# QUALITY AND STANDARDIZATION IN TECHNOLOGY-ENHANCED LEARNING

Irina Tal<sup>1</sup>, Eva Ibarrola<sup>2</sup>, Gabriel-Miro Muntean<sup>3</sup>

<sup>1</sup>Dublin City University, irina.tal2@mail.dcu.ie <sup>2</sup>University of the Basque Country-UPV/EHU, eva.ibarrola@ehu.eus <sup>3</sup>Dublin City University, gabriel.muntean@dcu.ie

# ABSTRACT

Education and technological advances have enabled digital learning technologies to become a key pillar holding up one of the main United Nations Sustainable Development Goals (SDGs): Quality Education. Technology-enhanced learning strategies have led to innovative ICT applications for the development of new improved learning and teaching practices aiding to guarantee inclusive and equitable quality education and promote opportunities for all. Nonetheless, there is still a big challenge to get hold of all the capabilities of these technology-enhanced learning strategies: improving the learner quality of experience (QoE). This paper presents an innovative technologyenhanced learning initiative that aims to attract students to STEM education and improve access for students with disabilities through the analysis of the learner QoE. Moreover, in this paper some of the required standards and specifications to be used for developing this initiative are identified. Another key contribution of the paper is that it explores the necessity of new related standards and introduces some novel proposals for standardization in this area.

*Keywords*— Technology-enhanced learning, QoE, mulsemedia, standardization.

### **1. INTRODUCTION**

The convergence of education and technological innovations are motivating digital learning to become one of the most significant models in all the teaching and learning environments. In addition, the rapid advance of new multidimensional applications and services, with new and modern functional facilities, like multisensory dimensions or augmented reality, drive growth in new technology-enhanced learning (TEL) strategies with significant capabilities to improve the quality and outcomes of teaching and learning. However, in order to make a whole of all the features and capabilities of these novel digital learning systems, it is crucial to analyze and enhance the learner QoE/.

A lot of studies and research have been carried out during the past years to define QoE evaluation methods [1, 2] and also to define and validate related standards [3, 4]. Nevertheless, as stated in [5]: "With the growing level of functional sophistication of services and systems, quality evaluation has become progressively more complex, notably due to the exponentially mounting number of dimensions involved. While some services and systems involve a small number of technologies, functional capabilities, sensory dimensions and consuming paths, other applications are an explosive cocktail of technologies, capabilities, navigation courses and sensations. These growing application scenarios involve larger user susceptibility, not only to the degree of usability of the overall system but also to the content itself". Therefore, the target of evaluating QoE to enhance the learner experience when using, for example, new mulsemedia (Multiple Sensorial Media Advances and Applications) technology-enhance learning applications [6, 7] may become a really hard task.

Even though some standardization activities related to general technology-enhanced learning have been defined [4] (in particular for mobile technologies and video), there is still a need to fulfill the gap of novel standards to define frameworks and procedures for the QoE evaluation of these new multimedia and mulsemedia TEL applications and systems.

In this paper, it is presented an initiative, NEWTON project [8], that aims to develop, integrate and disseminate innovative TEL methods and tools. The main goal of this project is to create new or inter-connect existing state-ofthe art teaching labs and to build a pan-European learning network platform. Next generation TEL methods are aimed to be integrated in the NEWTON platform that relate to gamification, augmented reality, mulsemedia, and adaptive multimedia. The project will be tested and validated in real life pilots across Europe, using a network of secondary schools, vocational establishments and third level institutes. One of the initial pilots that will be carried out in the context of this project is presented in more details in this paper. This pilot study will be carried out in November 2016, in the University of the Basque Country (UPV/EHU). Since the platform aims to integrate also others already existing teaching labs, it is a key target of the project to develop the system complying with the existing standards in this area. For that reason, a revision of the most important related standards that should be taken into account when designing, testing and deploying the platform is also included in the paper. Moreover, some novel proposals to fill the gap of standardization related to the analysis and evaluation of the learner QoE in these TEL systems and scenarios are presented.

The structure of the paper is as follows. In section 2 a review of recent literature on TEL strategies and related standardization activities is included. Section 3 presents a general description of NEWTON, the project that aims to build a novel TEL-based learning platform. Novel related standardization proposals for the enhancement of the QoE evaluation in this kind of platforms will be described in section 4. In section 5, the proposed pilot test bed to be deployed at the University of the Basque Country (UPV/EHU) and the expected results will be detailed. In the last section, main conclusions and contributions of this work are summarized.

# 2. BACKGROUND

One of the goals of the pan-European learning network platform proposed in NEWTON project is to be developed in a way that makes it possible integrate and interconnect different teaching platforms, existing teaching platforms or newly developed in order to support fast dissemination of STEM (Science, Technology, Engineering and Mathematics) learning content to a large audience and also to improve the access to the education for the people with disabilities in particular. Harmonization, alignment and compliance with related standards will promote this interconnection and facilitate integration of other TEL systems in the platform.

Therefore, in this section, a revision of some of the European initiatives in technology-enhanced learning TEL methods and tools is included. Some of them could be considered for integration in the NEWTON platform. On the other hand, the most important related standards in this area to be complied with are also identified and described as well as in the field of the QoE evaluation for TEL.

#### 2.1. Innovative initiatives in TEL platforms

A lot of studies and research have been conducted over the past few years focusing on the analysis and benefits of TEL [9, 10]. Nevertheless, few of them were successful in developing real functional platforms to fulfill concrete objectives, like the ones proposed in NEWTON project (encouraging young students to engage to STEM education or improving access for students with disabilities). Even fewer proposals can be found that relates to enhancing the learner QoE to reach those objectives.

One of the most remarkable initiatives in this context is the the Go-Lab Project (Global Online Science Labs for Inquiry Learning at School) [11]. In this project the goal is to promote student's engagement to science topics through the access to online laboratories. In this way, students may conduct their own experiments and analysis learning from their own experience and motivating them to make an STEM career in the future. For this purpose, the <u>Go-Lab</u> Portal [12] (Figure 1) has been developed "to provide access to a set of online labs from worldwide renowned research organizations, such as European Space Agency (ESA, the Netherlands), European Organisation for Nuclear Research (CERN, Switzerland), Núcleo Interactivo de Astronomia (NUCLIO, Portugal), as well as multiple universities and institutions. These online labs can be used by universities, schools, instructors, students and lifelong learners to extend regular learning activities with scientific experiments that can be conducted not only by teachers as a demonstration, but also by students themselves giving them real experience of scientific work." [12]

Another interesting initiative in this line is the Physics Education Technology (PhET) project [13] which provides simulations tools in the STEM areas over a free website: <u>https://phet.colorado.edu/</u>. Under this project, more than 80 interactive simulations have been developed covering different topics in Physics and also real-world applications, such as the greenhouse effect and lasers. In [14], more proposals of remote virtual laboratories with collaborative roles for learning environments are also described. It is demonstrated that this kind of virtual laboratories enhance the creativity and the natural dispositions of young people to experiment with ICT, as stated in [15], and may encourage them also to pursue their studies and a career in a STEM field.

Nevertheless, none of the above mentioned platforms makes use of the next generation of TEL strategies, like gamification, mulsemedia or interactive augmented reality teaching. In addition, in most of these platforms there is no analysis on the learner QoE and that is something really important in order to have the required feedback on the contribution of these TEL strategies and methods on enhancing the learning and teaching processes.

In this regard, some motivating studies were carried out [2, 16] to analyze how to improve the learner QoE, by means of different adaptive techniques. However, these studies did not consider the aforementioned next generation TEL strategies and methods.Very recently, new research on the QoE analysis when using this next generation strategies has been raised [17, 18] and very promising applications to enhance learning have been foreseen.

Nevertheless, there is a need to join efforts to integrate all these new advances and develop new network platforms based on innovative TEL methods and tools. This is the one of the goals of the NEWTON project.



Figure 1. The Go-Lab portal [12]

## 2.2. Standards for technology-enhanced learning

As mentioned in the beginning of this section, NEWTON platform aims to integrate and interconnect other existing teaching platforms. For that reason, one of the targets of the project is to be developed complying the most recent and applicable standards.

From the point of view of TEL, there is a website from the ITU (International Telecommunication Union) [19] and a report on it (see figure 2) [4] which covers in its section 5 a review of specific standardization activities for TEL. In this report it is stated that "Learning technology standards do not include instructional design, pedagogical norms, cultural conventions, learning objectives or specific learning content". However, it does consider the issues that are referred in Figure 3.

In this report, it is also highlighted the importance of the Recommendation ITU-T F.742 [20] which describes application scenarios of distance learning and deduces general requirements to be met by distance learning services, and other important initiatives and groups working on the standardization of LTE. Some examples are the "ITU's Focus Group on Innovation is maintaining a living list of emerging ICT products and services" [21], the "ISO/IEC JTC1 Subcommittee 36: Information technology for learning, education and training"[22] or the "The IEEE Learning Technology Standards Committee (LTSC)"[23]. It is important also to mention, when talking about next generation technologies, the "IMS Global Learning Consortium (IMS GLC)" [24] a community of educational institutions, government organizations and equipment vendors which aims is to bring advances in technology in order to improve educational participation. It is also remarkable the work that is being done in LTSC related to "Augmented Reality Learning Experience Model". This new LTSC working group is developing a standard model for defining AR-based learning activities. Also of interest in this context, is the "ISO/IEC 19796-1: Learning, education and training- Quality management, assurance and metrics" [25] defined by the ISO/IEC JTC1 Subcommittee 36.



Figure 2. Standards for technology-enabled learning [4]



Figure 3. Items addressed for TEL standards [4]

In the context of more specific technical standards related to mulsemedia and other next generation TEL strategies, there are some important standardization initiatives. One example is the media context and control MPEG-V standard (ISO/IEC 23005) [26, 27], capable of supporting mulsemedia applications, providing an architecture and specifications to enable the interoperability between virtual worlds (digital content providers of a virtual world, gaming, simulation, etc.) with the real world (sensors, actuators, vision and rendering, robotics, etc.). The multimedia content description MPEG-7 standard (ISO/IEC 15938) [28] is also to be mentioned in this context.

# 2.3. Standardization for QoE evaluation in TEL

Although some promising research related to the evaluation of the learner experience when using digital learning has been done [2, 16, 29], no standardization attempts for defining frameworks and procedures, as to have different comparable results, have been published so far. Likewise, remarkable efforts can be identified in the research literature that relates to the evaluation of the QoE when using mulsemedia (figure 4) and other next generation TEL strategies [6, 7, 17, 30-32], but still neither general nor specific standards have been developed in this area.

However, the interest for the standardization that relates to QoE in general us er applications is well evidenced by the increasing number of dedicated standards [33-42], whereas the need for specific standardization for QoE evaluation in TEL is underlined in [43]: "The absence of a standard, comprehensive approach to evaluating technology-enhanced learning (TEL) limits the utility of individual evaluations, and impedes the integration and synthesis of results across studies."

Therefore, future work and novel proposals are needed to standardize a framework and procedures for next generation TEL strategies to better understand how new generation learners would react to such experiences. Furthermore, it would be of high value if such efforts had also spread out to define and progress standards for unified architectures of mulsemedia, gamification, augmented reality and other next generation strategies for interoperability between real and virtual worlds. For a plus of value, these proposals could be accompanied with the definition of QoE metrics (KQI and KPI) for the evaluation of the quality of service (QoS) in these new emerging scenarios.



Figure 4. Capturing end-to-end QuaSE [7]

#### **3. INNOVATIVE TECHNOLOGY-ENHANCED** LEARNING INITIATIVE: NEWTON PROJECT

Networked Labs for Training in Sciences and Technologies for Information and Communication (NEWTON<sup>1</sup>) project is a Horizon 2020 funded project that brings together academia and industry partners from 7 different European countries (Figure 5). NEWTON aims to provide a pan-European learning platform that facilitates the delivery of STEM subjects to learners from a variety of backgrounds: secondary and vocational schools, third level education, people with disabilities. This pan-European platform will integrate a set of distributed labs: existing state-of-the-art teaching labs (e.g. FabLabs<sup>2</sup>) and newly created teaching labs as a result of the project. Moreover, the platform will be designed to be open to extension: the platform will allow for an easy integration of other new teaching labs created by different third-parties. The purpose is to facilitate the access of a large audience, including people with disabilities, to a large database of learning content that will be experienced in novel manners in order to enhance their STEM education.

Consequently, one of the main focuses of NEWTON project is to develop innovative TEL methods that will be integrated in the platform. The purpose of employing these novel methods is to increase learner QoE, improve learning process and increase learning outcome.

Such TEL methods that are aimed to be developed in the context of NEWTON project relates to:

- learner model-based personalisation
- gamification
- self-directed and independent learning
- augmented reality
- multimedia and multi-sensorial (mulsemedia) content delivery
- adaptation of content delivery to learner operational environment: variation of network conditions, user device characteristics and user profile.



<sup>2</sup> https://www.fablabs.io/



Figure 5. Horizon 2020 NEWTON Project and Partners

The last two listed innovative technologies are some of the main novelties of NEWTON project and represent the focus in this particular work. NEWTON aims to employ adaptive solutions for the delivery of multimedia content. This involves monitoring and content adjustment based on the combined effect of dynamic variation of network conditions, user device characteristics and user profile.

Mulsemedia is considered a new type of multimedia that unlike classic multimedia that usually involves two senses (audio/video), involves three or more human senses (olfactory, haptic, etc.). NEWTON project aims to provide the learners with mulsemedia experience in order to enhance their learning experience. Additionally a highly innovative solution for multiple-sensorial content adaptation is envisaged to be proposed and used.

NEWTON platform will be validated through Europeanwide pilots carried out in secondary and vocational schools and universities from 5 European countries, including learners with special needs.

## 4. NOVEL STANDARDIZATION PROPOSALS FOR QOE EVALUATION IN TEL

As identified in the review presented in section 2, there is an important lack of standardized methodologies for the evaluation of the learner QoE, in TEL context. Nowadays, TEL can be supported by a large plethora of technologies, from traditional digital technologies, like web-based technologies or streaming multimedia systems, to other next generation technologies, like mulsemedia, gamification or augmented reality. Therefore, defining a framework and methodology for the evaluation of the learner QoE in such a complex scenario is a big challenge.

In this section, a novel proposal for the QoE evaluation and standardization in TEL context is introduced that aims to do some steps forward towards achieving the aforementioned goal. However, this work is in early stages and, although evaluating QoE has also theoretical dimensions, is the later practical validation that will confirm the validity of the approach. At this point, some early guidelines to be followed in order to define the proposed standards will be described, only. These guidelines were defined based on general QoE frameworks [44]. As a first step, it will be important to identify the factors influencing QoE in TEL. ITU-T Rec. G.1031 [38] may be a good example of this approach. As referred in this recommendation, QoE influence factors are usually grouped in three main categories (#1 to #3 in Figure 6):

- User influence factors
- Context influence factors
- System influence factors

In the first category, some key factors like the learner expectations, previous good or bad experiences in TEL and the learner expertise with the subject and all the cultural aspects should be identified (student segment A or B in Figure 6). The context, in which the learning is developed, like location, type of task, level of interaction, must be also considered when analyzing the QoE of the learner (#2 in Figure 6). Finally, the system influence factors (#3 in Figure 6) must be determined. Being aware that the sort of system influence factors may vary a lot depending of the strategies that are being implemented in the TEL process (just web browsing, streaming, gamification, mulsemedia, etc.), our proposal is that the standard for determining the QoE factors in TEL should describe the different Key Quality Indicators (KQI) and the related Key Performance Indicators (KPI) that must be considered when using the different technologies that can be implemented (#4 to #6 in Figure 6). Separate standardization documents about subjective testing for each of the different technologies or

strategies will be necessary to be developed and the global standard would only include the reference to each of them.

Once, the standard for the "QoE factors in TEL" is defined, the next step would be the definition of the standard that describes the "Framework for the QoE evaluation methodology for TEL" (#7 to #9 in Figure 6).The subjective model should be defined in the standard and some generalized proposals for satisfaction models found in literature [45] (#7 to #9 in Figure 6) could be used.

Figure 6 illustrates the importance of the evaluation of the learner experience as an input used in the update and enhancement of TEL systems in order to improve the student's learning process. Another thing that we want to highlight in relation to Figure 6 is the fact that the update in student's expectations should be taken into account along the new generation of students. In addition, it must be considered that other factors that differ from the TEL management system factors may influence in the QoE results.

Nevertheless, as mentioned before, this entire proposal should be validated and this goal is intended to be achieved through the network of real life pilots to be developed across Europe in the NEWTON project that will give us the opportunity to verify how other context's and student's factors may have influence in the results.

In the next section one of the fist testing experiments to be developed in the University of the Basque Country (UPV/EHU) in Spain will be presented.



Figure 6. Proposals for the QoE evaluation and standardization process in TEL

#### **5. PILOT STUDY**

The Research Group NQaS (Networking Quality and Security) of the University of the Basque Country in Spain has a large experience in the definition and validation of QoS/QoE standards [46-55]. They have also participated as rapporteurs and editors in the ITU-T Study Group 11 being one of the first academia members to be actively involved in the standardization process developed in this SDO. In fact, recently, it has been approved one of the most innovative Recommendations in the area of Internet QoE/QoS measurements that was, indeed, edited by two members of this university [56].

For that reason, one of the first pilot studies that aims to bring advances in both NEWTON project in general and the research on the learner experience in TEL environments in particular, will be developed through the cooperation of this research group with DCU (one of the partners of the NEWTON project). The proposed study targets the students of the second year of the official Master in Telecommunication Engineering, attending the "Performance on Telecommunications Networks" course. This course is offered in the first semester of the year so it is intended that the pilot testing will be carried out sometime in November 2106, when some of the devices and testing platforms of the NEWTON project will be already ready for testing.

The experience and knowledge in the telematics area of the students that will participate in this validation will also assist to define the capabilities of NEWTON platform related to one of its target: attracting students to STEM higher education.

The general proposal is to provide certain parts of the *"Performance on Telecommunications Networks"* syllabus using both next generation TEL and traditional learning and analyze how the students learning experience is enhanced by TEL strategies.

The pilot will focus on two main innovative technologies that are brought by NEWTON project in the general context of learning: adaptive multimedia and mulsemedia content delivery.

The main goals of the study are to measure the following aspects that are highly important in the context of NEWTON project in particular and any TEL-related project in general:

- The influence of the employed innovative technologies on increasing learner QoE
- The influence of the employed innovative technologies on improving learning process
- The influence of the employed innovative technologies on increasing learning outcome.

In this purpose the proposed framework (Figure 6) will be used. In addition, in measuring the influence of TEL on improving the learning process we will also employ a questionnaire developed in collaboration with experts in Psychopedagogy from University of Bucharest, a partner of NEWTON project.

Moreover, in order to measure the influence of TEL on increasing the learning outcome, the knowledge of the students related to the material presented in the 2-hours course will be assessed via a test. The aim is to compare the students' performance in the questions related to the course aspects that were not presented employing TEL elements against the students' performance in the questions related to the course aspects that were presented employing TEL. A pre-test will be also given to the students to make sure that the results analysis is not influenced by pre-existent knowledge.

As mentioned before, the participants to the study will be master students attending their usual course that this time will be delivered employing the aforementioned technology advances.

The specific part of the course syllabus that will be carried out with the proposed TEL framework will focus on network performance metrics, quality of service, QoE and quality of perception concepts.

Parts of the course will be delivered using multimedia adaptive techniques. Short videos related to different network performance metrics will be delivered to the students. Note that NEWTON platform will not be available at the time of this pilot study, and therefore the delivery of these videos will not be done via the platform itself, but in a test-bed like manner (Figure 7).

A network emulator will be employed to simulate different network conditions. Some of the videos will be delivered in an adaptive manner, some in a non-adaptive manner in order for the students to be able to note the difference. All these aspects will be captured in the questionnaire.

Mulsemedia examples will be delivered as support for a better understanding of some of the taught concepts. In this particular case, mulsemedia will not be used to deliver the de-facto content of the course. Students will get to experience mulsemedia on short movies for a better understanding of the quality of perception metric. As depicted in Figure 8, different devices will be used to deliver mulsemedia content (e.g. air device – fan, haptic device – haptic vest, etc.).

Same pilot is planned to be carried also in Dublin, Ireland in Dublin City University (DCU), at the master level as well. Results obtained in both institutions, UPV/EHU and DCU, will be analyzed and compared.



Figure 7. Delivery of course content using adaptive multimedia



Figure 8. Mulsemedia experience during pilot study

#### 6. CONCLUSIONS

This paper presents a novel initiative to create a network of new and existing teaching labs in the aim to develop a pan-European learning platform targeting to attract students to STEM studies and to support the learning process of people with special needs through the enhancement of the student learning process by means of the analysis of the learner QoE.

This platform will be developed using next generation TEL tools and strategies (mulsemedia, gamification, augmented reality, etc.) and the platform will be tested and validated in real life pilots across Europe, using a network of secondary schools, third level institutes and some universities. One of the first pilot's studies will be carried out in November 2016 and will target master students of the University of the Basque Country (UPV/EHU). This pilot is described in details in the paper.

A parallel initiative related to this teaching platform, and based on the achieved results, aims to define and develop new standards to unify criteria on the QoE evaluation on TEL platforms for comparable results. This paper presents some initial steps in the context of this research initiative that is in early development stages. As such, in this paper it is introduced a novel proposal for the QoE evaluation and standardization in TEL context. In future works that will include NEWTON pilots studies, this proposal will be validated on the basis of the results of these studies.

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