

USABILITY EVALUATION CASE STUDY IN TECHNOLOGY ENHANCED LEARNING LARGE-SCALE PILOT IN PRIMARY SCHOOLS

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Abstract

This paper presents the Usability assessment of the *Earth Course* Large-Scale Technology Enhanced Learning (TEL) STEM education pilot, which is part of the European Horizon 2020 NEWTON project (www.newtonproject.eu). The pilot was carried out in two single-gender primary schools from Dublin, Ireland, where boys only participated in the first school and girls only in the second. Two experimental classes participated in each school. One group used the NEWTON-based lessons as an introduction to a topic (classes A with 30 boys and A' with 30 girls). The other group used the NEWTON-based lessons as revision on to the same topic, as they had previously covered the same content with their usual teacher 4 to 10 weeks earlier (classes B with 30 boys and B' with 27 girls). 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 within four main areas: Atmosphere, Geosphere, Biosphere and Astronomy. This paper reports the results of the usability evaluation for both schools. The majority of the participating students found the NEWTON-based lessons useful, particularly in classes that used it as an introductory tool. A comparison in usability between employing the NEWTON applications as introductory tools as opposed to revision tools was carried out for each school and grouping, showing that the classes participating in introductory NEWTON-based lessons provided higher usability scores compared to students participating in revision NEWTON-based lessons. It was also observed that the two boys' classes were much more open to using NEWTON-based lessons when learning, with the lowest scores received from the girls in experimental class B'. It was also reported by students, mainly in classes that used NEWTON-based lessons for revision, that they see it as a supporting tool for their teachers.

Keywords: TEL, STEM, learning management system, computer-supported education, gamification, game-based learning, Virtual Reality, Virtual Labs

1 INTRODUCTION

Technology-Enhanced Learning (TEL) approaches are currently very popular in an effort to address the decreasing engagement of students in science, technology, engineering and mathematics (STEM) subjects. This paper focuses on a Usability assessment of a technologically enhanced intervention project in two primary single-gender schools. The intervention used NEWTON project applications and its learning management platform on the topic of Earth Course. This paper is structured as follows: the next sub-section provides some related works in the area followed by an overview of NEWTON project and its components. Next, the Earth Course Large-Scale pilot, its set-up and participants are presented. This is followed by the Usability results and the conclusion of the reported work.

1.1 Related work

The NEWTON project is underpinned by the belief that novel technologies can give us, as educators, a powerful means of improving learning outcomes, increasing student engagement, enhancing the quality of the learning experiences and, ultimately, attracting and retaining students to subjects that they might otherwise view as challenging, difficult or 'not for them'. The application of this idea to the STEM field is particularly of interest due to the decrease in interest in these subjects and the subsequent impact on the talent pool and innovation capacity of those societies that fail to stimulate young people's enthusiasm for STEM learning.

Within the context of the Earth Course Large-Scale pilot that we report on here, we were particularly interested in the use of game-based learning as a mechanism to increase student engagement and improve learning. The literature on this approach to learning demonstrates the multiple benefits of

adopting a game-based approach to learning. Plass et al set out the key aspects of game-based learning as a strategy to support learners [1]. They talk about four key benefits to the approach: motivation: games have motivational impact that keep players engaged and that can encourage learners to stay focused for longer periods of time; player engagement: games can engage the learner in different ways through the use of characters, behavioural engagement through gestures and movements and social features that could facilitate social engagement; adaptivity: games have the capacity to be adaptable to the individual player, taking account of their level of knowledge or skill; graceful failure: games provide a safe space where the consequences of failure are mitigated thereby encouraging the player to try new things, take risks and explore. We might also consider as relevant here the concept of 'flow' – linked in the literature to the experience of gaming - in which the player is in a heightened state of concentration with regard to an activity [2]. This creates a highly desirable state for learning when applied effectively.

A key aspect of our investigation – within the NEWTON project and specifically with the Earth Course Large-Scale pilot – has been to investigate the gender aspect of using novel technologies to support the engagement of students. There is a well-documented history of gender differences between male and female students in relation to STEM learning and, subsequently, the choice to follow STEM careers. The study by Stadler et al framed the challenge, concluding that the key factor predicting STEM career interest at the end of high school was interest at the start of high school and that, furthermore, there was an additional effect of gender, indicating both a lower retention of STEM career interest among females and a greater difficulty in attracting females to STEM fields during high school. The US study concluded that during high school years, the percentage of males interested in a STEM career remained stable (from 39.5 to 39.7), whereas for females it declined from 15.7 to 12.7 [3]. This view is reinforced in the work of Reinking and Martin. Although they recognise that the number of women who have earned their bachelor's, master's or doctoral degrees in STEM fields in the United States has increased since the 1990s, there remains a problem that even when females perform as well or better than their male peers on STEM related tests or projects, females lose interest at a higher rate and do not pursue advance courses, majors, and careers in STEM [4]. Interestingly, they do not identify technology as a possible mechanism to address this problem, focusing more on socialisation and challenging stereotypes rather than any pedagogical or practical solutions.

With this in mind, our study presented here seeks to explore this context further and to specifically identify whether the attractiveness of STEM learning, engagement in the learning experience and achievement of learning outcomes can be positively influenced by the adoption of novel technologies like game-based learning, Augmented Reality (AR), Virtual Reality (VR) and so on. And we seek to understand whether such an approach can narrow the gap between male and female students in respect of enthusiasm for – and achievement in – STEM learning.

1.2 NEWTON Project and NEWTELP

The NEWTON Project is funded by Horizon 2020 and aims to make use of Technology-Enhanced Learning (TEL) methods and approaches in order to increase learner quality of experience, improve learning processes and maintain or increase learning outcomes [5]. The NEWTON Project employs a set of technologies, such as multimedia and multiple sensorial media (multimedia) [6], AR and VR-enhanced learning, Virtual Labs (VL) [7], [8], Fabrication labs and remote 3D printing [9], [10], [11], gamification and game-based learning [12], [13] as well as personalisation [14], inquiry-based and self-directed learning [15] including support for students with special educational needs [16], [17]. The NEWTON project also developed a learning management system, platform NEWTELP [18] containing all its components, including the gamification engine, all innovative educational applications and assessments.

2 EARTH COURSE LARGE-SCALE PILOT

Earth Course is one of NEWTON project's Large-Scale pilot and it was carried out in three countries: Ireland, Slovakia and Romania. This paper focused on the usability results of the Irish component of this pilot [18], which were carried out in two primary schools in Dublin, St. Patrick's Boys National School (BNS) and Corpus Christi Girls National School (GNS). This Large-Scale pilot focuses on 4 major topics: Atmosphere and Physics, Biosphere, Astronomy and Geosphere. As part of the Atmosphere topic NEWTON application *Water Cycle in Nature* was employed [19] focusing on precipitation formation and relevant Physics phenomena, employing computer-based VR and VL technologies. The applications focusing on Biosphere were *Wildlife I and II* and *Sea-life I and II* [18], [20], providing educational content on various terrestrial and aquatic animals and employing VR, VL and gamification. The Astronomy topic

was the focus of *Final Frontier I and II* [20], [21], focusing on Rocky and Gas Planets, employing gamification, game-based learning and a digital library. *Geography I* application was focused on the Geosphere topic, providing educational content about UK and Republic of Ireland [18], [20].

2.1 Pilot Set-up and Participants' Description

The Horizon 2020 NEWTON project Earth Course Large-Scale pilot was carried out in two Dublin primary schools, where in each school two 5th class groups participated. Experimental class A in St. Patrick's BNS with 30 boys and A' in Corpus Christi GNS with 30 girls used all NEWTON-based lessons as introduction to a topic, with facilitation by the NEWTON project research team. Experimental class B in St. Patrick's BNS with 30 boys and B' in Corpus Christi GNS with 27 girls used all NEWTON-based lessons, also carried out by the project's team, as revision to topics which were already presented to them by their usual teacher 4 to 10 weeks earlier during teacher-based lessons. In both schools, participated students were between 10 and 11 years of age and this pilot meets all Ethical requirements and was approved by Author's University. 8 NEWTON-based lessons were carried out in each experimental group over an 8-week period, where each lesson had the duration of a usual class, in order to comply with to the school timetable [18].

2.2 Assessment Procedure

During the Earth Course Large-Scale pilot, the NEWTON project Pedagogical Assessment Committee (PAC) Toolkit [22] was employed. It is composed of 7 main stages. 3 Stages are carried out in each experimental group before educational NEWTON-based lessons begin - Stage 1: Demographics, Stage 2: Knowledge Pre-Test and Stage 3: Affective and Motivation State Pre. The following stages are carried out after completion of learning activities – Stage 4: Affective and Motivation State Post, Stage 5: Usability, Stage 6: Knowledge Post-Test, Stage 7: Interviews and focus groups with students and teachers [18]. During the assessment of Affective State and Motivation and evaluation of the changes incurred following the finalisation of the pilot (Stages 3 and 4), very positive results were already observed [23]. Very positive knowledge acquisition results (Stages 2 and 6) were also exhibited during the majority of the NEWTON project educational sessions [24]. This paper focuses on Stage 5: Usability and the reported outcomes in both schools.

3 RESULTS

The PAC Toolkit employed a 5-Likert scale: Strongly Disagree – 1, Disagree – 2, Neutral - 3, Agree – 4, Strongly Agree – 5. The answers to some of the usability questions for classes A in St. Patrick's BNS and A' in Corpus Christi GNS, which employed the NEWTON-based lessons as introduction to every Earth Course topic are presented in Figure 1. Both genders reported very similar results in their perception of how fun NEWTON-based lessons were, where 92.3% of boys and 93.1% of girls agreed with the statement "*It is fun to use*". The boys in experimental class A were slightly more willing to recommend NEWTON technologies and platform to a friend, with 88.9%, compared to 82.8% of girls in class A'. Very similar answers were provided by the two classes regarding remembering how to use the NEWTON components and NEWTELP, with 85.2% of boys agreeing with the statement "*I easily remember how to use it*", compared with 82.8% of girls. Both classes also reported learning to use all components during NEWTON-based lessons very quickly, with 92.6% of boys and 86.7% of girls. The girls in class A' reported a much higher percentage of students who need additional written instructions when employing all components, with 58.6% agreeing that no instructions are needed, compared to 77.8% of boys. Girls also reported that they feel NEWTON-based lessons require more than necessary steps in order to achieve the final objective, with 52.7% agreeing with the statement "*It requires the fewest steps possible to accomplish what I want*", compared to 70.4% of boys in class A. However, when reporting on how easy it is to use, both genders reported very similar results, with 92.6% of boys in class A finding it easy and 90% of girls in class A'. Less girls believed that NEWTON components saved them time when learning, with 53.6% agreeing with the statement "*It saves me time when I use it*", compared to 61.5% of boys in class A. Girls also reported a lower percentage of students who find it useful. With 82.76%, compared to 96.3% of boys. The same trend was noted when assessing effectiveness of the NEWTON approach, as only 65.5 of girls in class A believe that it helps them to be more effective in a science class, compared to 77.8% of boys.

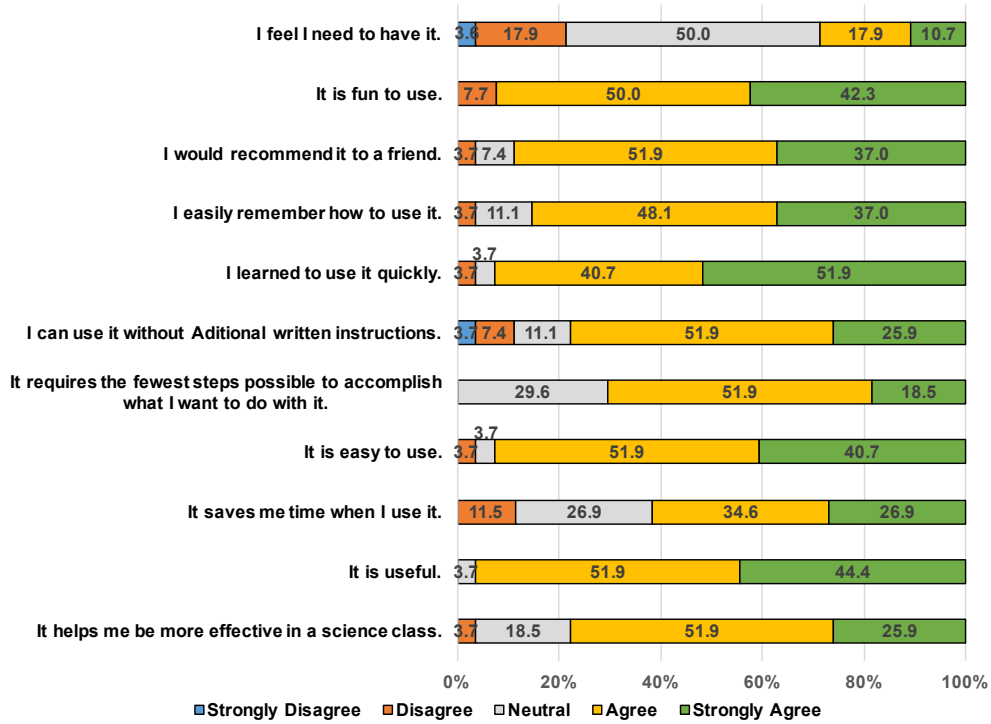
The same comparison is also performed for the two classes which employed the NEWTON-based lessons as revision to each topic, class B in St. Patrick's BNS and class B' in Corpus Christi GNS. This is presented in Figure 2. Firstly, it needs to be noted that these revision experimental classes provided

overall lower scores on the Usability assessment compared to the introduction approach classes. This was also confirmed during interviews where both boys' and girls' classes reported seeing NEWTON as a supporting tool for the teacher, rather than an independent mechanism for learning. The perception of NEWTON-based lessons being fun was lower for both classes B and B' compared to A and A', with 60.8% of girls in B' agreeing with the statement *"It is fun to use"* and 73.1% of boys in group B. Similar percentages of boys and girls in the two revision classes reported that they would recommend it to a friend, but these were much lower compared to the introduction approach classes, with 56.5% of girls in class B' and 57.97% of boys in class B. The revision classes reported similar outcomes to introduction classed regarding statement *"I easily remember how to use it"* with 88% of boys in class B and 78.2% of girls in class B' agreeing with it. These classes also reported learning how to use the NEWTON-based lessons less quickly compared to classes A and A', with 73.9% of girls in class B' and 80% of boys in class B agreeing with statement *"I learned to use it quickly"*, compared with 86.7% of class A' girls and 92.6% of class A boys. Regarding the need of additional written instructions when using NEWTON components and its platform, similar results were reported as during the introduction approach lessons, with 66.7% of girls in class B' and 73.1% of boys in class B finding that extra instructions are not necessary.

One of the biggest differences between the introduction and revision approach was in students' perception that NEWTON-based lessons are using the fewest steps possible to accomplish the outcome, with only 25% of girls in class B' agreeing with this, and 48% of boys in class B, compared with 51.7% of girls in class A' and 70.5% of boys in class A. A very big difference was also noted in the results for students' view of how easy NEWTON-based lessons are to use, where 62.5% of girls in class B', compared to 90% of girls in class A', finding it easy; and 76% of boys in class B, compared to 92.6% of boys in class A, agreeing with this. The two revision classes also reported a much less percentage of students who believe that NEWTON-based lessons save them time when using it during learning, with 43.5% of girls in class B' and 42.31% of boys in class B. They also found it less useful, with 72.7% of girls and 65.4% of boys in class B' and B respectively. Another very big difference between the NEWTON revision and introduction approach classes was noted in students' answers to statement *"It helps me be more effective in a science class"*, where only 26.1% of girls and 53.85% of boys in the revision classes agreed with it.

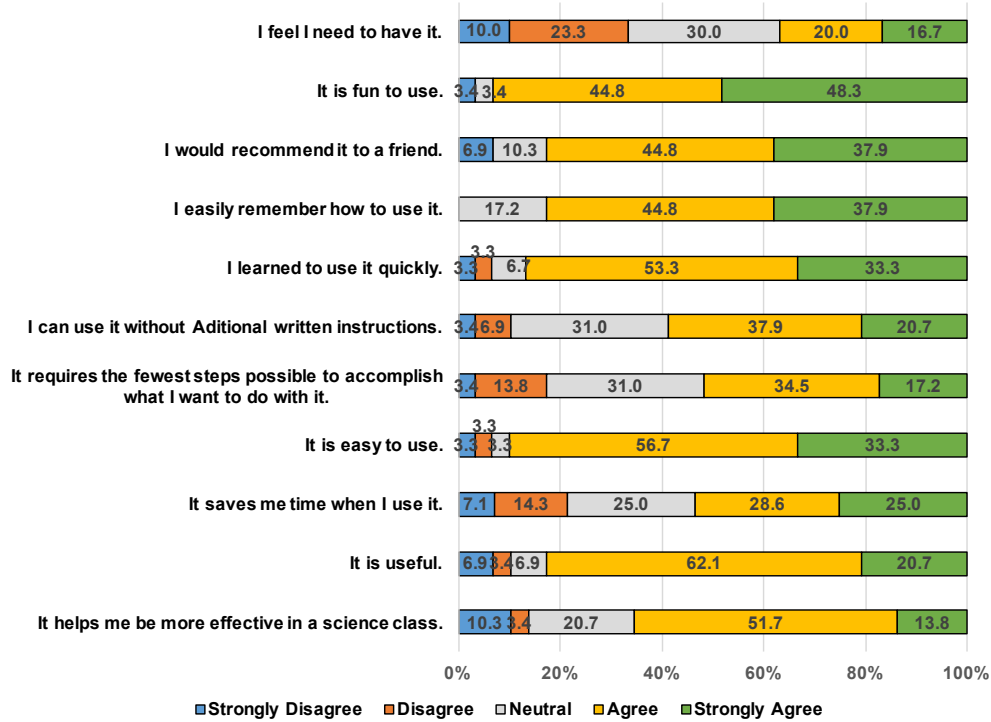
It needs to be emphasised that some very positive comments were received during the post-learning focus groups from participating students, such as in Corpus Christi GNS: *"it's easy to use, I like the animation and I like the way we can roam the earth"*, *"I like that you get learn about animals and sea life"*, *"they're interesting unusual and fun"* in class A'; and *"I like how we learn a lot and the games are fun and the questions"*, *"more games would be spectacular"*, *"I liked that it was like a game, I like all the animals we did, I liked the games"* in class B'. As well as in St. Patrick's BNS with *"I like how it was a bit of a free roam game. I like how you had to collect stars and other things throughout the game. I like how three was a bonus level at the end of each game."*, *"It's interesting. It's easy and it's beautiful"* in class A; and *"I like magnetism, planets and psychics"*, *"I liked learning about the different planets I also liked the animation and the questions"*, *"The game is fun, the facts are interesting and the game is easy to learn and use"* in class B.

St. Patrick's BNS Class A: USABILITY results



a) St. Patrick's BNS Class A: Usability

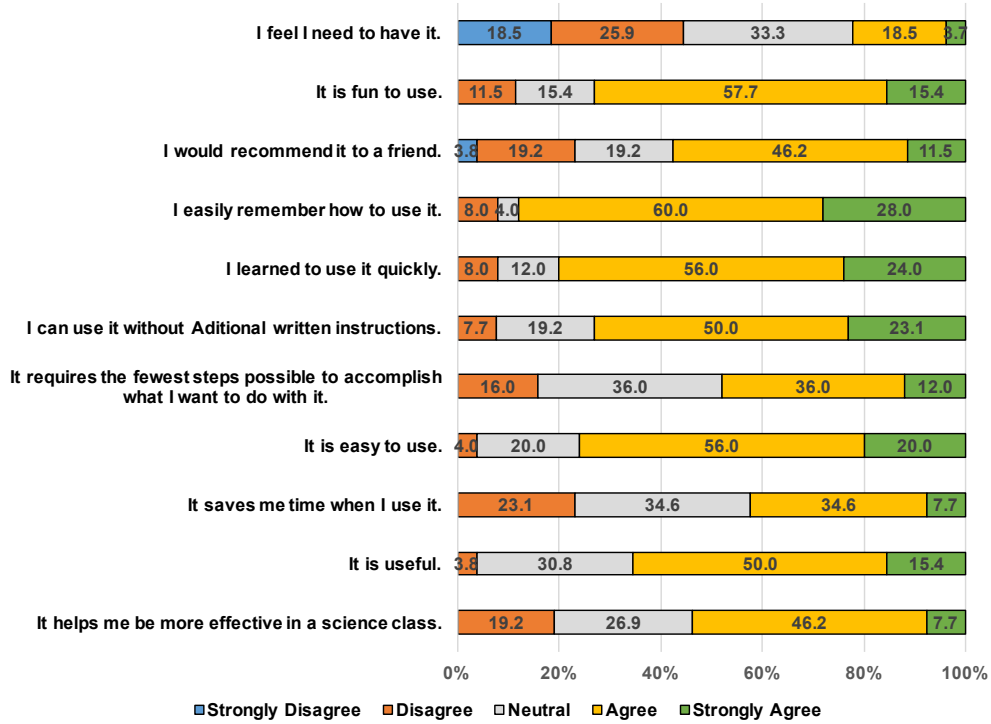
Corpus Christi GNS Class A': USABILITY results



b) Corpus Christi GNS Class A': Usability

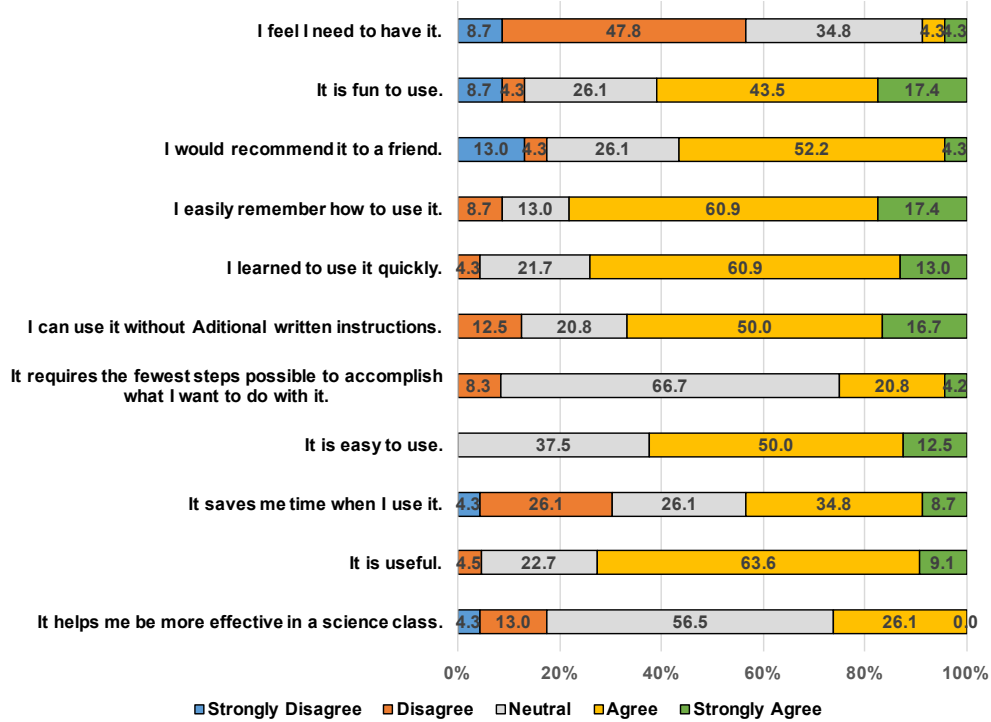
Figure 1. Usability Evaluation for classes A and A' in St. Patrick's BNS and Corpus Christi GNS

St. Patrick's BNS Class B: USABILITY results



a) St. Patrick's BNS Class B: Usability

Corpus Christi GNS Class B': USABILITY results



b) Corpus Christi GNS Class B': Usability

Figure 2. Usability Evaluation for classes B and B' in St. Patrick's BNS and Corpus Christi GNS

4 CONCLUSIONS

This paper reported usability evaluation and its findings following a Horizon 2020 NEWTON Project Large-Scale pilot carried out in two single-gender primary schools in Dublin, Ireland. In St. Patrick's BNS a class of 30 boys participated in NEWTON-based lessons which were introducing students to a particular topic and another class of also 30 boys participated in NEWTON-based lessons which were revising the educational content presented by the students' usual teacher 4 to 10 weeks earlier. The same approach was employed in Corpus Christi, with 30 girls in the introduction approach class and 27 girls in the revision class. All participating students were in 5th grade and between 10 and 11 years of age.

It was observed that overall girls seemed less positive about the NEWTON TEL approach, especially the ones in the revision-approach class. The girls seemed to be much more attached to their usual teacher and sometimes it appeared they feared that by using NEWTON and TEL approaches they were risking losing their valuable bond with their teacher. It was very much emphasised during the interviews that they would prefer to see NEWTON being used by their usual teacher during their usual classes as a supporting tool, rather than an independent approach to learning. The boys in the revision approach class vocalised similar feelings, but to a lesser extent. Positive comments were received from participating students, where girls provided more detailed responses to the open-end questions.

We also note that there is a key difference between 'use' and 'usability'. The level of usability – that is the ability of students to successfully use the NEWTON technologies – was generally high and this encourages engagement in the learning tasks. However, the figures fall away when questions relating to 'use' – that is the perception of value in relation to the students' learning – are asked. This shows that although usability is key, understanding the value and relevance of a learning technology is a critical aspect to the successful integration of that technology within a learning context.

As in some previous findings during the NEWTON project, it was confirmed that the role of the teacher and their leadership plays a vital role in all lessons, including those employing TEL methods [25]. A high percentage of students perceived NEWTON-based lessons fun and easy to use. It also needs to be noted that, as previously reported, the post-pilot assessments were affected by the last NEWTON-based lesson, Geography, which encountered various technical issues. It is believed that some of the answers would have been more positive would they have been reported by students following some of the previous NEWTON-based lessons which did not have any notable problems. Analysis of this data demonstrates how critical it is to the successful perception and use of a technology that the chosen technology avoids any technical issues. Students expect technology to work and are disappointed and, potentially, disengaged if they meet with technical problems. The problems observed during this pilot were reported to the developers and they have been solved.

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