STEM EDUCATION WITH ATOMIC STRUCTURE VIRTUAL LAB FOR LEARNERS WITH SPECIAL EDUCATION NEEDS

Ioana Ghergulescu[1], Tiina Lynch[1], Marilena Bratu[2], Arghir-Nicolae Moldovan[3], Cristina Hava Muntean[3], Gabriel Miro Muntean[4]

[1]Adaptemy (IRELAND)
[2]University of Bucharest (ROMANIA)
[3]National College of Ireland (IRELAND)
[4]Dublin City University (IRELAND)
ioana.ghergulescu@adaptemy.com, tiina.lynch@adaptemy.com, marilena.bratu@fpse.unibuc.ro, arghir.moldovan@ncirl.ie, cristina.muntean@ncirl.ie, gabriel.muntean@dcu.ie

Abstract

The Atomic Structure virtual lab was employed in a small-scale pilot carried out in a school for students with special education needs (SEN) from Ireland, as part of the European Horizon 2020 Project NEWTON. Atomic Structure virtual lab places the learner in the centre of the learning experience through implementation of personalisation, inquiry-based learning, and self-directed learning. These pedagogies, combined with interactive activities and the use of multimedia, make Atomic Structure an engaging, encouraging, and fun learning environment. In the lab students are active participants, not passive listeners: they are in charge of their own learning. The Atom Structure virtual lab teaches concepts regarding atoms, isotopes and molecules. Learners can also interact with atoms, build an atom from information available in the periodic table, build isotopes and molecules. Students with hearing impairment from two secondary school classes participated in the pilot. A number of surveys and questionnaires were used in the evaluation methodology including demographic questionnaire and Torrance Tests of Creative Thinking (TTCT) questionnaire. The evaluation results showed that the students' creative thinking has improved significantly in terms of various mental characteristics such as fluidity, flexibility and originality.

Keywords: Virtual labs, STEM education, special education needs (SEN), personalisation, evaluation.

1 INTRODUCTION

Virtual laboratories have been hailed as the answer to the problems faced by educational institutions struggling to offer Science students the experimental learning experiences they need. Organizing laboratory spaces is time consuming, expensive, and requires mindfulness of health and safety regulations. Furthermore, when students are unable to attend real lab session they might not get a second chance to practice. As opposed, virtual labs offer a space for empirical learning, and provide students with the chance to experiment repeatedly with different solutions to problems in Science. Moreover, virtual labs can reduce the cost of running and overall maintenance of lab facilities, while offering students a safe environment to build up experience and enthusiasm for STEM (Science, Technologies, Engineering and Math) subjects [1].

A number of virtual labs that have been developed for STEM education were reviewed by Lynch and Ghergulescu [1]. Several European projects have previously focused on virtual labs such as: Go-Lab [2] that enabled educators to create their own labs and share them with other users through the platform, VccSSe [3] that provided virtual labs and training in physical laws including simulation-based exercises, and GridLabUPM [4] that offers students practical experience in the fields of electronics, chemistry, physics and topography. Other subject specific virtual labs include ChemCollective [5] and Open Source Physics [6]. The virtual labs make use of multimedia material, virtual experiments and/or simulation-based exercises, as well as video games, gamification and game avatars.

Virtual labs provide a number of benefits including the ability to share resources between geographically distributed educational institutions saving time and money [7], the ability for students to repeat the experiments many times and as often they wish, as well as the ability to conduct experiments that would be too dangerous or not feasible in a real lab [8]. Furthermore, virtual labs enable inquiry-based learning [2], while previous research also showed that students can learnt quicker in a virtual lab with tangible objects than in a traditional lab, or in a virtual lab with non-tangible objects [9]. However, virtual labs have also faced some criticism such as disregard of health and safety procedures or unrealistic lab experiences if the implementation is not done correctly [10]. Many existing virtual labs do not integrate personalisation and adaptation, which are recognised as a key feature of future pedagogies [1]. Moreover, special education has been neglected in most of the existing virtual labs, despite previous research showing that online learning can improve the learning experiences of students with disabilities such as hearing impairment [11].

In this context, this paper aims to evaluate the benefits of the Atomic Structure virtual lab for students with special education needs (SEN). The small-scale pilot was conducted with twelve SEN students from a school in Ireland, which filled up a number of questionnaires and surveys before and after experimenting with the Atomic Structure virtual lab. The research is conducted as part of the NEWTON Horizon 2020 project [12], a large-scale innovation action project that aims to build a network of virtual labs linking European educational institutions to provide students with innovative technology enhanced learning (TEL) methods and tools. The NEWTON virtual labs focus on self-directed and inquiry-based learning, which place students at the centre of the learning experience [13]. Personalization and adaptation are central to these virtual labs, as they allow each student to proceed at his/her own pace. Atomic Structure is a lab that focuses on teaching abstract scientific concepts such as the atomic structure and bonding of molecules, gaining and losing electrons, that can be hard for students to grasp, and difficult for teachers to present with traditional teaching materials.

The rest of the paper is structured as follows: section 2 describes the Atomic Structure virtual lab, section 3 presents the methodology for the evaluation study with SEN students, section 4 presents the results analysis, while section 5 concludes the paper.

2 ATOMIC STRUCTURE VIRTUAL LAB

The Atomic Structure Virtual Lab [14] is based on self-directed and inquiry-based learning, with different levels of adaptation and personalization. Self-directed learning is utilized at the start of each stage of the virtual lab (i.e., stage 1: Atoms, stage 2: Isotopes and stage 3: Molecules), where students answer four questions on personal management, desire for learning, self-control and self-efficacy. Each student's level of motivation determines what level of questions they receive in the quizzes, and what types of atoms, isotopes and molecules they are presented with to build. Low and medium motivated students are restricted to atoms, isotopes and molecules which have been deemed suitable to each of those levels, and highly motivated students have access to more complex atoms, isotopes and molecules.

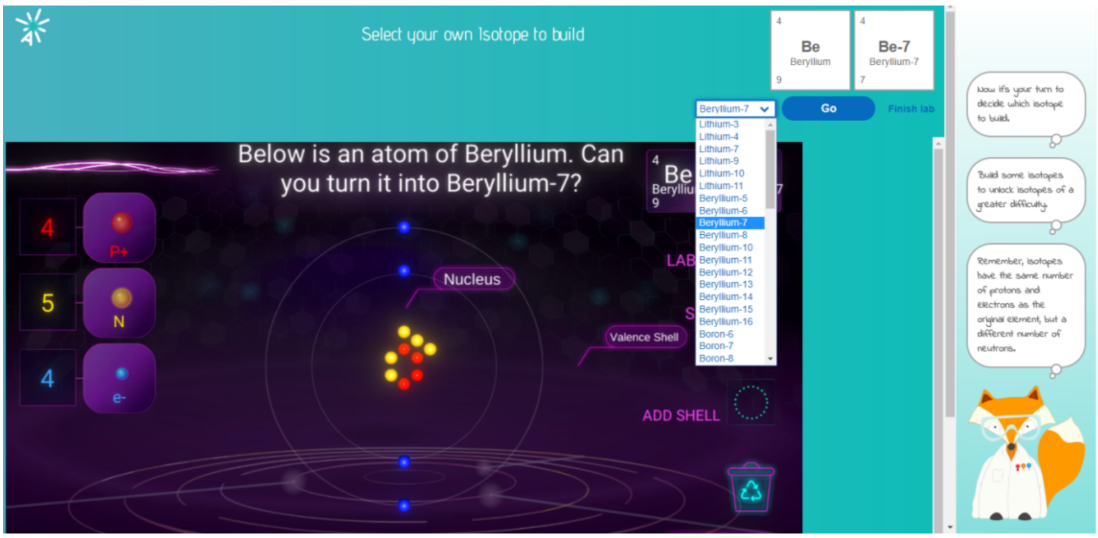

Figure 1. Illustration of building an isotope of Beryllium in inquiry-based learning phase.

Figure 1 illustrates the process of building an isotope of Beryllium with the Atom Structure virtual lab. The inquiry-based learning phase is offered at the end of each of the three stages in the form of atom, isotope and molecule builders. At first, students are given either easy, medium or hard level of atoms, isotopes and molecules, based on their results from the previous quizzes and their level of self-directedness, determined by the motivational quiz at the start of each stage. After they master building the suggested objects, students can freely choose their own, and experiment further in the atom, isotope and molecule builders. Students are offered help in the form of the fox avatar, Tilda, who offers feedback, encouragement and hints, but more importantly they get to experiment with a base of an atom (and in later stages, an isotope and a molecule), where they insert and remove particles (protons, neutrons and electrons) and they can spin the atoms in 3D to get a visual of how the particles move. In the last stage, molecules, students add atoms to the centre of the screen and then connect them by adding covalent and ionic bonds, which represent the movement of the electrons between the atoms.

Personalisation in this virtual lab is implemented at different levels throughout the entire learning journey. The levels of personalisation include: learning loop-based personalisation, feedback-based personalisation, innovative pedagogies-based personalisation (inquiry-based learning and self-directed learning), gamification-based personalisation, and special education needs-based personalisation. As shown in Figure 2 the SEN-based personalisation enables sign language for hearing impaired students consisting of a translator signing on screen as the audio is being played, to help make the abstract concepts become less vague and more concrete [15].

Figure 2. Educational video in the Atomic Structure virtual lab with a sign language interpreter for hearing impaired students.

3 METHODOLOGY

A small-scale pilot was conducted with twelve SEN students (three boys and nine girls) with hearing impairment from two classes of a secondary level school in Ireland. The assessment methodology was defined by the NEWTON Pedagogical Assessment Committee [16]. The evaluation methodology involved four stages before and four stages after interacting with the Atomic Structure Virtual Lab. The four stages before interaction are: Torrance Tests of Creative Thinking (TTCT) Questionnaire; Demographic Questionnaire; Knowledge Pre-Test; and Affective, Motivation state and attitude regarding STEM. The four stages after interaction are: Affective, motivation state and attitude regarding STEM; Usability Questionnaire; Knowledge Post-Test; and TTCT Questionnaire.

The TTCT Questionnaire is one of the most popular tests measuring creativity. It is addressed to children (over 5 years), adolescents and adults. The figural form of the TTCT was used, which involves students constructing images (i.e., build an image that includes another image already printed on the page and give it a title), completing images (i.e., draw some objects from an image already printed on page), construct images from lines (i.e., build an image that includes lines already printed on the page and give it a title).The Demographic questionnaire is a survey to be completed by all learners, prior to starting the virtual lab collecting information such as age, gender, attitude towards STEM learning, and use of technology. The Knowledge Pre-Test and Knowledge Post-Test are used in order to evaluate learners knowledge of learning concepts regarding Atomic Structure before and after interacting with the Virtual Lab. The Affective, Motivation state and attitude regarding STEM questionnaire captures information regarding student's intrinsic motivation, confidence, emotions (e.g., enjoyment, anxiety, boredom, happiness, sadness). The Usability Questionnaire assesses learners' feeling about the usability related to the learning experience with the Atomic Structure Virtual Lab.

4 RESULTS

4.1 Student Perception

Figure 3 presents distribution of student answers for three questions of the demographic questionnaire, where students were asked to rate their perception about school, STEM subjects and STEM grades. The results show that in general the students had a positive perception of school, with 8% indicating that they love it, 42% like it, and 33% indicating that school is OK. Students also had a positive perception regarding STEM subjects, with 33% of students indicated that they love them. Regarding student's grades for STEM subjects, 50% indicated that they get good grades sometimes and another 25% indicating that they get average grades.

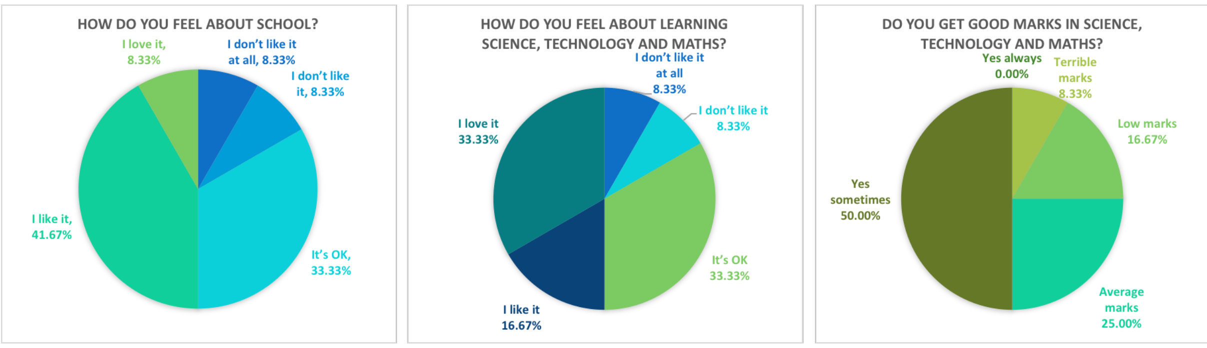

Figure 3. Student's perception of school, STEM subjects and STEM grades.

4.2 TTCT Results

Figure 4 presents the average results for the figural TTCT test administered before and after the students experimented with the Atomic Structure virtual lab. The results show that the students' creative thinking has improved in terms of different mental characteristics such as: fluidity (i.e., rapidity and easiness in association at thinking level measured by the number of images completed with sense), flexibility (i.e., the capacity of restructuring the thinking in comparison with the new situation), and originality (i.e., the independence towards the reason, the capacity to integrate various elements in the perceptive field).

The paired student t-test was used in order to assess if the improvement was statistically significant. The post-test fluidity score (M = 32.83, SD = 7.57) was statistically significant higher than the pre-test fluidity score (M = 25.00, SD = 7.34) at 0.001 significance level ($t(11) = 2.201$, $p = 0.0007$). The post-test flexibility score (M = 22.33, SD = 4.10) was statistically significant higher than the pre-test flexibility score (M = 17.67, SD = 5.52) at 0.01 significance level ($t(11) = 2.201$, $p = 0.0037$). The post-test originality score (M = 31.00, SD = 8.62) was statistically significant higher than the pre-test originality score (M = 26.08, SD = 10.57) but only at 0.1 significance level ($t(11) = 2.201$, $p = 0.0586$).

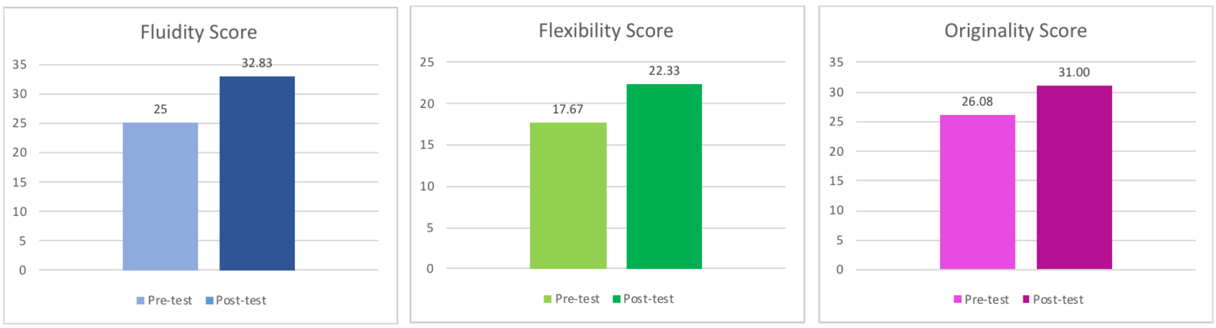

Figure 4. Student's average figural TTCT scores before and after experimenting with the Atomic Structure virtual lab.

5 CONCLUSIONS

Virtual laboratories offer students a safe environment for empirical learning and provide students with the chance to experiment at their own pace and as often as they wish. This paper presented results from a small-scale evaluation pilot of the Atomic Structure virtual lab with secondary school students that have special education needs. Developed as part of the NEWTON H2020 Project, Atomic Structure virtual places the learner in the centre of the learning experience through implementation of personalisation, inquiry-based learning, and self-directed learning. Results analysis of the pictorial Torrance Tests of Creative Thinking (TTCT) showed that the students' creative thinking has improved significantly in terms of various mental characteristics such as fluidity, flexibility and originality.

ACKNOWLEDGEMENTS

This project has received funding from the European Union's Horizon 2020 Research and Innovation programme under Grant Agreement no. 688503.

REFERENCES

[1] T. Lynch and I. Ghergulescu, "Review of Virtual Labs As The Emerging Technologies For Teaching STEM Subjects," *INTED2017 Proceedings, 11th International Technology, Education and Development Conference, 6-8 March, Valencia, Spain*, pp. 6082–6091, 2017.

[2] T. de Jong, S. Sotiriou, and D. Gillet, "Innovations in STEM education: the Go-Lab federation of online labs," *Smart Learning Environments*, vol. 1, no. 1, p. 3, 2014.

[3] "VccSSe - Virtual Community Collaborating Space for Science Education." [Online]. Available: http://www.vccsse.ssai.valahia.ro/.

[4] D. Fernández-Avilés, D. Dotor, D. Contreras, and J. C. Salazar, "Virtual labs: A new tool in the education: Experience of Technical University of Madrid," in *2016 13th International Conference on Remote Engineering and Virtual Instrumentation (REV)*, 2016, pp. 271–272.

[5] "ChemCollective." [Online]. Available: http://chemcollective.org/.

[6] "Open Source Physics." [Online]. Available: https://www.compadre.org/osp/?

[7] T. Wolf, "Assessing Student Learning in a Virtual Laboratory Environment," *IEEE Transactions on Education*, vol. 53, no. 2, pp. 216–222, May 2010.

[8] X. Chen, G. Song, and Y. Zhang, "Virtual and remote laboratory development: A review," in *12th Biennial International Conference on Engineering, Construction, and Operations in Challenging Environments*, Honolulu, Hawaii, United States, 2010, pp. 3843–3852.

[9] L. Shapira, J. Amores, and X. Benavides, "TactileVR: Integrating Physical Toys into Learn and Play Virtual Reality Experiences," in *2016 IEEE International Symposium on Mixed and Augmented Reality (ISMAR)*, 2016, pp. 100–106.

[10] H. Culbertson and K. J. Kuchenbecker, "Importance of Matching Physical Friction, Hardness, and Texture in Creating Realistic Haptic Virtual Surfaces," *IEEE Transactions on Haptics*, vol. 10, no. 1, pp. 63–74, Jan. 2017.

[11] S. M. Baladoh, A. F. Elgamal, and H. A. Abas, "Virtual lab to develop achievement in electronic circuits for hearing-impaired students," *Educ Inf Technol*, pp. 1–15, Sep. 2016.

[12] "NEWTON Horizon 2020 Project." [Online]. Available: http://www.newtonproject.eu/.

[13] T. Lynch and I. Ghergulescu, "NEWTON Virtual Labs: Introduction and Teacher Perspective," in *2017 IEEE 17th International Conference on Advanced Learning Technologies (ICALT)*, 2017, pp. 343–345.

[14] T. Lynch and I. Ghergulescu, "Innovative pedagogies and personalisation in STEM education with NEWTON Atomic Structure Virtual Lab," presented at the World Conference on Educational Media and Technology (EdMedia 2018), Amsterdam, The Netherlands, 2018.

[15] D. Passig and S. Eden, "Enhancing the Induction Skill of Deaf and Hard-of-Hearing Children with Virtual Reality Technology," *J Deaf Stud Deaf Educ*, vol. 5, no. 3, pp. 277–285, 2000.

[16] L. Montandon *et al.*, "Multi-dimensional Approach for the Pedagogical Assessment in STEM Technology Enhanced Learning," presented at the World Conference on Educational Media and Technology (EdMedia 2018), Amsterdam, The Netherlands, 2018.