NEWTON Virtual Labs: Introduction and Teacher Perspective

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***Abstract*—Virtual labs play an important role in the current evolution of practical training in STEM (Science, Technology, Engineering, and Math) education, as they provide a solution to challenges faced by teachers in traditional labs, such as providing instant feedback to students, keeping them engaged and motivated, and enabling all students to carry out experiments at their own pace. They also reduce the set-up and maintenance costs associated with lab management, while removing dangerous hazards and geographical limitations. This paper discusses the status of virtual labs in education and introduces the NEWTON virtual labs which are designed as part of an innovative, large-scale H2020 project. The paper also presents a preliminary study, investigating teachers' perspective and challenges using questionnaires and interviews. The preliminary results indicate that the biggest challenges to teachers in a science class are facilitating learning to slow and fast learners, giving individual feedback and getting students to engage and stay motivated. The results show that teachers value instant feedback to students, the opportunity for inquiry-based learning, as well as the utilization of technology and lack of hazards.**

Keywords-virtual labs; STEM education; personalised learning; online labs

I. INTRODUCTION

Practical activities are considered a key component of STEM (Science, Technology, Engineering and Math) education [1], [2]. Future job markets require science graduates with practical abilities, independent research skills and inquisitive mindsets [2], [3]. Virtual labs, where students can practice their science experiments without limitations posed by time, space or lack of equipment, while being free from hazards, have been suggested as the best solution to increase practical experience in STEM education [4]. Virtual labs function as an environment for students to use virtual objects and apparatus, through software interface which is connected to hardware in one centralized place [1]. Missing a lab does not mean being left behind anymore, as students can catch up in the virtual environment, and receive instant feedback on their work [1].

Furthermore, at a time when the cost of setting up and maintaining traditional labs is increasing, while funding for practical training is being cut, virtual labs provide an option for cheaper set up and maintenance costs than traditional labs, with unlimited possibilities to share information between institutions, educators and learners [5], [6]. These online-labs are also key tools in distance education.

In virtual labs, students learn team work and inquisitive skills through interacting with each other, while educators benefit from the instant feedback provided by the system and automatic marking, leaving them more time to focus on teaching. This is quite a different way of learning for students, as they are not just passive observers, but active participants. Inquiry-based practical labs, where the students develop research questions, plan and carry out their own experiments, have been found to be more effective in developing students' scientific inquiry and communication skills compared to traditional methods [7]. In virtual labs, there is no limit to the number of times students can repeat the experiment. Students have reported this to be one of the primary benefits of virtual labs, alongside the absence of real hazards, which has been found to improve their concentration on the task at hand, thus providing a better learning experience [2].

The incorporation of virtual worlds, augmented reality, gamification and multisensorial activities means that virtual labs offer students an incredibly life-like learning experience. Optimal learning occurs when multiple senses are involved in the learning experience, and a responsive environment can enable faster learning [8]. However, even though the possibilities and benefits of virtual labs are widely recognized by educators, there is a need to implement these new technologies on a large-scale to truly revolutionize the way STEM subjects are taught. Special education has also been neglected in the development of most existing virtual labs, even though several studies have reported that utilizing virtual reality, augmented reality and multisensorial activities improve the quality of disabled students' learning [9], [1].

This paper introduces the NEWTON Virtual Labs and provide the teachers' perspective of virtual labs and the challenges teachers face in STEM education. The rest of the paper is structured as follows. Section 2 presents the NEWTON Virtual Labs, section 3 presents the preliminary study while the last section discusses and concludes the paper.

II. NEWTON VIRTUAL LABS

NEWTON, a large-scale European H2020 project funded by the EC, is in the process of building a network of virtual labs linking European educational institutions [10]. NEWTON is developing innovative technology enhanced learning (TEL) methods and tools, with a focus on employing novel technologies to increase the quality of the

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learning experience, improve learning process and increase learning outcome. Thus, the NEWTON project will tackle the worrying trend of decreasing numbers of European science graduates by making STEM subjects equally accessible to all students, while motivating students to study science further [10].

The NEWTON virtual labs will offer students visual software simulations, which can be utilized across a variety of science courses, from secondary to higher levels as well as applied to vocational training. An inclusive interface will make access easy for all students, including users with disabilities, for example by offering sign language for students with hearing impairments. The NEWTON virtual labs will include aspects of gamification, where game mechanics are integrated into a non-game learning experience to increase user enthusiasm and assist engagement in the exercise [10].

The NEWTON virtual labs have a focus on self-directed inquiry-based learning, that places the student at the center of the learning experience. Personalization and adaptation, which are the fastest-growing trends in e-learning, will be central in these virtual labs, as they allow each student to proceed at his or her own pace.

III. PRELIMINARY EVALUATION OF VIRTUAL LABS

Prior to the implementation of the NEWTON virtual labs to educational institutions it is vital to understand the challenges faced by educators. In this study, teachers were interviewed and surveyed on their general opinions on the benefits of virtual labs, and the biggest challenges they face in a lab.

A. Methodology

Five scenarios for secondary schools (three lab exercises in Biology; one in Chemistry and one in Physics) were designed in accordance with the Irish Junior Certificate Science Curriculum.

- Scenario 1: Light Microscope (Biology) - Students will learn about how a light microscope functions, and study an animal cell and a plant cell as well as the organelles found within them.
- Scenario 2: Photosynthesis (Biology) – Students will carry out an experiment investigating the factors affecting photosynthesis in plants.
- Scenario 3: Adaptation and Natural Selection (Biology) - Students will learn about adaptation as a driving force for natural selection, and how adaptation affects a species' likelihood to survive. They will then take part in a gamified experiment.
- Scenario 4: Building Atoms (Chemistry) - Students learn the components of atoms. Students learn to appreciate how substances react in relation to their atomic structure.
- Scenario 5: Density, sinking and floatation (Physics) - In the first part students will learn about the mass and density calculations of an object, and in the second part they will learn about whether an object sinks or floats. Students will then design their own experiment, and carry this out.

The educators involved in this study were science teachers in Irish secondary schools. In total, 106 teachers were approached via phone to inquire about their interest in taking part in the survey about NEWTON virtual labs. During these initial phone calls, teachers were asked their opinions on where they see the value of virtual labs and what challenges they face in a traditional lab setting. As a result of these discussions, 95 teachers from 76 schools expressed an interest in answering the survey, and subsequently received the email. Out of these, 22 teachers (12 females and 10 males) completed the survey.

The survey questions for teachers included: level of technology used by students (personal smart devices, computer room, none); level of satisfaction about the level of technology used the class (comfortable, would like more, would like less, none); challenges in a science class (teaching a mixed ability class, marking, preparation, feedback, managing the class, motivating students, safety); value of virtual labs (repeatability of experiments, personalization, automated marking, instant feedback, inquiry-based learning, no hazards, little management).

B. Results

1) Interview Results

The teachers very positively perceived the NEWTON project: *"It's definitely a very interesting project and we would be more than happy to be involved in any pilot program here", "Your work is definitely excellent", "Scenarios look great".* Teachers commented that the project *"sounds very novel and interesting".* Virtual labs were seen as a useful tool to explain abstract scientific concepts that students might otherwise struggle with: *"They give a dynamic visual representation to an abstract concept that they cannot encounter in the physical lab", "This would be an extremely useful tool in the classroom. Of course, there is no way to reproduce this in a physical lab, and this is far more effective than drawing diagrams, as the introduction and removal of particles gives a real-time feedback as to how this affects the atom. Vocabulary is always a challenge with this topic, I think that reinforcing it within the virtual lab is a great idea".* Teachers were keen on the virtual labs to incorporate questions from past exams, and to be very specific in their learning objectives, as well aligned with the curriculum: *"I would see much more value in the virtual lab if it incorporated past exam questions and answers from the marking schemes."* From the interviews, it became clear that teachers would like to see more virtual and augmented reality in science labs, as the common census was that this would help engage students and keep them motivated:" "*Would love to see Google cardboard VR incorporated into virtual labs as this would be sure to engage students....*".

2) Survey Results

a) Technology in the classroom

9.52% of teachers mentioned that their students have tablets or similar devices in the classroom, while majority (90.48%) of the teachers answered that students have access

to a computer lab. More than two thirds of teachers wanted to use more technology in the classroom (68.18%), while 31.82% were happy with the level of technology used.

b) Challenges in science teaching

The biggest challenges to teachers in a science class were facilitating learning to slow and fast learners, giving individual feedback and getting students to engage and stay motivated (Fig. 1). The smallest challenges were tracking experiments, safety issues in a lab and managing the class.

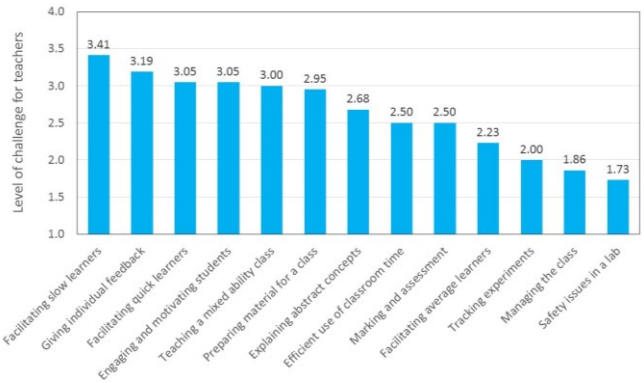

Fig. 1. Biggest and smallest challenges faced by science teachers in a lab (average values on the 1-5 scale).

c) Value in using virtual labs

Teachers found the greatest value of virtual labs to be in the instant feedback for students (Fig. 2). They appreciated the inquiry-based learning, lack of hazards and recognized that students enjoyed using technology in their studies. Reduced management, repeatability of the experiments and personalization of the labs were of medium importance in the teachers' opinion. Automatic marking was considered the least important benefit of virtual labs.

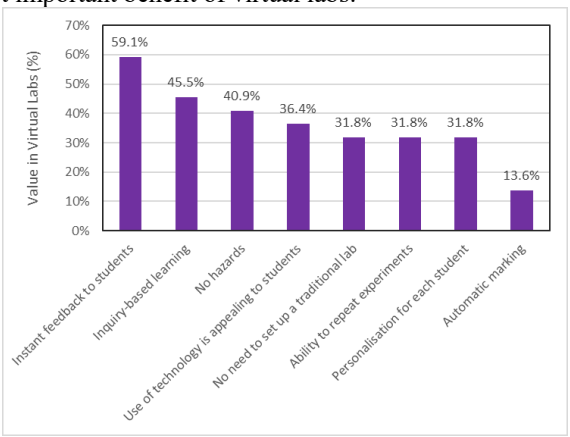

Fig. 2. The biggest value for teachers in using a virtual lab was the instant feedback to students.

IV. Discussion and Conclusions

Replacing traditional labs with their virtual equivalents results in the removal of real-life hazards, time, space and geographical limitations. Virtual labs enable students to get the practical training that is essential in the study of STEM subjects. Furthermore, NEWTON virtual labs enable students to experience inquiry-based learning, which is highly valued by Irish science teachers. Personalization in the virtual labs will also assist teachers with one of their biggest challenges: facilitating learning for both slow and fast learners. Students of today are highly technology-orientated and teachers recognize this, as one the most valued characterictics of virtual labs was that students got to utilize technology in learning.

Virtual labs offer a practical solution to the challenges faced by traditional labs, and this was reflected in the answers given by the science teachers who took part in this study. Teachers saw the biggest value of virtual labs in instant feedback and inquiry-based learning. The results from this survey are a good indicator of teachers' perceptions on virtual labs and what they value the most, and further results will be analyzed once the survey is distributed to other European teachers.

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