Technical Performance Evaluation of a Technology Enhanced Learning-based Platform for Education

Nasim Ferdosian, Diana Bogusevschi, Gabriel-Miro Muntean
School of Electronic Engineering, Dublin City University, Ireland
nasim.ferdosian@dcu.ie, diana.bogusevschi@dcu.ie, gabriel.muntean@dcu.ie

Abstract

Technical performance evaluation is an important plan of actions for assessing the efficiency of an education system, developed based on Technology Enhanced Learning (TEL) strategies. The problem arises that there is not a single comprehensive framework for evaluating the technical performance of large-scale TEL-based learning platforms such as the European 2020 NEWTON project platform. This paper presents a framework consisting of the explicit metrics and appropriate methods to evaluate the quality of service and technical system performance of a TEL-based learning platform. Evaluation is made under two directions: the educationalists and the software developers. Moreover, some of the required standards and specifications to be used for developing this performance evaluation framework are identified in this paper. 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.

1. Introduction

Penetration of technology into the educations' instructional base opens many doors for teachers and students at all academic levels to work virtually anywhere as they teach and study a particular subject. Currently the integration of innovative technologies with educational functions is increasing around the globe [1]. Technical and networked education services have been improving the quality of teaching and learning practices at a fast pace in recent years [2], thanks to the advancements in Technology Enhanced Learning (TEL) strategies and network communication technologies.

The higher adoption of TEL strategies such as Augmented Reality, Virtual Reality and Gamification leads to the higher level of user interaction with the TEL-based learning platform (TEL system) and more quality-aware users. The system's performance is one of the main factors influencing user experience and consequently the learning outcome. Therefore, it is crucial to evaluate and analyse the technical performance of such a system to enhance learner Quality of Experience (QoE) [3]. However, the technical performance evaluation of the TEL-based learning platforms has become progressively more complex, while the functional sophistication level of them is growing due to the exponentially increasing number of technical aspects involved [4].

A comprehensive survey of the existing quality frameworks (SCORM, IEEE P1484 and IMS Global Learning Consortium) and standards (ISO/IEC 19796, Open ECBCheck and ISO 9126) dedicated to the e-Learning systems can be found in [5]. There are many research studies which have used some of these mentioned standards and frameworks as a tool for evaluating such systems, particularly for teachers and educational administrators [6, 7]. Even though some standardization activities related to general TEL have been defined, there is still a need to fulfill the gap of novel standards to define frameworks and procedures for the technical performance evaluation of these new technology-rich innovative learning systems.

This paper presents a framework consisting of the explicit technical aspects of TEL-based learning platform in the educational environment and their appropriate performance evaluation methods. The set of technical aspects of e-learning service quality proposed in the model is based on a literature study, software quality standards and relevant whitepapers and guidelines. In this regard, the main objectives of this paper are as follows:

- Define technical evaluation criteria
- Define quality standards and evaluation methodologies

This proposed instrumental framework presents a basic structure for evaluating and assessing technical performance of a large-scale TEL system. The proposed structure is a part of the NEWTON project education platform which is a European Horizon 2020 project and will facilitate standardization and evaluation of a TEL system in an educational environment. The rest of the paper is structured as follows. Section 2 presents related work in the area of technical performance assessment and relative issues. Sections 3 presents the proposed technical performance evaluation framework, including a set of technical criteria and respective evaluation methodologies, while Section 4 concludes the paper.

2. TEL Systems Performance Evaluation Aspects

Research into evaluating TEL systems comes from two directions: the technical performance evaluation and the pedagogical evaluation. Technical performance evaluation is what comes apart from the pedagogical evaluation. Technical performance evaluation measures system's performance from a technical point of view, whereas pedagogical assessment measures students' performance from an educational point of view where the system is evaluated according to the curriculum standards, practices, and student assessment [15]. In this regard, the strategies for the evaluation of a TEL system can be classified into two types: User-centric evaluation and Developer-centric evaluation through the real-life testing. Each evaluation strategy is suited to evaluate specific goals.

2.1. User-centric evaluation

A User-centric evaluation focuses on the perceptions of users and the performance aspects of the system in application level. User-centric measures, such as end user experience or user satisfaction, are best evaluated by asking users themselves. Therefore, in particular for TEL systems, user-centric evaluations are crucial, but expensive to conduct because the technical teams often only realize that there are delays and performance issues after receiving users complains. It can be conducted as a real-life evaluation, where a large community of users is observed while using and interacting with the system under realistic conditions or as a pilot study where a system is deployed under normal settings. By applying the real-life testing, most user-centric goals, such as measuring user experience or user satisfaction, can be effectively evaluated.

As defined in [8]: "End User Experience is essentially a quantification of the entire time it takes a user to perform a specific function, regardless of how many network hops, data calls, applets and other application elements are utilized in the process." Despite the widespread research on user-centric evaluation over a wide variety of applications and services, there is a crucial need to propose solutions to quantify the experience of end users. Authors in [9] proposed standardization approaches for evaluation of users' QoE in TEL systems. Accordingly in [10], a subjective study is presented on the user QoE when experiencing mulsemedia as one of innovative TEL strategies applied in education systems.

In the end, User-centric evaluation provides a clear understanding of how well the whole aggregated TEL-based learning system including, network infrastructure, device and application elements are working together to meet end user expectations of how the service should operate. Focusing on the end user experience will ensure that development teams can easily diagnose and fix technical issues.

2.2. Developer-centric evaluation

The main target of Developer-centric evaluation is to evaluate the technical infrastructure of a TEL system which includes all aggregated devices, cloud computing architecture, network elements, and software applications from the viewpoint of developers. Since the end user experience is affected by technical factors, the development team must be able to track all these effective metrics in order to optimize performance and the value of its application investments. The research study in [11] presents an approach to evaluate the quality performance of e-learning systems from the developers' perspective. The e-Learning Success Model proposed in [12] points out the fact that the overall success of an e-learning system depends on the attainment of success on each of the three stages of systems development including system design, system delivery, and system outcome.

One of the major technical aspects of the Developer-centric evaluation is a network and cloud computing landscape. To keep the pace with the technology, the new TEL systems are switching to cloud computing usage and Internet environments. Therefore, technical evaluation has become more complex and specialized developers move their focus on the overall efficiency of the applied cloud computing services [13].

3. Proposed Performance Evaluation Framework

The most important reason for the technical performance evaluation of a TEL-based learning system, is that the impact of platform on learners' experience, satisfaction and learning outcomes is dependent upon how successful technology is integrated and how efficiently the services are delivered. The best indicator to measure performance is based on clear and reasonable criteria. Here, two efforts are presented that address, respectively, the criteria to be employed and the measurement approach through the following subsections.

3.1. Criteria

In this section, a criteria model is presented (shown in Figure 1), based on the knowledge of factors, having influence on quality and efficiency of the system outcome. The proposed criteria set is based on the technical quality model proposed in [14], which was used as a useful approach to assess mobile learning services and help learners, instructors, learning providers and decision makers in developing or selecting mobile learning services in the education environment. This model has been modified to cover specifically the performance-wise technical evaluation criteria, focusing on the infrastructure, instrumentation, dependencies, and external influencing factors as follows:

- Functionality: The capability of the TEL system to provide the intended functions which meet the specified and implied requirements of users according to the specifications of usage accurately. The application must include all functionalities and features that are necessary to provide an enhanced learning experience. Metrics: response time and bug-feature ratio.

- Reliability: The capability of the TEL system to maintain its level of performance and consistency under specified conditions for a defined period. This criterion also characterizes how the system is tolerable to the failures and errors. Metrics: number of impacted users, error rates, recovery time, task success probability, stalling time, fault tolerance.

- Efficiency: The capability of the TEL system to provide desired performance, under specified conditions in an efficient manner. The TEL system, while integrating a wide range of technologies, must provide users with fast access to the content and interaction with the components in a good speed. Metrics: throughput, delay and data loss.

- Connectivity: The capability of the TEL system to provide seamless delivery of the required services to the users through the specified network connectivity infrastructure and learning settings. Connectivity criteria concerns more about the network and cloud service provider's ability to handle users and application demands. For example, some of the current innovative learning technologies, such as an HD videoconferencing solution, are effective for on-line learners with fast Internet connections. Metrics: available capacity, link latency, network throughput, data Jitter, and availability of the cloud.

- Security: The capability of the TEL system to provide a secure platform while users firmly access resources and services. The new communication technologies come along with increased threats to system and data security and privacy. The TEL system must be equipped with security tools, providing privacy settings and security controls. Metrics: number of denied attacks and data security efficiency (percent).

- Resource Utilization: The capability of the TEL system to efficiently manage and control all the resources of the system. Inefficient use of the system resources will lead to service disruptions that ultimately diminish end-user experience. Metrics: bandwidth consumption, CPU, memory usage and power consumption.

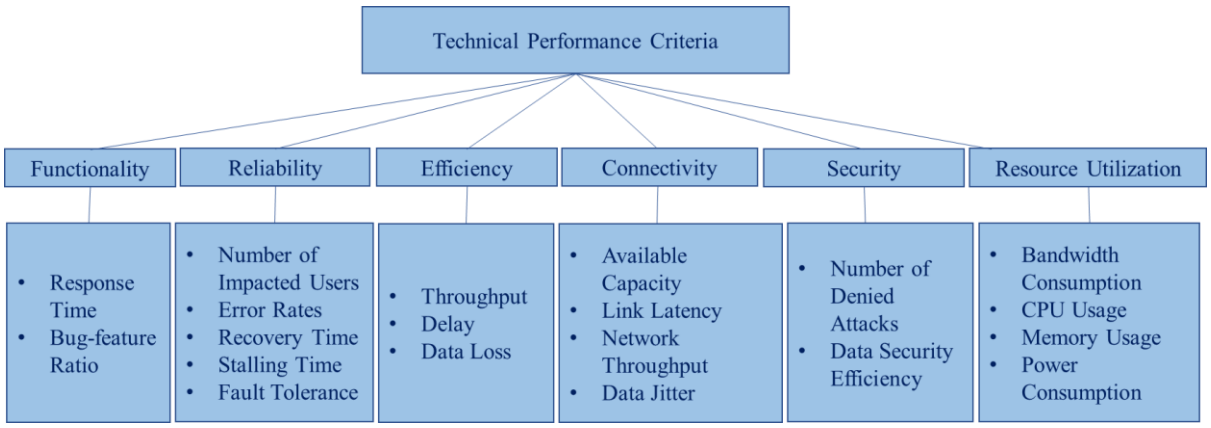

Figure 1: Technical Performance Criteria Model

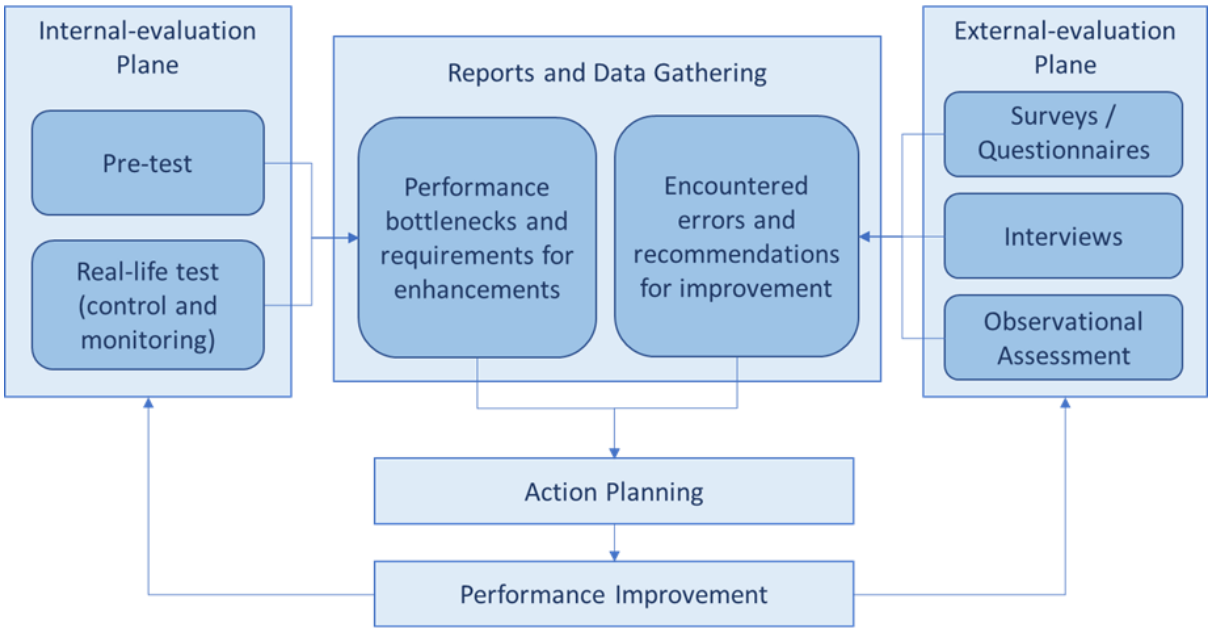

Figure 2: Performance Evaluation Framework

3.2. Methodologies

The main aim of the TEL system performance evaluation methodologies is to provide solutions to accurately assess actual end user experience and measure effective metrics on what users are really encountering. As it is explained in Section 2, the TEL systems performance evaluation aspects are divided into two directions, user-centric and developer-centric. Accordingly, the corresponding evaluation methodologies are performed in two planes, internal-evaluation and external-evaluation. The external-evaluation plane includes the evaluation methodologies such as: purpose-built surveys, questionnaires, interviews and observational assessment. This part of evaluation is conducted in user side, to test the behavior of the system when the access is granted to a large number of users, in widespread locations and different technical environments, with varied resource needs.

The internal-evaluation plane methodologies are conducted on the developers' side and includes performance monitoring tools and solutions which evaluate the data automatically gathered through the platform. Currently there are a big number of performance monitoring tools and products, while the TEL platform either is located and performs on enterprise's own data centre or migrated to a cloud. For example, AppNeta is an Application Performance Monitoring product which provides performance evaluation solutions and data for cloud-derived applications to their development team to discover performance bottlenecks.

The proposed performance evaluation framework is illustrated in Figure 2. As shown in this figure, the outputs from the evaluation planes are gathered and then analyzed in Action Planning step. The required actions for correcting, improving and enhancing the system performance are decided. The decided corrective actions are established and executed to the corresponding parts of the platform through the Performance Improvement step. The improved TEL platform is presented again to the evaluation planes in an iterative manner for achieving high technical performance continuously.

4. Conclusion

The learners' experience, satisfaction and learning outcomes is influenced by the quality of the services and by the way in which they are delivered to learners through the TEL strategies. It is a challenging issue for technology planners and administrators to choose what measures and standards are best to apply for their developed or adopted learning platform. In this paper we proposed a technical performance evaluation framework for TEL-based learning systems containing the criteria and performance measurement methodologies. This instrumental framework presents a basic structure for evaluating and assessing technical performance of a large-scale TEL-based learning platform. The proposed structure will facilitate standardization and evaluation of e-content. For the future work we plan to investigate the components of the proposed model in different TEL-based learning systems empirically.

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