

Mulsemmedia in Education: A Case Study on Learner Experience, Motivation and Knowledge Gain

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Keywords: Technology Enhanced Learning, Mulsemmedia, STEM Education.

Abstract: Science, Technology, Engineering, and Mathematics (STEM) subjects are generally perceived to be quite challenging for students. Hence there are also challenges from the educators' perspective as they need to find a solution to improve the engagement, motivation and the academic performance of their students in these subjects. Technology enhanced learning (TEL) methods could be the answer to these challenges. This paper presents a study on a novel TEL method, mulsemmedia, and its impact on learner experience, motivation and learning outcome. The research study has been conducted in Ireland with postgraduate students from Dublin City University. The results of the study demonstrated that mulsemmedia can be successfully employed as a TEL to improve the academic performance, the learning experience, the engagement and motivation of the students. More than 70% of the participants in the study stated they have enjoyed the mulsemmedia-enhanced learning and agreed with the fact that mulsemmedia is highly motivating for learning. 69.44% of the participants stated they would want to have more mulsemmedia-enhanced learning experiences.

1 INTRODUCTION

The rapid growth and development of information and communication technologies (ICT) have enabled the fast evolution of technology enhanced learning (TEL), which is very likely to continue. An increasing number of individuals, corporations, and institutions are showing interest in TEL, mostly due to its effectiveness and market potential: the worldwide e-learning market is projected to be worth \$325 Billion in 2025¹.

Although many advancements have been noted in the context of TEL, there are many avenues for additional improvement. The research presented in this paper was conducted in the context of NEWTON project², a EU Horizon 2020 project that developed a pan-European learning platform (NEWTELP platform) that facilitates the delivery of STEM subjects to learners from a variety of backgrounds: secondary and vocational schools, third level education, and to people with disabilities. The

platform incorporates some very novel TEL methods such as personalised virtual labs and Fab Labs, novel adaptive and personalisation techniques and mulsemmedia. The latter is quite a novel concept, as mulsemmedia has not really been considered before as a TEL method. The term mulsemmedia – multiple sensorial media – was introduced relatively recently and represents a type of multimedia that involves senses beyond audition and vision (Ghinea, Timmerer, Lin, & Gulliver, 2014). Mulsemmedia content includes in addition to audio-visual components, metadata to trigger stimuli for other senses (e.g. touch, smell, taste).

This paper presents the results of a study aiming to show the impact of this novel TEL method, mulsemmedia, on learning experience and outcome, on learner's motivation and engagement. The results demonstrate that mulsemmedia has potential as a TEL method.

The remainder of this paper is organized as follows. Section 2 presents the related work, Section

¹ Astonishing E-Learning Statistics For 2020, <https://techjury.net/stats-about/elearning/#gref>

² NEWTON project website, <http://www.newtonproject.eu/>

3 provides details about mulsemedia-enhanced teaching, Section 4 outlines the research methodology which involved a case study and its results. Section 5 draws out the conclusions of the paper.

2 RELATED WORK

In the current digital era, TEL is experiencing a fast and complex evolution. Various technologies have been put to use to enhance learning such as Augmented Reality (AR)/ Virtual Reality (VR) (Garzón, Pavón, & Baldiris, 2019; Bogusevschi, Muntean & Muntean, 2019), game-based learning and gamification, virtual labs and fabrication labs (FabLabs), personalisation and adaptation techniques applied to the learning context/content in order to suit learner. Moreover, there are standardization efforts that focus on the measurement of learner's quality of experience (QoE) when subjected to TEL (Tal, Ibarrola, & Muntean, 2016).

Game-based learning defined as an educational approach integrating video games with well specified learning outcomes, has been quite intensively researched. Games have the potential to provide extremely engaging activities, are able to generate strong emotions, can provide challenges, hence they can support learning and make the learning experience more memorable (Boyle, Connolly, & Hailey, 2011).

Various studies have been conducted that show game-based learning can lead to improved learner experience, motivation, but also to an improved academic performance (Ghergulescu & Muntean, 2012; El Mawas et al. 2018). Educational games however need to be designed carefully, as they can easily transform from motivators to distractors in learning and they can lead to the learner disengagement and frustration (Chen et al., 2019).

A very recent study demonstrated the positive impact on students' motivation and academic performance/knowledge gain of a personalised virtual lab in teaching secondary school students chemistry concepts (Ghergulescu, Moldovan, Muntean & Muntean, 2019). Fab Labs potential as a TEL was also investigated and it was found that their employment in teaching K-12 students Science can foster students' interest in science, reduce boredom in the class and result in increased engagement (Togou, Lorenzo, Cornetta, & Muntean, 2020).

While there is quite significant effort and research in this area of TEL, there is always place for improvement and innovation. In the context of the NEWTON project, we have considered mulsemedia

as a potential novel TEL method. Some results on the impact of this novel TEL method were presented in Zou et al. (2018) and Tal et al. (2019). The focus of the aforementioned studies was more on the learning experience and knowledge gain. The study presented in this paper contains new results and a new perspective and analysis of mulsemedia as a TEL, including educators and future educators in the study.

3 MULSEMEDIA-ENHANCED TEACHING

Until the NEWTELP platform came into existence, mulsemedia was not really considered as a possible TEL method as it was used mostly in entertainment (Covaci et al., 2018). The NEWTELP platform which was built in the context of the NEWTON project introduced this novelty, based on past pedagogical experiences and theories that encouraged learning in a multi-sensorial environment (Broadbent et al., 2018).



Figure 1: Students learning in Mulsemedia Lab.

NEWTELP is an enhanced learning management system that connects institutions across Europe (primary, secondary and third level institutions) and brings together several novel TEL methods, mulsemmedia being one of them. NEWTELP platform was presented in more details by Tal et al. (2019). Mulsemmedia teaching content was created and made available through the NEWTELP platform. The mulsemmedia content includes videos and metadata that trigger the stimuli for other senses. The mulsemmedia content is delivered following a client – server model. At client side, relevant software was developed and deployed to control the devices stimulating the other senses. We have created a mulsemmedia lab (see Figure 1) as part of the NEWTON project, composed of several mulsemmedia units. Each mulsemmedia unit (Figure 2) had a laptop (the 5th item in Figure 2) to which were connected 4 devices:

1. a smell dispenser with four different aroma cartridges that released the smell in line with the multimedia content offered to the students,
2. an airflow device (i.e. a computer case fan that allowed for the control of the intensity of the airflow),
3. a haptic device (i.e. a haptic mouse with controllable vibration that was adjusted in line with the content streamed by the aforementioned software deployed at the client-side),
4. headphones (used to deliver noise free high-quality audio to the students).

Each participant in the study was assigned a unique user id (item 6, Figure 2) to allow for the anonymized collection of data.

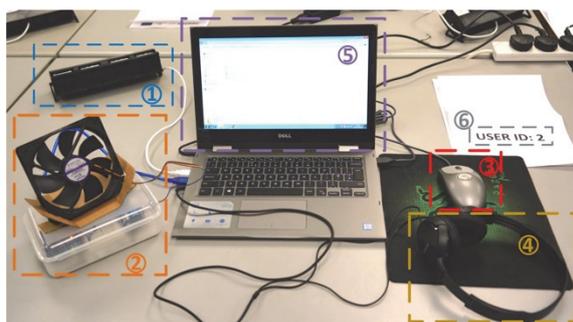


Figure 2: Mulsemmedia Unit.

4 CASE STUDY

The goal of this research study was to investigate the impact of using mulsemmedia in learning on learner’s

experience, knowledge gain, and on learner’s motivation and engagement. The intention was to understand more about the potential of mulsemmedia as a TEL method.

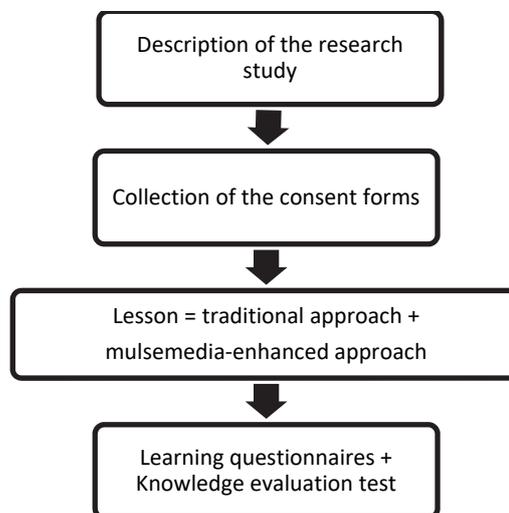


Figure 3: Research methodology – workflow.

4.1 Research Methodology

The study was conducted in Dublin City University (DCU) with 36 postgraduate students from the School of Electronic Engineering (20) and the School of STEM Education, Innovation and Global Studies, DCU Institute of Education (SEIGS) (16), respectively. The latter were educators with particular interest in TEL, hence their interest in participating in the study.

The study meets all Ethics requirements. Prior to carrying out the case study, the Ethics approval was sought and obtained from the DCU Ethics Committee and all required forms were provided to the students (i.e. informed consent form, plain language statement and data management plan). These documents informed the students about the aim of the study, data processing and analysis, data protection, etc. The main steps followed in the methodology are described in Figure 3 and presented in more details in the next sections.

4.1.1 Lesson Design

After the collection of the consent forms students were exposed to a lesson that employed mulsemmedia. The lesson design is presented in the next paragraphs. For the engineering students that participated in the study, the lesson was part of their normal teaching hours, while for the education students, the lesson was outside of their timetabled classes.

The learning outcomes proposed for the lesson included the following: 1) Describe the concept of Quality of Experience (QoE) and its influencing factors as defined by International Telecommunication Union – Telecommunication Standardization Sector (ITU-T) 2) Critically analyze different QoE measurement techniques such as objective quality assessment, physiological/cognitive-based techniques, subjective quality assessment. The students had no prior knowledge of the content taught in the lesson. No other pre-requisite knowledge was required, hence the postgraduate students from SEIGS, DCU Institute of Education were suitable participants for the study.

The teaching material was split into two parts. A part of the lesson was delivered using a traditional audio-visual approach based on a Microsoft PowerPoint presentation. The other part was delivered in an experimental setup where mulsemmedia was employed. During the mulsemmedia-enhanced part of the lesson, students were exposed to a QoE evaluation: they watched a series of videos enhanced with various combinations of sensory effects (from no effects to all effects - haptic, airflow, olfaction - in one video). At the end of each video, they were asked to assess the perceived quality.

The topic for the lesson was chosen by the lecturer in charge with *Performance of Data Networks* module that is delivered at master level in DCU. The reason for selecting this topic is that it is usually regarded by the students as quite a theoretical and boring topic that it is hard to engage with. Moreover, the lecturer felt that mulsemmedia could really help the students to better understand the QoE concept, defined as "the degree of delight or annoyance of the user of an application or service", and how it is influenced by user expectations and context as stated by ITU-T (e.g. will a bad smell negatively influence the degree of delight or annoyance; how about a pleasant one? Does a combination of haptic, airflow, smell provide a better experience than smell alone?).

4.1.2 Learning Questionnaires

The students were presented with two questionnaires at the end of the lesson that required them to reflect on their learning experience with mulsemmedia, but also on the learning process in general. The first questionnaire was built in collaboration with Psychopedagogy Department, University of Bucharest, Romania. In the design of this questionnaire, as its main focus was on the learner QoE, we have followed the research that measured mulsemmedia QoE presented in Yuan, Ghinea, &

Muntean (2014). Their QoE measurement questionnaire and methodology is based on ITU-T standardization guidelines. However, the context for the QoE measurement was not a learning context, hence, we slightly adapted the questions. The aforementioned standardization guidelines were followed in validating that the number of participants was sufficient for our study.

Table 1: Learning questionnaires.

Questionnaire 1 (a 5-point Likert scale was used for the answers to all questions <i>Strongly Disagree, Disagree, Neutral, Agree and Strongly Agree</i>)	
Q11. The multisensory experience helped me to better understand the concepts.	
Q12. The multisensory experience helped me to better assimilate the concepts.	
Q13. The multi-sensorial experience did not improve my learning experience.	
Q14. The multi-sensorial experience helped me to be more practically engaged in the learning process.	
Q15. I enjoyed the multi-sensorial experience during the class.	
Q16. The multi-sensorial effects were disturbing for me during the class.	
Q17. I would like to have more classes/labs/courses that include multi-sensorial experience.	
Questionnaire 2	
Question	Answer/Scale
Q21. How would you define learning?	Open question
Q22. What benefits do technology-enhanced systems offer the learner?	Open question
Q23. What benefits do technology-enhanced systems offer the teacher?	Open question
Q24. Which is your preferred learning style?	<ul style="list-style-type: none"> - visual – pictures, images, spatial - aural – sound and music - verbal – words, speech and writing - physical – body, hands and touch - social – learning in groups or other people - solitary – working alone and using self-study
Q25. The use of multisensorial media is highly motivating for learning	<ul style="list-style-type: none"> - Strongly Disagree - Disagree - Neutral - Agree - Strongly Agree

The second questionnaire was built specifically for this case study that included current/future educators interested in TEL. It aimed to measure the impact on students' motivation of the mulsemmedia as a TEL method, but also to get the participants in the study to think about the advantages of TEL in general for both parties involved in the learning process: educators and students, respectively.

The questions in these two questionnaires that relate to the learning process, experience, motivation and engagement are listed in Table 1.

4.1.3 Knowledge Evaluation Test

This test was conceived by the lecturer of the *Performance of Data Networks* module and its purpose was to evaluate students' knowledge gain at the end of the lesson. The test comprised 8 questions that carried equal marks (10 marks). The questions were divided into 2 types/classes: 4 questions assessing the students' knowledge in material that was taught using the traditional approach (i.e. PowerPoint-assisted approach) and 4 questions assessing students' knowledge in material covered using the mulsemmedia-enhanced approach.

These questions were designed to have the same level of difficulty and were paired per topics, measuring the same learning outcomes. This allowed for a fair comparison between the performance of the students in the questions covering material taught using the traditional PowerPoint-assisted approach vs the students' performance in the questions covering material taught using mulsemmedia-enhanced approach. All tests were marked by the same lecturer.

4.2 Results Analysis

4.2.1 Learner Experience, Engagement and Motivation

The impact of mulsemmedia on learner experience, engagement and motivation was investigated and evaluated using the two questionnaires where the students were asked to reflect on their learning experience with mulsemmedia, but also on the learning process in general. The answers collected from the students are summarised in Table 2, where, *SD* = *Strongly Disagree*, *D* = *Disagree*, *N* = *Neutral*, *A* = *Agree*, *SA* = *Strongly Agree*. It is important to note that the answers to question Q25 are based on 35 filled-in questionnaires, as one of the participants in the study did not fill in the second learning questionnaire.

Table 2: Answers on the learner satisfaction questionnaire.

	SD	D	N	A	SA
Q11	2.78%	13.89%	16.67%	58.33%	8.33%
Q12	5.56%	8.33%	22.22%	58.33%	5.56%
Q13	0	36.11%	25%	27.78%	11.11%
Q14	5.56%	11.11%	11.11%	58.33%	8.33%
Q15	5.56%	0	13.89%	61.11%	19.44%
Q16	19.44%	38.89%	22.22%	16.67%	2.78%
Q17	2.78%	11.11%	16.67%	44.44%	25%
Q25	2.86%	8.57%	17.14%	48.57%	22.85%

The overall learning experience of students was good with 70.55% of students clearly expressing the fact that they enjoyed the multi-sensorial experience during the class. More than 60% of the participants in the study stated that the mulsemmedia experience helped them to better understand and assimilate the concepts delivered. The results presented in section 4.2.2. demonstrate that this was not only subjective feedback from the students, but mulsemmedia actually led to an improvement in the knowledge gain – the vast majority of the students scored better in the questions related to the learning content taught using mulsemmedia. Moreover, 58.33% disagreed with the fact that multi-sensorial effects were disturbing, while 22.22% were neutral to this statement.

The results also demonstrated that mulsemmedia can lead to an increased engagement of the students with the learning content as noted by 66.66% of the students that participated in the study. Furthermore, the vast majority of the students (more than 70%) agreed with the fact that mulsemmedia is highly motivating for learning.

69.44% of the students stated they would like to have more teaching content delivered using mulsemmedia.

It is important to mention the fact that there was no particular correlation observed between the learning styles and the impact that mulsemmedia had on the student learning experience, engagement or motivation.

4.2.2 Knowledge Gain

An analysis of the impact of mulsemmedia on students' knowledge gain was carried out using the knowledge evaluation test previously described in section 4.1.3. The test evaluated the knowledge that the students acquired during the lesson. A comparison-based

evaluation was employed, namely comparing the students' performance in the questions covering material taught using the traditional PowerPoint-assisted approach vs the students' performance in the questions covering material taught using mulsemmedia-enhanced approach. For this purpose, for each student two average marks were calculated for the two types of questions.

The results shown that the vast majority of the students, namely 75% scored better in the questions covering material taught using the mulsemmedia-enhanced approach. 16.67% of the students scored less in these questions, while the remaining 8.33% had the same average for both types of questions. The overall average (for all students) of the students marks in questions covering material taught using mulsemmedia-enhanced approach was 6.42 (out of 10), while the overall average of the students marks in questions covering material taught using the traditional approach was 4.71 (out of 10).

The statistical significance of the results obtained for the two types of questions was demonstrated through a t-test. At $\alpha = 0.05$, $t(5.2628)$, $p < 0.0001$, the t-test demonstrated that the average score obtained in questions covering material taught with the mulsemmedia-enhanced approach is statistically significantly higher than the average score obtained in questions covering material taught using the traditional approach. This demonstrated that mulsemmedia had a positive contribution on the learning outcome, leading to a significant improvement in the students' knowledge gain.

4.2.3 TEL & Mulsemmedia as a TEL Method – Students & Educators Perspective

The second learning questionnaire comprised two questions in particular that asked students to reflect on the benefits of TEL from the student perspective, but also from the perspective of an educator (see Q22 and Q23 in Table 2). The latter question was quite valid considering that almost half of the participants in the study were educators or educators in training (16 postgraduate students from SEIGS, DCU Institute of Education) and some of the engineering students were also involved in teaching activities (teaching assistants in the university). Hence, while they participated in the study as students, they were well able to express opinions about the benefits offered by TEL in general (and mulsemmedia in particular) to the educators.

The answers to these two questions were in general very positive, the majority of the participants listing significant benefits brought by TEL to both

students and educators. Noteworthy is the fact that out of 35 participants in the study that answered these questions, only 2 were sceptical about TEL. One engineering student stated that: "I don't think they [TEL systems] benefit a lot the learner, except perhaps to help him get more focused in a course". However, the same participant noted in the answer referring to the benefits brought by TEL to the teachers that: "he [the educator] can associate stimuli with some part of the course to make them more enjoyable for the students". This answer seems to be quite clearly linked to the participant mulsemmedia-enhanced learning experience. The other participant that was not that positive about TEL was a postgraduate from DCU Institute of Education that noted that TEL can be a burden (the exact word used by the participant was "torture") for an educator most probably due to the extra time involved in the setup, preparation, etc. However, the same participant saw value in TEL from the student perspective, noting that it could be beneficial especially for the students with special needs.

All the other 33 participants in the students were extremely positive in relation to TEL's benefits from an educator, and especially from a student perspective. A considerable number of participants clearly related TEL to mulsemmedia noting that TEL would "allow the teacher reinforce the learning experience by stimulating more of the learner's senses" and TEL systems could bring the following benefits to the students: "can enhance the memory by olfaction/haptic information", "provide the possibility of a more realistic experience", "a fuller experience/more memorable experience", "tech-enhanced systems offer learners a hands-on, multi-sensory learning experience".

There were few patterns that arose from the participants answers in relation to the benefits that TEL provided to the learner, namely: **increased engagement** ("engagement increased", "improved engagement"), **improved learning experience** ("improve the experience and reinforce learning", "they [TEL systems] enable them to get more involved in what they are doing, and consequently enjoy more and retrieve better experience and knowledge", "funny and interactive", "easier to learn/easier to remember") and **personalization** ("more personalised", "can be used over distance/at learner's own pace"). The engagement theme was also present in the benefits that TEL provides the educators as noted by the participants in the study: "technology systems keep engagement high and increases teacher moral and satisfaction", TEL systems are seen as "another way in which to engage

students”, “new actively engaging techniques to motivate all learners in the classroom”. In general, participants in the study see TEL systems as allowing educators to “make the teaching more realistic” and giving them more teaching possibilities.

Mulsemmedia as a TEL method, through a multi-sensorial setting, allows the educator to create a more realistic teaching experience that is enjoyed by the students and leads to an increase in their engagement and motivation resulting in an improvement in their academic performance, as indicated by the results of our study. Moreover, 69.44% of the participants in the study stated they would like to have more teaching content delivered using mulsemmedia, a fact that demonstrates the students are quite ready to embrace mulsemmedia as a TEL method.

5 CONCLUSIONS

This paper presents the results of a case study carried out with 36 postgraduate students from DCU that were exposed to a mulsemmedia-enhanced lesson. The purpose of the study was to gain a better understanding of the potential of mulsemmedia as a TEL method and the impact of mulsemmedia on learner’s experience, motivation and on learning outcomes. The results of the study were very positive, with more than 70% of the participants in the study stating that they enjoyed the multi-sensorial experience during the class, while 69.44% of them expressed an eagerness to have more teaching content delivered using mulsemmedia. More than 60% of the participants in the study stated that the mulsemmedia experience helped them to better understand and assimilate the concepts, while the results of the knowledge evaluation test demonstrated that mulsemmedia actually helped more than 75% of the participants to better assimilate the taught concepts.

ACKNOWLEDGEMENTS

This research was supported by the NEWTON project (<http://www.newtonproject.eu/>) funded under the European Union’s Horizon 2020 Research and Innovation programme, Grant Agreement no. 688503. We would like to thank Dr. Marilena Bratu, Department of Psychopedagogy, University of Bucharest for her help in developing one of the learning questionnaires used in the study.

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