EVALUATING THE IMPACT OF NOVEL LEARNING TECHNOLOGIES IN STEM SUBJECTS: RESULTS FROM PROJECT NEWTON AND THE GAM LAB-ITALY PILOT EXPERIENCE

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Abstract

Many European countries face a crisis amongst their younger generations in relation to the number of young people choosing to follow scientific learning pathways. The number of students specialising in science, technology, engineering and maths (STEM) disciplines is declining and this is leading to a real risk of a shortage of suitably qualified scientists, technicians and engineers to build the economic and innovation strength of Europe in future. We then need to find better ways to attract young people into STEM subjects and, furthermore, better mechanisms by which we can promote learning, stimulate engagement and increase interest and motivation.

We also need to address challenges in relation to STEM teaching, much of which remains teacher-led, didactic and one-dimensional. This can lead to the learning experience being less effective, less engaging and can result in STEM students struggling to fully engage in their lessons and, ultimately, choosing subjects that they perceive to be easier, more fun and offering a better chance of employment. There is also a need to ensure that STEM teachers are given the opportunity to be innovative in the way they teach and in the content they develop.

To address the challenges relating to the attractiveness of STEM subjects to learners and the effectiveness of STEM teaching, the NEWTON project – funded under the Horizon2020 E.U. programme – has been conceived as a large scale initiative to develop and integrate innovative technology-enhanced tools for teaching and learning and to create a pan-European learning network platform that supports fast dissemination of learning content to a wide audience in a ubiquitous manner. NEWTON is seeking to deploy a range of novel techniques and methodologies, such as AR/VR, Fab-Lab, Virtual Labs, user profiling, self-directed learning and Gamification – considered as the use of game mechanics, graphics and concepts – along with game-based learning contents (the use of so-called 'serious games') for the attraction and engagement of the student and for the enhancement of the learning (and teaching) experience, in general. The project is now into its third (and last) year of life and we are already able to see interesting results emerging from the pilots that have been run so far.

In this paper, we briefly present our evaluation model and then go on to report on our findings, trying to answer to some stimulating research questions, specifically focusing on GAM LAB-Italy Pilot, one of the most representative Large Scale Demonstration experience, that has been run with two secondary institutions in the south of Italy.

Our ultimate aim is to understand different aspects relating to impact and to develop a deeper sense of which of the NEWTON technologies have a positive effect on learners and are, therefore, likely to be adopted in the classrooms and laboratories of our schools and colleges across Europe. The paper will report on three specific aspects of our evaluation: first, we consider knowledge and skills acquisition: what is the extent to which these new technologies have a genuine impact on the educational development of students and what is the evidence to support impact? Second, we look at student engagement and student motivation. What we know is that a more inspired, engaged, and motivated student is likely to be a better learner - to what extent have NEWTON technologies increased the level of engagement and motivation and what has the impact on learning been?. And finally, we explore the impact of the technology on teachers: how far do teachers embrace these new technologies? To what extent do these approaches make their teaching more effective? What are the barriers that might stop early adoption of these technologies within a classroom setting?

Our conclusions propose a set of ideas for how we can better use novel technologies within an educational context and, more specifically, how these technologies can be useful as a set of tools for increasing interest in STEM subjects and improving learner outcomes for a possible future novel approach of learning and teaching

Keywords: STEM, pilot study, technology enhanced learning, research projects.

1 INTRODUCTION

It is widely recognised that as a continent, we need to better develop the skills, competencies and talents in the area of STEM learning in order to ensure we are feeding the requirement for 21st century skills, driving up innovative and ensuring we are able build strong, dynamic, creative economies. Our methods of teaching and learning are evolving fast but we still need to find way to bring more innovation into the classroom and to ensure that the experience of learning STEM is consistent with the massive leaps in consumer technologies that we have witnessed over recent years.

These technologies offer vast potential in terms of engagement, motivation, skills development, experiential learning and so on. However, there is clearly a gap between the technologies that innovative companies across the globe are developing and the effective use and implementation of these technologies within our classrooms. There are many learning technologies that enable us to push the boundaries of how we educate – and, indeed, the European Union has spent billions in support of this learning revolution – but there remains a gulf between innovation within learning technologies on the one hand and the enthusiasm of teachers, school leaders and the education community on the other. This means that we need to find better ways to bring emergent technologies into the classroom. We need to find better ways to create learning environments that match and surpass the technological experiences of young people. And we need to do this in STEM subjects more than ever as it is here where the shortfall in enthusiasm, motivation and learning progress is most acute.

The focus of this paper is to report on the large-scale technology pilot – GamLab – run as part of the NEWTON project. We outline the key aspects of the pilot, the approach we have taken to evaluation – a critical part of the challenge of understanding the value of learning technologies - the key results from the pilot in terms of learner motivation and engagement, learner progress and teacher role and we draw some conclusions regarding the implications for technology-enhance learning within a STEM context.

To put the GamLab pilot into context, it is important to set out the main aspects of the NEWTON project. NEWTON Project [1] is a large-scale initiative funded by European Commission in the H2020 program aiming at developing, integrating and disseminating innovative technology enhanced learning (TEL) methods and tools. The main objectives are to create new or interconnect existing state-of-the-art teaching labs and building a pan-European learning network platform that supports fast dissemination of learning content to a wide audience in a ubiquitous manner, by focusing on employing novel technologies in order to increase learner quality of experience, improve learning process and increase learning outcome. Figure 1 summarizes the main ambitions of the NEWTON Project [2].

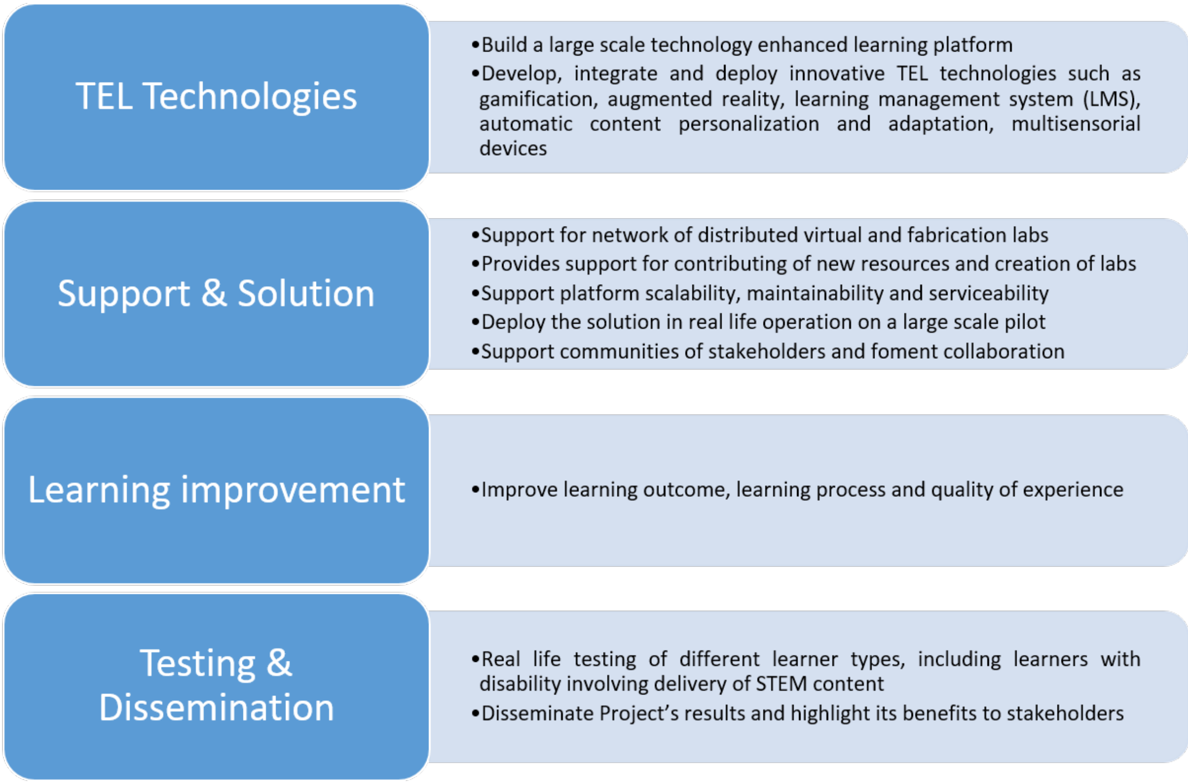


Figure 1. NEWTON main ambitions

About impact evaluation of Project results in the *learning and teaching* domain, NEWTON has developed a methodological framework designed to evaluate the impact on learning experience, skills development and teaching practice within the context of STEM subjects. This framework considers a range of aspects including consideration of learners with special needs, user (learner and teacher) satisfaction, engagement and usability. This is covered in Section 3 of this paper under 'Methodology'.

2 THE GAMLAB PILOT

Since Newton is an Innovation Action project, the final aim consists of evaluating and validating the impact of adopting different technologies integrated in a single platform in the traditional learning and teaching processes with main focus on STEM subject by designing and implementing many pilots involving secondary, vocational schools and Universities across European countries. In particular, here we refer to the Large Scale Pilot (LSP) "GAM Lab" which gave us a set of results as input for the evaluation process. The basic idea of GAM Lab was to create a new learning experience in which learners can use Newton platform to access to a set of content supported by new technologies such as virtual reality and remote fabrication laboratories, and are engaged through gamification mechanisms. The pilot was run in two secondary Italian schools. The first step was the execution of some Small Scale Pilots with some of all content and technologies (as in LSP) in order to check the functionalities and to have preliminary feedback from learners to be used to refine the initial design. The complete LSP schema is shown in the following picture in which all stages, content, technologies and equipment are indicated.

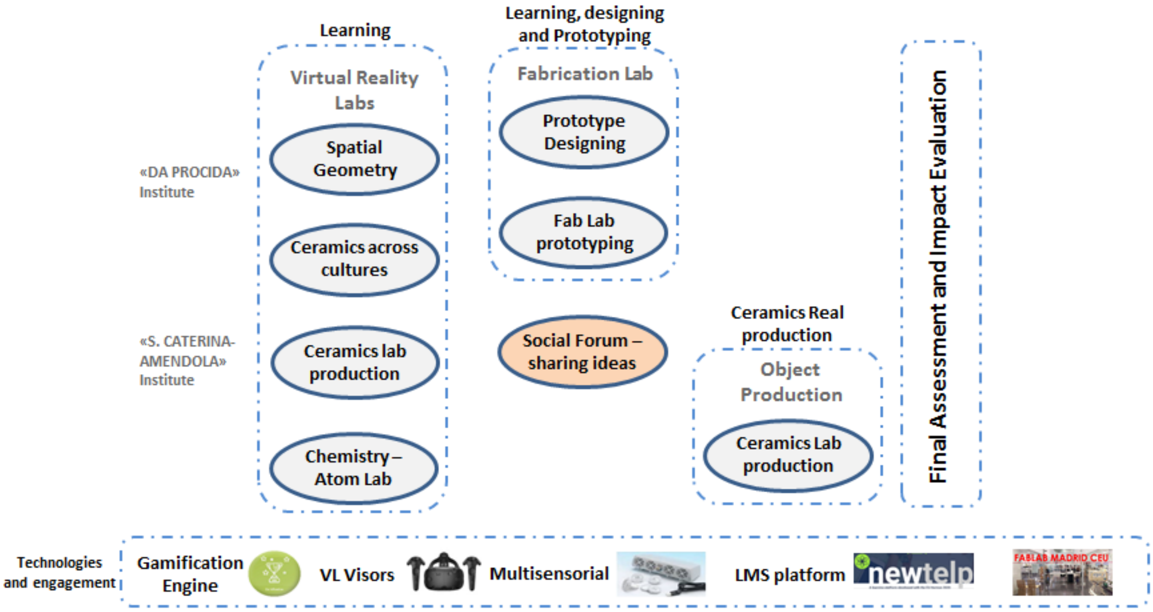


Figure 2: The GamLab pilot structure

The experience pathway as designed represents a supply process developed through different stages, starting from the learning of spatial geometry and ceramics concepts (in terms of cultural meaning, production process and chemistry elements), after that students can design some shapes and prototyping them using Fabrication Lab connected to Newton platform. The prototypes are used by a part students for the real production of ceramics shape in the referred school lab. The motivations and engagement of learners are enabled by using gamification elements/rules, virtual reality equipment, mulsemedia devices and social forum. The final stage regards the application of Newton impact evaluation methodologies starting by results (survey, feedbacks, etc.) collected during the pilot from both schools' learners and teachers, as described in this paper.

3 METHODOLOGY FOR EVALUATION

We have developed a blended approach to evaluation that addresses key aspects of what we need to understand when we are running technology pilots. The objectives for this evaluation are highlighted below:

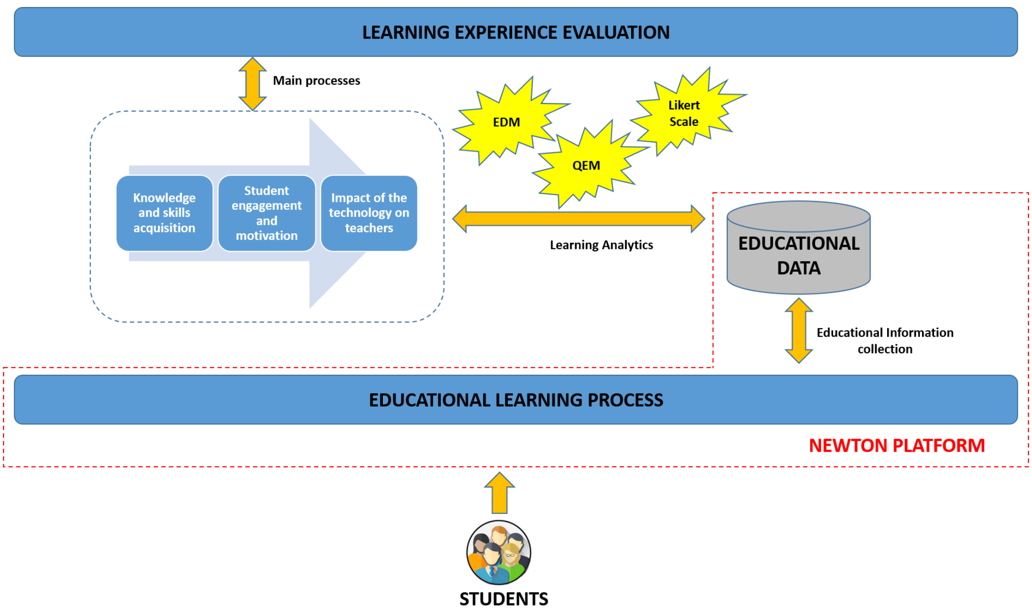


Figure 3. Overview of the evaluation model for learning experiences

Figure 3 shows the model we are using to evaluate the innovative educational learning processes realized through the NEWTON Learning Platform. Information generated during the educational experience is collected via appropriate ICT tools and methods thereby generating learning analytics in order to support a more qualitative evaluation of the learning experience. The main areas of focus for the evaluation are: (i) knowledge and skills acquisition; (ii) student engagement and motivation; (iii) impact analysis of the technology on teachers [3].

Our evaluation methodology is a blend of qualitative approaches – based on learner and teacher interviews, focus groups and teacher/researcher observations - coupled with data gathered from the end users of the technology in relation to the key metrics outlined above. The key challenge was to track learner progress (in terms of the development of understanding/knowledge/skills) but to also provide equal focus to the affective state of the learner, particularly in relation to their motivation and engagement in learning. Alongside this, we give significant weight to the feedback and experiences of teachers with particular reference to their view on the impact on learners and to their own acceptance of the technology coupled with the impact it has had on teaching practice.

4 RESULTS

The results from the GamLab pilot provided significant insight into the possibilities of fast-growing consumer technologies as they might be applied to a STEM learning context. These results are summarised below. We report the results in relation to the different individual technologies that were used as part of the GamLab pilot:

4.1 Impact on learner progress

For the use of fab-lab technology in learning (FAB LAB process with focus on graphic design of geometric shapes and preparation for 3D print by FreeCAD, Ultimaker Cura and Cloud Hub software)

- By analysing knowledge tests submitted on paper to learners (Pre & Post) about FAB LAB and the answers to submitted quizzes on Platform, we can noticed a significant increase of knowledge about concepts related to graphic design and 3D print for all learning. Before starting FAB LAB experimentation, no learners knew anything about FAB LAB process but after the learning path, they were able to correctly associate information
- In the experimental group the mean of the results for the knowledge pre-test was x=0,11 and in the post-test the average score was x = 1,26 that show an important progress in knowledge.

		Knowledge's Mean Value	Numbers of learner	Std. Deviation
Pair 1	FabLab Knowledge Posttest results	1,26	19	1,046
	FabLab Knowledge Pretests results	0,11	19	0,315

- The results of a paired t-test for dependant groups showed that the post-test results were statistically significant higher than the pre-test results for the experimental group at $p \leq 0.05$ ($p=0.000$) significance level as we can observe in the following table:

	Paired variables	t	df	p

	Paired variables	t	df	p
Pair 1	FabLab Knowledge Posttest results - FabLab Knowledge Pretests results	4,726	18	,000

For the use of web app Virtual Lab for teaching Chemistry subject about atoms, isotopes and molecules

- By analysing knowledge test submitted on paper to learners (Pre) related to basic concepts about atomic structure and the answers given by learners after the Virtual Lab experimentation, we can notice a significant increase of knowledge. In fact, no learner knew the fundamentals of atomic structure (Pre Test were negative for each learner) but, repeating the same test after the learning process proposed with VL, all learners gave most of the correct answers.

For the use of VR technology within a learning environment (Different and specific Virtual Reality environments for teaching and learning Spatial Geometry and Ceramics subjects by HTC-Vive technology):

- By analysing knowledge tests submitted on paper to learners (Pre & Post) we can noticed a significant increase of knowledge about Spatial Geometry concepts for some learners and a slight increase for other ones
- Differently, there was a very significant increase of knowledge by all learners in the quizzes phase of Virtual Reality environment that highlighted the ability of VR technology to enhance memory retention of learners
- Pupils with SEN completed all questions in TTCT test and let their imagination run free by providing interesting results

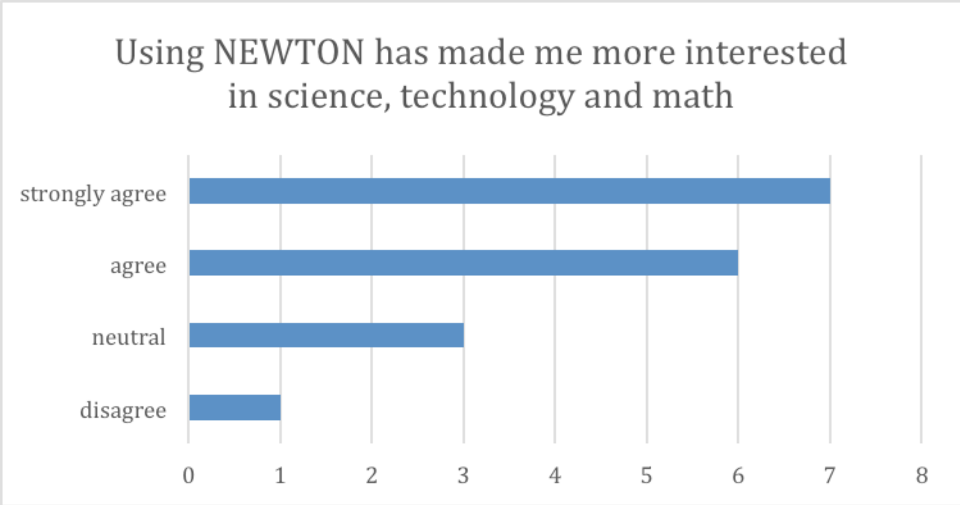
4.2 Impact on learner motivation and engagement

For the use of fab-lab technology in a structured learning environment (details as before):

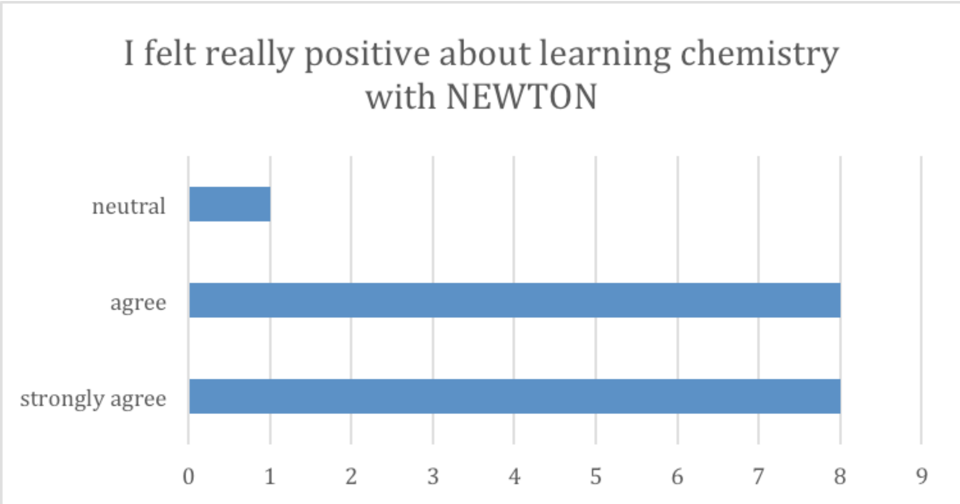
- The FAB LAB experience has developed self-learning and learning by doing skills in the students
- Using interactive software allowed students to learn faster than a traditional classroom lesson
- It is important to learn the digital fabrication process from a practical rather than a theoretical point of view by practicing with the specific software
- For the virtual lab technology:
  - The graphic interaction with the virtual laboratory is the most memorable aspect
  - Students prefer to learn the chemistry subject in the classroom through traditional lessons than by Virtual Lab on PC
  - Learning concepts by Virtual Lab is less engaging than learning by Virtual Reality
  - It is more effective for experimentation by some approaches like quizzes, learning by doing, etc.

For the use of VR technology within a learning environment:

- High learner engagement and interest for the technology which allows to learn by having fun
- Exciting and inquiring environment that encourages the learning
- Interesting and enjoyable alternative learning approach than traditional one within classroom that helps to enhance the knowledge of topics



- The virtual environment with its functionalities implemented like teleportation, handling objects, etc. managed to arouse curiosity also towards the students initially reluctance to have such an experience



- Fun support for learners with S.E.N. that helped them to enhance own learning skills and to interact with an environment by going beyond own limits and barriers

4.3 Teacher reaction/response

For the use of fab-lab technology in a structured learning environment (details as before):

- FAB LAB
  - Learners demonstrated full involvement and enthusiasm of learning; they were protagonists as group or by-self in the educative path they participated
  - Activities from FAB LAB experience were examples of problem solving and/or cooperative (and "competitive") learning
  - The technology has been an activator of interactions among learners who have maintained a high level of attention and involvement in the various activities
- Virtual Lab
  - Learners have certainly improved their graphic ability to make atomic structures
  - Teacher thinks learners felt satisfied when they went through the different steps of the experience; a bit like when they pass the different levels of their electronic games

- The use of Virtual Laboratory does not require a change in the way of teaching; it is an integrative tool for teaching that already uses a lot of technology
- Effective way of learning the topic due to the specific problem-solving oriented approach of Virtual Lab
- Need of more training for Teachers (in general)

For the use of VR technology within a learning environment:

- Innovative approach of learning favors memorization, the familiarization and help to develop abstraction skills
- Virtual Reality has given the way for pupils to "see" and "touch" the objects they already knew and what they did it has encouraged learning and memorization with a very positive impact on their direct involvement in the learning process and making them autonomous and protagonists
- Virtual Reality has favored the learning of students who have enriched themselves with new knowledge about unknown contexts, enhancing their skills
- Learners were more responsible, attentive, concentrated than traditional classroom; no need to stimulate their attention at all
- Stimulation of sharing, reciprocity, self-esteem, comprehension and bio-psycho social wellbeing of learners with SEN
- Need of more training for Teachers
- Need of more interaction with the LMS NEWTON platform
- Even if only partially tested, positive results from SEN learners

5 CONCLUSIONS

Through the design, development and implementation of the GamLab pilot we investigated the impacts of NEWTON learning technologies combined with innovative pedagogical approaches on learners' engagement and learning outcomes as well as on Teachers' didactic methodologies, by implementing these technologies within a traditional classroom setting. The blend of quantitative analysis and the various qualitative returns (focus groups, interviews, observations, direct feedbacks) have clearly indicated that GAM LAB experience was able to bring fun and motivation elements to the classroom, stimulate Learners' interests on subjects, foster to a more socializing/cooperating attitude. Tests results already indicate knowledge levels enhanced after the exposition to NEWTON contents.

We also see clear benefits for learners with special needs and, more broadly, a greater degree of enthusiasm for STEM in general as a result of the implementation of these technologies. Analysis is on-going and the next phase of our work will consider more specifically the impact of these technologies on specific typologies of learners (based on gender/age/educational ability/location etc.) but it is clear that by bringing emergent technologies into the classroom and implementing them in combination, it is possible to both increase learner outcomes and to build greater enthusiasm for subjects that are otherwise thought of as difficult or boring. Some challenges exist for teachers in respect of usability (which will be further reported on in future studies), requirements for training and the need to integrate the technologies into the existing curriculum. However, wider analysis of the NEWTON pilots suggest that these barriers are easily overcome and that the impact on student affective state and motivation outweighs any challenges to implementation that may exist.

As such, the NEWTON approach to STEM learning offers significant promise as a means of stimulating future engagement and promoting new approaches and pedagogies within the traditional classroom setting.

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