

A CASE STUDY IN STEM EDUCATION FOR LEARNERS WITH SPECIAL EDUCATION NEEDS

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Abstract

This paper presents the results of a case study that evaluated the Atomic Structure virtual lab application combined with Special Education Needs (SEN) support with secondary level students with special needs from a school located in Ireland. The Atomic Structure is an interactive virtual lab where the entire learning journey is personalised. The application integrates various types of personalisation including learning loop-based, feedback-based, innovative pedagogies-based, gamification-based and special needs-based personalization for hearing impaired students. An analysis of the questionnaires filled by students before and after the Atomic Structure based learning session was conducted to investigate the impact of the Atomic virtual lab technology on students' learning outcomes, motivation and affective states. The results showed that the students had an increase in learning outcomes as well as motivation dimensions such as confidence. The results of the usability questionnaire provided to the students at the end of the learning session showed that most students liked the lab features such as videos, quizzes and the interactive atom builder.

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

1 INTRODUCTION

Educational institutions are facing challenges related to attracting students to STEM (Science, Technology, Engineering and Maths) courses and providing well equipped and up to date laboratories to support the practical learning experiences required for different STEM subjects. Physical laboratories are expensive and resource intensive, and require adherence to strict health and safety regulations. Virtual labs have been proposed as a solution to overcome the limitations of physical labs and can have a reduced cost as compared to physical labs [1]. Virtual labs enable students to acquire inquiry skills which are essential in order to develop scientific literacy and factor into student's decision to pursue STEM further education and careers [2]. Students can define their own experiments and conduct them as many times both in class or outside of it, which makes virtual labs also suitable for providing practical learning experiences in online courses. Other benefits of virtual labs include the ability to share resources between teachers from different institutions or countries [3], as well as the ability to conduct experiments that would be too dangerous or not feasible in a physical lab [4].

A number of virtual labs and platforms were developed for STEM education such as: Go-Lab [5] platform that enables teachers to host labs and share them with other users; GridLabUPM [6] that offers students practical experiences in the fields of electronics, chemistry, physics and topography; Chemistry Lab and Wind Energy Lab [7]; ChemCollective [8]; Open Source Physics [9], and Labster [10]. Limitations of virtual labs include unrealistic experiences if the implementation is not done correctly [11], lack of personalisation and adaptation [12], as well as lack of support for learners with special education needs [13].

This paper presents the results of a case study aimed to evaluate the benefits of the Atomic Structure virtual lab for students with special education needs (SEN). The case study methodology made use of multiple questionnaires and surveys filled in by the students before and after the Atomic Structure learning session that evaluate the benefits of the Atomic Structure virtual lab in terms of learning outcomes, motivation and affective states, and usability. Atomic Structure [14], [15] is an interactive personalised virtual lab for secondary level students, that teaches abstract scientific concepts such as

the structure of atoms, isotopes, 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 lab places the student at the center of the learning experience by implementing multiple types of personalisation during the learning journey, such as: 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. The SEN-based personalisation enables sign language for hearing impaired students to help make the abstract concepts become less vague and more concrete. A detailed description of the Atomic Structure virtual lab is provided in [15].

This research is part of the NEWTON Project (<http://newtonproject.eu>), a large scale EU H2020 innovation action project that focuses on employing novel technologies in STEM education in order to increase learner quality of experience, improve learning process and increase learning outcomes. Innovative technologies include Augmented Reality and Virtual Reality [16], virtual teaching and learning laboratory [17], remote fabrication labs [18], adaptive and personalised multimedia and multiple sensorial media [19], [20], user modelling and personalisation [21] and interactive educational computer-based video games [22]. Different innovative pedagogical approaches are also deployed as part of the STEM teaching and learning process such as flipped classroom, game-based and problem-based learning [23]–[25].

The rest of the paper is structured as follows: section 2 describes the case study methodology, section 3 presents the results analysis, while section 4 concludes the paper.

2 METHODOLOGY

A small-scale case study was conducted with twelve special education needs students (three boys and nine girls) with hearing impairments from a secondary school in Ireland. The case study was performed according to the multi-dimensional methodology for pedagogical assessment in STEM technology enhanced learning defined by the NEWTON Pedagogical Assessment Committee [26]. The activities performed by the students during the case study are presented in Table 1. A demographic questionnaire was used for collecting information such as student age, gender and use of technology. Pre- and post knowledge tests consisting of several multiple choice and short answer questions were used to assess students' learning outcome. A Torrance Tests of Creative Thinking (TTCT) questionnaire was used to assess students' creative thinking before and after the learning session. The other dimensions assessed before and after the learning session include learner affective, motivation state and attitude towards STEM education. The usability questionnaire was used after the learning session to assess the usability of the Atomic Structure virtual lab in terms of different dimensions such as usefulness, ease of use, ease of learning and satisfaction, as well as to assess how much students liked different features of the lab.

Table 1. Methodology - case study activities.

Activity	Type
Torrance Tests of Creative Thinking (TTCT) Questionnaire	Pre-learning
Demographic Questionnaire	Pre-learning
Knowledge Pre-test	Pre-learning
Affective, Motivation state and attitude regarding STEM Questionnaire	Pre-learning
Atomic Structure Virtual Lab Session	Learning
Affective, Motivation state and attitude regarding STEM Questionnaire	Post-learning
Usability Questionnaire	Post-learning
Knowledge Post-Test	Post-learning
TTCT Questionnaire	Post-learning

3 RESULTS

This section presents the results of the case study involving the Atomic Structure virtual lab deployment for SEN students. The results are focused on the following aspects: learning outcome, affective, motivation state and attitude towards STEM, as well as usability. The TTCT results were presented in [14].

3.1 Learning Outcome Results

An analysis of the pre-test and post-test was conducted to investigate the impact of the Atomic Structure virtual lab on the students' learning outcome. One participant was excluded from the analysis as s/he did not answer any question in the pre-test. Therefore, the pre- and post-test scores of 11 participants were considered for the learning outcomes analysis. The results analysis showed a mean correct response rate of 31% for pre-test and 35% for post-test, which results in a 4% increase. The results of a paired t-test for dependant groups showed that there was no statistically significant difference between pre- and post-test results at $\alpha = 0.05$ significance level ($t(10) = 0.454$, $p = 0.66$).

While the results showed a slight improvement of the post-test scores, the small number of participants from this pilot does not allow to draw a clear conclusion regarding the benefits of the NEWTON technology for SEN students in terms of learning outcome.

3.2 Affective, Motivation State and Attitude towards STEM Results

An analysis of the learner affective, motivation state and attitude towards STEM based on questionnaires filled by the students before and after the learning session was also conducted. The results are summarised in Table 2. The positive results are an increase in confidence, a decrease in anxiety and boredom and an increase in enthusiastic affective states, as well as a decrease in students' perception that STEM education is boring and difficult.

Table 2. Affective, motivation state and attitude towards STEM results.

Stage	Dimension	Mean Pre	Mean Post
Motivation	Confidence	2.57	3.14
Motivation	Interest	3.43	2.71
Affective	Anxiety	2.29	2.00
Affective	Engagement	2.86	2.43
Affective	Boredom	2.43	2.00
Affective	Enthusiastic	3.14	3.29
Attitude Regarding STEM	Boring	2.71	2.43
Attitude Regarding STEM	Difficult	3.29	2.86

3.3 Usability Results

An analysis of the learner usability questionnaire completed by the students after interacting with the Atomic Structure virtual lab was conducted. One participant was excluded from this analysis as they did not answer all the questions, thus the data from 11 participants from the experimental group were used. The results analysis showed the following main findings:

- 57.6% of students provided agree or strongly agree ratings and 6.1% of students provided disagree or strongly disagree ratings on usefulness dimension.
- 51.1% of students provided agree or strongly agree ratings and 6.1% of students provided disagree or strongly disagree ratings on ease of use dimension.

- 54.5% of students provided agree or strongly agree ratings and 13.6% of students provided disagree or strongly disagree ratings on ease of learning dimension.
- 51.5% of students provided agree or strongly agree ratings and 15.2% of students provided disagree or strongly disagree ratings on satisfaction dimension.

Fig. 1 presents the percentage of users that provided positive rating for the features / technology of the Atomic Structure virtual lab as follows: 90.9% for videos, 100% for quiz, 81.8% for feedback after the quiz, 90.9% for reminder of correct answer after the quiz, 63.6% for atom builder, 54.5% for isotope builder, 90.9% for receiving badges, and 81.8% for reading facts about atoms and isotopes.

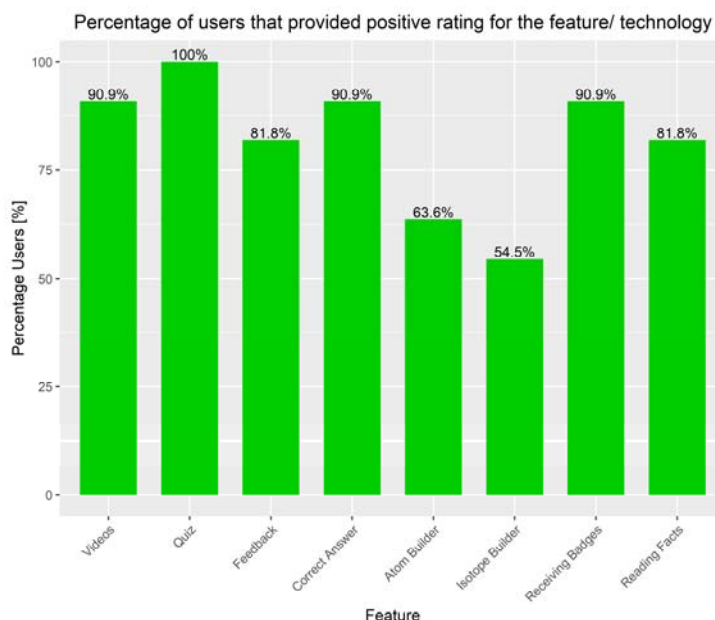


Figure 1. Percentage of users that provided positive rating for the features / technology of the Atomic Structure virtual lab.

4 CONCLUSIONS

This paper presented the results of a case study that evaluated the Atomic Structure virtual lab with special education needs students from a secondary school in Ireland. The results of the pre and post test showed that the students had a small increase in learning outcome. Moreover, the results showed positive changes in learner motivation, affective states and attitude regarding STEM dimensions. The usability questionnaire completed by the experimental group showed that most students found the virtual lab useful, easy to use and liked its features such as videos, quizzes and interactive atom builder. The main limitation of the pilot was the small number of participants that made it difficult to draw strong conclusions.

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