Improving Learner Experience, Motivation and Knowledge Gain When Using Mulsemedia-Based Technology Enhanced Learning

Irina Tal[1(✉)], Longhao Zou[2], Margaret Farren[3], and Gabriel-Miro Muntean[1]

[1] Faculty of Engineering and Computing, LERO, Dublin City University, Dublin, Ireland
irina.tal@dcu.ie
[2] Southern University of Science and Technology, Shenzen, China
[3] Institute of Education, Dublin City University, Dublin, Ireland

Abstract. Lately there is an increasing interest from educators to find solutions to improve student engagement, motivation and academic performance of their students, especially in Science, Technology, Engineering, and Mathematics (STEM) subjects. This is as most students believe that STEM subjects are either too challenging or require disproportionate effort for the returned benefit. Diverse technology-enhanced learning (TEL) methods are employed in order to reverse this student perception and attract them to STEM education. This paper studies the impact of multiple sensorial media (mulsemedia)-based learning on postgraduate students from Dublin City University Ireland. The study analyses the impact of this novel TEL method on learner experience, motivation and learning outcome. The results of the study show that academic performance, learning experience, engagement and motivation of the student improve when employing mulsemedia-enhanced learning. More than 80% of the participants in the study stated they have enjoyed the use of mulsemedia during learning and agreed with the fact that mulsemedia is highly motivating for learning. Additionally, about 70% of the participants indicated that they would want to continue to be exposed to mulsemedia-enhanced learning.

Keywords: Multiple sensorial media (Mulsemedia) · Technology Enhanced Learning (TEL) · STEM education

1 Introduction

There is a fast evolution of technology-enhanced learning (TEL), fueled by the latest rapid growth and development of information and communication technologies (ICT) and recent societal progress. 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 2025. However, these statistics figures may look different after the disruption in education that

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COVID-19 caused worldwide. The interest in e-learning, remote learning and TEL has grown much more and it is expected to have an even steeper growth in the next years.

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 the NEWTON project, a large-scale EU Horizon 2020 project that has designed and developed solutions for innovative TEL for the benefit of diverse learners from primary and secondary schools to vocational schools and third level education institutions, including people with special learning needs. The NEWTON project has also developed NEWTELP, a pan-European learning platform that facilitates remote delivery of STEM subjects using some of the latest TEL methods and tools, including virtual and fabrication labs, novel adaptive and personalisation techniques, gamification and mulsemedia-based learning. The latter is relative novel as a TEL method and the impact of its use in education has not been extensively studied. The term mulsemedia – multiple sensorial media – refers to multimedia content enhanced with components targeting human senses beyond vision and hearing [13]. Mulsemedia content includes in addition to audio-visual components, metadata to trigger stimuli for other senses such as touch, smell or even taste.

This paper extends one of our previous papers [15] by adding a more detailed analysis of the results of a study with the goal to show the real impact mulsemedia-enhanced TEL has on learning experience and outcome, as well as on learner motivation and engagement. The results clearly demonstrate that by employing mulsemedia in STEM education, highly positive results are obtained.

This paper is organized as follows. Section 2 discusses related works and Sect. 3 provides details about mulsemedia-enhanced teaching and learning. Section 4 outlines the research methodology employed in the study described in this paper and analyses its results. Finally, Sect. 6 concludes the paper, highlighting the major results of the study. Subsequent paragraphs, however, are indented.

2 Related Work

Technology-enhanced Learning (TEL) is experiencing a fast and complex evolution fueled by the advances in the technologies, and lately by the changes introduced by the current pandemic situation. These changes are envisaged to have a serious impact on the pedagogies and learning in general with a shift towards online learning in general and TEL in particular.

Various technologies have been put to use to enhance learning such as Augmented Reality (AR)/Virtual Reality (VR) [2, 9], 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 [17].

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 [3].

Various studies have been conducted that show game-based learning can lead to improved learner experience, motivation, but also to an improved academic performance [7, 8, 10]. Game-based learning has proven to be efficient in the primary and secondary level education, as the latter references are demonstrating, but also in the third-level education. For instance, Zhao et al. [20, 21] have developed a serious gaming to support undergraduate students in learning programming concepts. The results demonstrated a very positive impact of the game on the learning process, especially in terms of knowledge gain.

However, educational games 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 [5].

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 [12].

Fab Labs are small workshops equipped with a set of computer-controlled tools such as 3D printers providing personalized digital fabrication. In general, Fab Labs were proven to have a positive impact on learners' academic and personal growth, however, they were mostly used in the extracurricular activities. NEWTON connected FabLabs solution was analysed as a TEL method in the context of in-class (curricular) activities and it was found that its employment in teaching K-12 students Science can foster students' interest in science, reduce boredom in the class and result in increased engagement [18].

Artificial Intelligence in Education (AIEd) is one of the currently emerging research field for the TEL. Google Vision API provides some ways to enhance the education experience in a classroom by using its the face recognition and labelling tools for teachers. The Google Colaboratory (Colab) platform allows students quickly create the GPU-driven deep machine learning and data training environment in free. Three different categories of AIEd are proposed in [1]: a) learner-facing, b) teacher-facing, and c) system-facing AIEd. Learner-facing AI tools adapted learning management systems or ITS to support student learning. Teacher-facing systems reduce teachers' workload by automatic assessment, management, feedback, student learning inspection and guideline, and plagiarism detection intelligently. System-facing systems provide the institutional-level information administration and management.

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 [16] and [22]. 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 Learning Environment

Until the NEWTELP platform came into existence, mulsemedia was not really considered as a possible TEL method as it was used mostly in entertainment [6]. The NEWTELP

Fig. 1. Students learning in Mulsemedia Lab [15].

platform which was built in the context of the NEWTON project introduced this novel approach, based on past pedagogical experiences and theories that encouraged learning in a multi-sensorial environment [4].

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. There is also a particular focus on supporting students with special needs. In this sense, NEWTELP demonstrated very good results in the learning process for the students with special needs [11]. NEWTELP platform was presented in more details in [16].

Mulsemedia teaching content was created and made available through the NEWTELP platform. The mulsemedia content includes videos and metadata that trigger the stimuli for other senses (e.g. the stimuli for smell). The mulsemedia 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 mulsemedia lab (see Fig. 1) as part of the NEWTON project, composed of several

mulsemedia units. Each mulsemedia unit (Fig. 2) had a laptop (the 5th item in Fig. 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, hence allowing for synchronization between this effect and the audio-visual content delivered),
3. a haptic device (i.e. a haptic mouse with controllable vibration, programmed to be 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, Fig. 2) to allow for the anonymized collection of data.

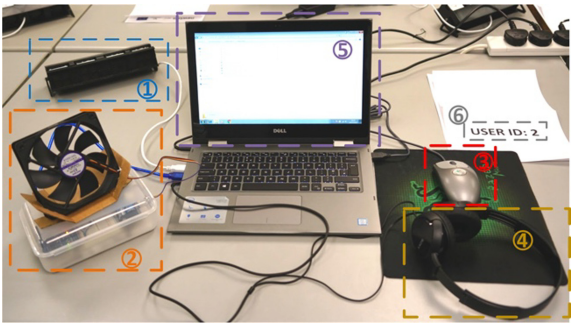

Fig. 2. Mulsemedia unit [15].

4 Research Study

This research study aimed to investigate the impact of using mulsemedia in learning. In particular, we looked at the impact on learner's experience, knowledge gain, and on learner's motivation and engagement. The ultimate goal was to answer this research questions: Has mulsemedia the potential to be employed as a TEL method and how is mulsemedia benefiting the learning process? The next sections present the methodology followed in the study, followed by a detailed analysis of the results obtained.

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

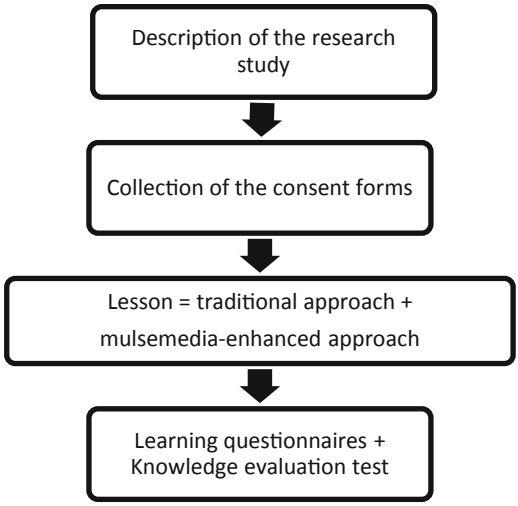

Fig. 3. Research methodology – workflow [15].

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 Fig. 3 and presented in more details in the next sections.

Lesson Design. After the collection of the consent forms students experienced a lesson that employed mulsemedia. 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 students from Institute of Education, the lesson was outside of their timetabled classes.

The learning outcomes of the lesson designed were the followings: 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 mulsemedia was employed. During the mulsemedia-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 is hard to engage with. Moreover, the lecturer felt that mulsemedia could really help the students to better understand the QoE concept, defined as "the degree of delight or annoyance from 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?).

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 mulsemedia, but also on the learning process in general. The first questionnaire was built in collaboration with Psycho-Pedagogy 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 mulsemedia QoE presented in [19]. 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.

The second questionnaire was built specifically for this case study that included educators interested in TEL. It aimed to measure the impact on students' motivation of the mulsemedia as a TEL method, but also to gather the views of the participants in the study on the advantages of TEL in general for both parties involved in the learning process: educators and students. While they participated in the study from the study perspective, the participants were also requested to project their experience as educators and comment on mulsemedia as a TEL in particular and TEL in the learning process in general.

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

Knowledge Evaluation Test. This test was developed by the lecturer of the *Performance of Data Networks* module. The aim of the test 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 mulsemedia-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

Table 1. Learning questionnaires [15].

Questionnaire 1 (a 5-point Likert scale was used for the answers to all questions *Strongly Disagree, Disagree, Neutral, Agree and Strongly Agree)*	
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?	- **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	- Strongly Disagree - Disagree - Neutral - Agree - Strongly Agree

questions covering material taught using mulsemedia-enhanced approach. All tests were marked by the same lecturer.

4.2 Analysis of the Impact on Learner Experience, Engagement and Motivation

The impact of mulsemedia 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 mulsemedia, but also on the learning process in general. We first analysed the overall results and then we performed a separate analysis for the Engineering students and for the participants in the study attending the Institute of Education.

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 (all the participants in the study) [15].

	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 80.55% 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 mulsemedia experience helped them to better understand and assimilate the concepts delivered. The results demonstrate that this was not only subjective feedback from the students, but mulsemedia 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 mulsemedia. 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 mulsemedia 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 mulsemedia is highly motivating for learning.

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

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

Table 3. Answers on the learner satisfaction questionnaire (Institute of Education students).

	SD	D	N	A	SA
Q11	6.25%	12.5%	25%	50%	6.25%
Q12	12.5%	6.25%	31.25%	43.75%	6.25%
Q13	0	31.25%	25%	31.25%	12.5%
Q14	6.25%	6.25%	12.5%	62.5%	12.5%
Q15	12.5%	0	12.5%	56.25%	18.75%
Q16	12.5%	56.25%	18.75%	6.25%	6.25%
Q17	6.25%	0	31.25%	43.75%	18.75%
Q25	0%	6.25%	25%	50%	18.75%

In the next section we divided the results and looked at a comparison between the Engineering students and Institute of Education students. The results for Institute of Education students are summarized in Table 3, while the results for Engineering students are summarized in Table 4. There are some differences between the 2 classes of participants, however not very significant. Some of the most important ones are discussed next.

Table 4. Answers on the learner satisfaction questionnaire (Engineering students).

	SD	D	N	A	SA
Q11	0%	15%	10%	65%	10%
Q12	0%	10%	15%	70%	5%
Q13	0	40%	25%	25%	10%
Q14	5%	15%	10%	55%	15%
Q15	0%	0	15%	65%	20%
Q16	25%	25%	25%	25%	0%
Q17	0%	20%	5%	45%	30%
Q25	5.26%	10.53%	10.53%	47.37%	26.31%

In terms of their self-evaluation on how much multisensorial learning experience help them to better understand the concepts (Q11), more engineering students stated that the experience was helpful in this regard. 75% Engineering students stated that multisensorial experience helped them better understand the concepts. By comparison, only 56.25% Institute of Education students stated the same thing. 25% Institute of Education students were neutral, as compared to 10% Engineering students. The disagreement with the statement was quite similar, 15% Engineering students, 18.75% Institute of Education students. Figure 4 presents an overview of these responses.

In terms of learning experience, 85% of the Engineering students enjoyed the mulsemedia lesson, the rest (15%) were neutral. None of these participants expressed disagreement. Among the Institute of Education students, 80% agreed and strongly agreed that they enjoyed the mulsemedia experience in the class, but there were also a few of them that strongly disagreed (12.5%). The overview of these results is presented in Fig. 5.

In terms of mulsemedia impact on motivation (Q25), the results are pretty similar, approximately 73% of Engineering students stated that mulsemedia is highly motivating for learning as compared to 69% Institute of Education students that stated the same things. There was a slightly bigger difference in the neutral opinion (10.5% Engineering students vs. 25%) and disagreement (15.7% Engineering students vs 6.25%). An overview of these results can be seen in Fig. 6.

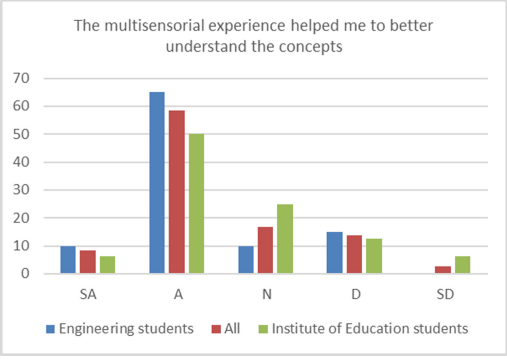

Fig. 4. Q11 – overview.

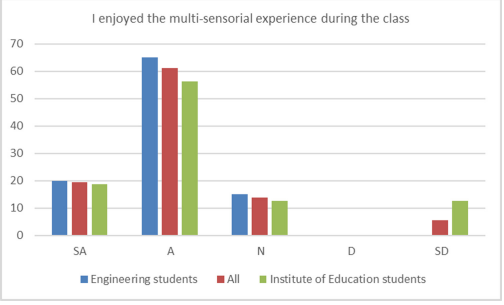

Fig. 5. Q15 – overview.

4.3 Analysis of the Impact Knowledge Gain

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

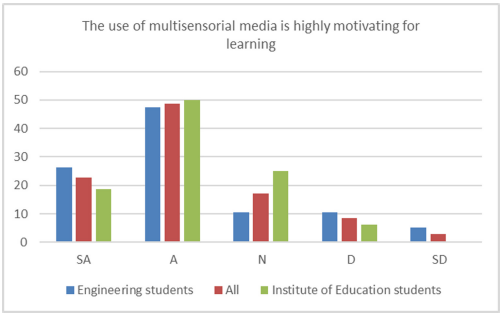

Fig. 6. Q25 – overview.

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 mulsemedia-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 mulsemedia-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 mulsemedia-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).

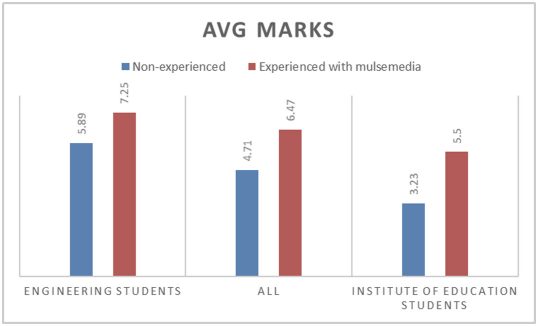

Fig. 7. Average marks – overview.

There are some differences in the results obtained by the Engineering students and Institute of Education students in terms of the average marks obtained in the sense that Engineering students scored better. This is however expected, considering the nature of the content that relates to technical concepts. However, the Engineering students did not have prior knowledge on the concepts taught in the lesson either. The important

aspect from the perspective of this research study is that for both groups/classes of students the scores in average are higher for the questions from the content taught with the mulsemedia-enhanced approach. An overview of the average marks obtained by Engineering students vs Institute of Education students in both types of questions (questions that cover content experienced with mulsemedia and questions covering content delivered using the traditional approach) can be seen in Fig. 7. The difference between the average scores obtained in the questions covering material taught with the mulsemedia-enhanced approach and the average scores obtained in the questions covered with the traditional approach is more significant in the case of Institute of Education students. The statistical significance was proven through a t-test at $\alpha = 0.05$, $t(4.4244)$, $p = 0.0005$. Similar for the Engineering students, the difference in average scores between the 2 types of questions it is clear, and statistically proven to be significant ($\alpha = 0.05$, $t(3.1443)$, $p = 0.0053$. The statistical significance of the overall results, for all participants, is also demonstrated, 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 mulsemedia-enhanced approach is statistically significantly higher than the average score obtained in questions covering material taught using the traditional approach. This demonstrated that mulsemedia had a positive contribution on the learning outcome, leading to a significant improvement in the students' knowledge gain.

5 TEL and Mulsemedia as a TEL Method: Students and Educators Perspective

This section analyses some of the results of the research study performed from the 2 important perspectives in the learning process: from the student's perspective and from the educator's perspective. The second learning questionnaire that was used in the study 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 (the 16 postgraduate students from the Institute of Education). Moreover, some of the Engineering students were also involved in teaching activities, as they were teaching assistants in DCU. Hence, while the students participated in the study in their quality of students, they were well able to express their views about the benefits offered by TEL in general (and mulsemedia in particular) to educators.

The answers to these two questions were in general very positive, the majority of the participants detailing significant benefits of 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: "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 mulsemedia-enhanced learning experience. The other participant who was not that positive about TEL was a postgraduate from DCU

Institute of Education who 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 the benefits of TEL from an educator's perspective, and especially from a student's perspective. A considerable number of participants clearly related TEL to mulsemedia 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 a few patterns that emerged 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 observed 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 view TEL systems as allowing educators to "make the teaching more realistic" and giving them more teaching possibilities.

The results of this study indicates that mulsemedia as a TEL method, through a multisensorial 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, culminating in an improvement in their academic performance. Moreover, 69.44% of the participants in the study stated that they would like to have more teaching content delivered using mulsemedia, thus demonstrating that students are quite ready to embrace mulsemedia as a TEL method.

6 Conclusion

In the context of an increasing number of individuals, corporations, and institutions adopting TEL, there is a significant interest to assess the effectiveness of some innovative technologies in education. The NEWTON project has designed and deployed several such technologies in real life pilots hosted by several educational institutions across Europe. This paper presents the results of a NEWTON project pilot which involved Irish postgraduate students from Dublin City University with a background in Engineering and Education. The participants were exposed to a mulsemedia-enhanced lesson

and the impact of mulsemedia on learner's experience, motivation and on learning outcomes was measured in the quest to understanding better the potential of mulsemedia as a TEL method. As more than 80% of the participants stated that they enjoyed the multi-sensorial experience, the overall results of the study were highly positive. Some differences were noted between the Engineering and Education students were noted. 85% of the Engineering students enjoyed the mulsemedia lesson, whereas the rest were neutral. 80% of the Education background participants also agreed and strongly agreed that they have enjoyed the mulsemedia experience in the class, but there were also some of them that strongly disagreed (12.5%). Very important to note is that about 70% of the participants expressed an eagerness to have more teaching content delivered using mulsemedia-enhanced TEL, which is an excellent result. However, of most important to education is that more than 60% of the participants in the study stated that the mulsemedia experience helped them to better understand and assimilate the concepts, while the results of the knowledge evaluation test demonstrated that mulsemedia actually helped more than 75% of them to better acquire the taught concepts. This result, along with others obtained in the NEWTON project [14], demonstrates that TEL in general and mulsemedia-enhanced learning in particular are highly beneficial and should be used more in education as important tools to increase learner quality of experience and improve their learning outcome, especially in the context of STEM education, helping to reverse the current perception as a difficult and boring education avenue.

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