellyfish, octopus, orca, turtle, clownfish, puffer fish, seahorse, shark and stingray. It is a VL with interactive content combined with VR technology and its set-up is similar to the *Wildlife* application, whereby two separate environments are present for each animal, a Nature VR and a VL Environment.

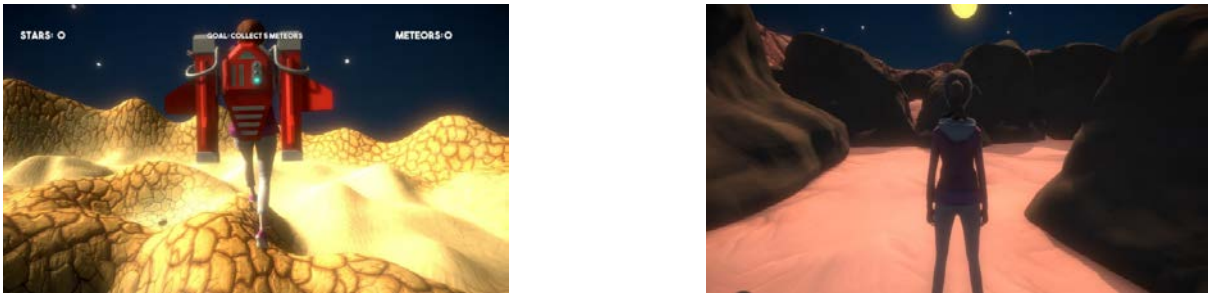


a) Clownfish in Nature VR Environment *b) Clownfish in VL Environment*

Figure 4 NEWTON Project Sea-Life application

2.1.4 Final Frontier

The *Final Frontier* application is an interactive 3D video game developed by the NEWTON Project consortium partner, National College of Ireland (NCI) and it makes use of gamification and game-based learning [9], [10].



a) Mercury Environment *b) Mars Environment*

Figure 5 NEWTON Project Final frontier application

It is part of the *Earth Course* Astronomy Module and it provides educational content on various astronomical bodies, such as Mercury, Venus, Moon, etc. It provides different levels for each object with some examples presented in Figure 5.

2.1.5 Geography

The *Geography* application was developed by the team of NEWTON Project Consortium partner, Slovak University of Technology in Bratislava (STUBA). It is part of the *Earth Course* Geosphere Module, focusing on Ireland and United Kingdom. This application employs multiple technologies, including VR and AR. One of the assessment procedures is identifying various locations on a blind globe lacking any political borders, in order to evaluate learners' knowledge on Geography (Figure 6).

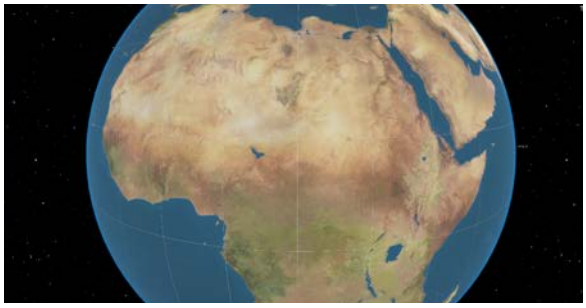


Figure 6 NEWTON Project Geography application

2.2 *Earth Course* Large-Scale Pilot Set-up

Two primary schools from Dublin, Ireland are taking part in the NEWTON Project *Earth Course* LSP – Corpus Christi GNS and St. Patrick's BNS. The schools involved their 5th class in this course, as principals and teachers agreed on the most suitable age for participating learners. Two classes, one control and one experimental, are part of this case study and these were randomly assigned. In Corpus

Christi GNS the control class contains 27 learners and the experimental class has 30 learners. In St. Patrick's BNS each class has 30 students. The control class is firstly presented with the educational material for each module by their regular teacher using presentations prepared by the NEWTON Project research team, in order to ensure that the content in classic approach and NEWTON approach lessons is the same. The control class is also exposed to the NEWTON approach, as a revision tool, 4 to 10 weeks after the classic approach lesson for a specific module. The experimental class is only exposed to the NEWTON approach methodology, employing the TEL applications.

2.2.1 Assessment Description

The core of assessment procedure employed in all NEWTON Project educational pilots was developed by the project's Pedagogical Assessment Committee (PAC) [18] and it provides templates and guidelines for various assessments, including demographics, learner usability of NEWTON Project platform and individual applications, affective state prior the case study and subsequent each session as well as an overall affective state evaluation after finalising the LSP. The list of all activities and assessment procedures carried out in the experimental group (E) and control group (C) during the *Earth Course* LSP in the two primary schools is presented in Table 1.

Certain assessments, such as Demographics and Learner Motivation and Affective State, are carried out only once, during the first NEWTON approach session. Others are implemented during each session, such as the knowledge pre and post-tests. Learners' observational assessment is carried out by the researchers present at each pilot session. Focus groups and interviews with learners and teachers are carried out after the LSP is finalised, according to PAC templates and guidelines. The control group is given knowledge tests before and after the classic approach session, both groups are exposed to knowledge assessment before and after each NEWTON approach session and 4 weeks after the *Earth Course* LSP is finished. The final knowledge assessment is performed in order to evaluate learners' knowledge retention after participating in a NEWTON Project LSP.

Table 1 Assessment procedure for the NEWTON Project Earth Course LSP

Activity	Classic Approach – Session 1		NEWTON approach – Session 1		NEWTON approach – Session X		NEWTON approach – Last Session		Final LSP Session	
	C	E	C	E	C	E	C	E	C	E
Power Point presentation	✓	-	-	-	-	-	-	-	-	-
Stage 1: Demographics	-	-	✓	✓	-	-	-	-	-	-
Stage 2: Knowledge Pre-test	✓	-	✓	✓	✓	✓	✓	✓	-	-
Stage 3: Learner Motivation and Affective State Pre	-	-	✓	✓	-	-	-	-	-	-
NEWTON approach lesson	-	-	✓	✓	✓	✓	✓	✓	-	-
Stage 4': Learner Motivation and Affective State Post – Reduced	-	-	✓	✓	✓	✓	✓	✓	-	-
Stage 5': Learner Usability - Reduced	-	-	✓	✓	✓	✓	✓	✓	-	-
Stage 6: Knowledge Post-Test	✓	-	✓	✓	✓	✓	✓	✓	-	-
Observational Assessment	-	-	✓	✓	✓	✓	✓	✓	-	-
Stage 4: Learner Motivation and Affective State Post - Final	-	-	-	-	-	-	✓	✓	-	-
Stage 5: Learner Usability - Final	-	-	-	-	-	-	✓	✓	-	-
Interviews and focus groups	-	-	-	-	-	-	-	-	✓	✓
Knowledge Retention Test	-	-	-	-	-	-	-	-	✓	✓

3 RESULTS

3.1 Demographics

During the first NEWTON approach session in Corpus Christi GNS 23 learners were present in the control class and 27 in the experimental class. In St. Patrick's BNS 27 learners were present in the control class and 26 in the experimental. It needs to be noted that some students provided multiple answers to single-answer questions or ignored certain questions.

All learners are between 10 and 12 years of age. When asked on how participating learners feel about school (Table 2), the vast majority of answers in both schools range from *"It's OK*" to *"I love it"*. The interesting fact is that boys' answers were mostly in the "*It's OK"* and *"I like it"* range, whereas girls' answers were leaning more towards *"I like it"* and *"I love it"* range. Regarding learners' attitude to STEM subjects (Table 3), all groups presented similar answers of around 30% stating *"I love it"*, except for the Corpus Christi GNS experimental group, with 50%. The learners' view on using technology in STEM subjects is presented in Table 4, where over 60% of girls from the control group would like more technology use, compared to over 74% of girls in the experimental class. Over 77% of boys in the control class would like to use more technology in STEM subjects, compared to over 90% in the experimental group in St. Patrick's BNS.

Table 2 Demographics Questionnaire Answers: How do you feel about school?

School	Group	I don't like it at all (%)	I don't like it (%)	It's OK (%)	I like it (%)	I love it (%)
Corpus Christi GNS	Control	4.35	0	13.04	52.17	30.43
	Experimental	0	7.41	22.22	33.33	33.33
St. Patrick's BNS	Control	3.70	7.41	33.33	48.15	7.41
	Experimental	3.85	11.54	46.15	42.31	7.69

Table 3 Demographics Questionnaire Answers: How do you feel about learning science, technology and maths?

School	Group	I don't like it at all (%)	I don't like it (%)	It's OK (%)	I like it (%)	I love it (%)
Corpus Christi GNS	Control	0	0	13.04	65.22	26.09
	Experimental	0	7.41	11.11	29.63	51.85
St. Patrick's BNS	Control	0	0	25.93	33.33	37.04
	Experimental	0	0	26.92	46.15	26.92

Table 4 Demographics Questionnaire Answers: I would like to use more technology in the classroom when I'm learning science, technology and maths.

School	Group	SD (%)	D (%)	Neutral (%)	Agree (%)	SA (%)
Corpus Christi GNS	Control	0	13.04	26.09	21.74	39.13
	Experimental	3.70	0	18.52	33.33	40.74
St. Patrick's BNS	Control	3.7	7.41	11.11	44.44	33.33
	Experimental	0	0	23.08	38.46	53.85

3.2 Learner Motivation and Affective State

Another assessment employed during the NEWTON Project LSPs is on the Learner Motivation and Affective State prior to beginning the TEL educational material to evaluate learners' engagement and motivation towards science classes. It needs to be noted that some students provided multiple answers to single-answer questions or ignored certain questions. When learners' confidence in science problems is assessed (Table 5), over 70% of control group girls are *"Somewhat Confident"*, compared to just under 26% of girls in the experimental group. Both groups in St. Patrick's BNS show similar confidence results, at around 50% in the *"Somewhat Confident"* range. Most students in both schools feel engaged during science classes (Table 6), at nearly 73% in the control group in Corpus Christi and over 95% in the experimental group of girls, and over 77% of boys in the control group and just under 85% in the experimental group. Most students do not feel bored during science classes, as seen in Table 7, where around 55% of learners in St. Patrick's BNS and the control group in Corpus Christi GNS provided the

answer *"Not at all"*. Over 77% of girls in the experimental class provided the same answer. When investigating learners' attitudes towards regular textbooks (Table 8), where answers are Strongly Disagree (SD), Disagree (D), Neutral, Agree (A) and Strongly Agree (SA). The participating girls are mostly Neutral, with around 30% of the control class preferring to learn without textbooks. Just under 50% of girls in the experimental class would prefer to learn without textbooks. A much higher percentage of boys in the experimental group want the same, at over 73%. Agreement on this is obtained from over 55% of boys in the control group.

Table 5 Learner Motivation & Affective State: How confident are you that you can solve any/all of the problems and challenges you experience in your science classes?

School	Group	Not at all (%)	Slightly (%)	Somewhat (%)	Very (%)	Extremely (%)
Corpus Christi GNS	C	0	8.7	73.91	13.04	0
	E	0	37.04	25.93	33.33	3.7
St. Patrick's BNS	C	18.52	7.41	55.56	18.52	0
	E	0	19.23	50	23.08	7.69

Table 6 Learner Motivation & Affective State: While you were learning in your science class, to what extent did you feel engaged?

School	Group	Not at all (%)	Slightly (%)	Somewhat (%)	Very (%)	Extremely (%)
Corpus Christi GNS	C	13.04	8.7	21.74	43.48	8.7
	E	0	3.7	14.81	62.96	18.52
St. Patrick's BNS	C	11.11	7.41	18.52	33.33	25.93
	E	0	15.28	30.77	38.46	15.38

Table 7 Learner Motivation & Affective State: While you were learning in your science class, to what extent did you feel bored?

School	Group	Not at all (%)	Slightly (%)	Somewhat (%)	Very (%)	Extremely (%)
Corpus Christi GNS	C	56.52	39.13	4.35	0	0
	E	77.78	22.22	0	0	0
St. Patrick's BNS	C	55.56	18.52	14.81	0	7.41
	E	53.85	42.31	7.69	0	3.85

Table 8 Learner Motivation & Affective State: I would prefer to learn without textbooks.

School	Group	SD (%)	D (%)	Neutral (%)	A (%)	SA (%)
Corpus Christi GNS	C	4.35	26.09	43.48	17.39	13.04
	E	3.7	11.11	37.04	33.33	14.81
St. Patrick's BNS	C	0	14.81	25.93	33.33	22.22
	E	3.85	11.54	26.92	38.46	34.62

4 CONCLUSIONS

This paper presents the European Horizon 2020 NEWTON Project Large-Scale STEM Education Pilot, *Earth Course*, and its set-up. This pilot is carried out in two primary schools in Dublin Ireland, Corpus Christi GNS and St. Patrick's BNS, over 8 sessions in each school. 5th class students participate in this case study, randomly divided in two groups, one control and one experimental. The assessment procedure is presented in this paper as well as some results for Demographics and Motivation & Affective State of learners showing that most students are open to innovative solutions in STEM learning and TEL as an additional tool to classic approach lessons.

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