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RESEARCH ARTICLE

Towards a Software Quality Factor Assessment Model for Learning Management Systems (LMS)

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Abstract

Objectives: Software quality models are well-accepted ways to control and guide software quality to enhance user effectiveness and work productivity. However, an adequate understanding of software quality assessment factors that promote the effective operation of Learning Management Systems (LMS) among users in educational contexts needs to be adequate. This study aimed to identify from the literature quality factors, sub-quality factors of the quality factors and their meanings from mainly used software quality factor models, explain Ehlers's Model of subjective quality requirements of e-learning systems and match the quality factors with Ehlers's model and develop a software quality model for e-learning. **Methods:** Drawing on software quality literature and Ehlers' Quality Model for educational technologies, we propose an LMS Software Quality Factor Model for assessing LMS effectiveness among users in educational contexts. **Findings:** The proposed model highlights relevant user-centred parameters (predominantly, "Reliability", "Efficiency", and "Flexibility/Evolvability") that ensure LMS quality and effectiveness among users. **Novelty :** This research is novel from the point of view of determining quality factors for LMS using an existing e-learning model, **Ehlers's user-based e-learning requirement model** in this particular instant.

Keywords: Software quality factors; LMS; Ehlers's Model; ISO 9126; Educational technologies

1 Introduction

The postmodern era has witnessed an upsurge in educational institution's ability to innovate due to advancements in software quality. Hence, the relevance of software quality should be emphasized [(1)]. In the educational sector, software such as the learning management system (LMS) is considered a strategic tool for educational continuity and enhanced institutional performance. Hence, developing acceptable quality models and

attributes that define LMS quality, usefulness, and relevance is essential.

Thamilarasan et al.[2] investigated this space by conducting a systematic literature review to collect and analyze data on software quality models for Learning Management Systems (LMS). The research questions guided the data collection process, utilizing various search engines and sources such as Scopus, Elsevier, and Science Direct to gather relevant articles. The study focused on identifying existing software quality models and attributes and determining suitable models for LMS by comparing quality characteristics. Their main objectives were to investigate the software quality models and quality attributes, identify suitable existing software quality models for Learning Management Systems (LMS), and determine common quality attributes used in software quality models for LMS. They concluded by emphasizing the significance of improving quality metrics, particularly usability, in software development for Learning Management Systems (LMS) to enhance user experience. Researchers were also encouraged to focus on enhancing usability metrics to improve the quality of educational systems and software. The study emphasizes the importance of software quality models in ensuring the delivery of high-quality products that meet user satisfaction in the online learning environment. Even though Thamilarasan et al.[2] did not explicitly mention a specific gap in the research, they highlighted the importance of further research on software quality models and attributes for Learning Management Systems (LMS) to enhance the quality and effectiveness of online learning platforms.

Pinedo et al.[3] employed a systematic review methodology to identify and analyze software quality models developed between 2016 and 2020. It focused on extracting information from various sources to provide an updated overview of the field and offer insights for researchers and software developers. The main objectives were to identify software quality models proposed between 2016 and 2020, update the state of the art regarding the software quality models proposed in recent years, and provide valuable information for researchers and software developers seeking evaluation models that align with specific needs. The document's conclusion highlights the importance of using established standards like CMMI and ISO regulations as fundamental bases for developing new software quality models. It emphasizes the significance of internationally recognized frameworks in software quality management and their versatility in creating customized models. The article provided relevant information for academics, students, and professionals interested in software quality to enhance software development processes and end-user satisfaction. In as much as the paper of Pinedo et al.[3] touched on software quality factors, it is directed to something other than LMS specifically. It touched on the importance of software quality factors in general and has little bearing on this work. The paper of Thamilarasan et al.[2], however, has a direct bearing on this paper. Regardless of their work concluding on the importance of usability as the critical factor for consideration in designing LMS, they also pointed out that more research needed to be done in this space. Most papers reviewed and not included in this paper point to the importance of software quality factors in general and not tailored to LMS usage.

The discussion above suggests limited peer-reviewed studies highlight software quality factors for LMS usage in educational contexts. The gap in the literature identified above is filled in this study by the authors addressing the following research objectives:

i. To identify from literature quality factors, sub-quality factors of the quality factors and their meanings from mainly used software quality factor models.

ii. To explain Ehlers's Model of subjective quality requirements of e-learning systems.

iii. To match the quality factors with Ehlers's model and develop a software quality model for e-learning.

This study is organized as follows: the subsequent section presents the method employed, followed by the results and discussion comprising a comprehensive review of software quality literature to understand software quality models and factors, the examination of Ehlers' Quality Model and its relationship with LMS, and then matching of the quality factors and the Ehlers' Quality Model with the sole aim to propose an LMS Software Quality Factor Model for assessing LMS effectiveness in educational contexts. The conclusion and limitations of the study are presented in the last section.

2 Methodology

We extensively reviewed the literature on software quality to address the research objectives stated in the preceding section. We drew on the principles of Ehlers' Quality Model to develop the LMS Software Quality Factor Model for LMS effectiveness in educational contexts. We followed the methodological approach described by Bendermacher et al.[4] to conduct this systematic review. This included developing a search strategy for using multiple databases, defining exclusion and inclusion criteria for publications and assessing their eligibility, defining review and coding schemes, analyzing and synthesizing data, and developing a write-up. This methodology guarantees rigour and transparency in choosing and analyzing publications.

Keywords and titles were used to search many sources for information on software quality aspects, LMS, Ehlers' Model, ISO 9126, and educational technology. The databases used to determine the work's relevance were limited to ScienceDirect, IEEE Xplore, Scopus, Association of Computing Machinery (ACM), and Emerald Insight. We conducted the eligibility assessment to improve the rigour, accuracy, and dependability of the publication selection process, which entailed manually screening each

article. Because there is little research in this field, most papers found were irrelevant.

From the 300 publications that the database search produced, we chose 105 by looking at the titles. After the publications' abstracts were examined, a total of thirty-five (35) publications were found to be irrelevant. Additionally, thirty (30) articles were removed for being duplicates, leaving forty (40) publications. Furthermore, fifteen (15) papers were removed based on the inclusion and exclusion criteria because they needed to match the research aim. After reading through the articles and assessing the language, the researchers eliminated five (5) of them since their main points did not align with the study's goals. This left a total sample size of twenty (20) publications thoroughly reviewed and synthesized. It is important to note that, although working with twenty (20) articles, the review was greatly aided by two additional books: Software Quality: Concepts and Practice by Galin and Software Quality Assurance by Laporte and April. The literature review was aimed at identifying all the software quality factors related to the LMS and matching them with Ehlers's model and then developing a software quality model for e-learning using the central tendency measure mode in tallying the occurrences of the quality factors for the various quality fields of the Ehlers's model.

In summary, this study advances the literature on software quality in the following areas. First, it presents more encompassing specifications and assessment components of software quality assurance for educational institutions (specifically, using the LMS). Second, it proposes a Software Quality Factor Model for LMS that specifies factors users can adopt to assess LMS quality in the educational sector.

3 Results and Discussion

As indicated in the methodology section, the review employed yielded the following results, which are discussed below in the indicative sub-captions and **Supplementary Tables 1 and 2**.

3.1 Software (LMS) quality

To benefit the most from LMSs, institutions need to acquire and implement high-quality LMS, which can be done with evaluation methods that compare the differences among the various options in the LMS ecosystem [5]. For instance, the analytic hierarchy method of evaluation outlines the system quality, information quality, reliability, and attractiveness of an LMS as the key factors to consider when searching for a suitable LMS for an institution [6]; another example is the UseLearn evaluation model that was developed from the criticality metric analysis by Oztekin et al. [7] which considered critical human-computer interaction (HCI) issues related to LMSs and emphasized usability as the vital factor to be considered when evaluating the quality of an LMS. Rahman et al. [8] do not consider a single metric but propose a scale of critical targets that an LMS must reach for it to be considered for implementation as a quality system: effectiveness or how fast and error-free the interaction with the system; learnability or how easy it is for new users to learn to use the system and how likely they are to adopt and use it; flexibility or the ability to adapt the system to tasks and environments beyond what comes in the box; and attitude or the levels of human costs in terms of tiredness, discomfort, frustration and personal effort towards using the system. Furthermore, Jafari et al. [9] identified factors that indicate the quality of LMS implementation using the DeLone and McLean information system success model. According to Jafari et al. [9], this model has had various empirical studies successfully establish its solid theoretical foundation and ability to assess LMS quality; it is considered one of the most widely acknowledged information system evaluation models. This model establishes the following six factors necessary to gauge an LMS's quality: system quality, information quality, service quality, use/intention to use, user satisfaction, and net benefits.

According to Benson and Palaskas [10], a case study of the trial adoption of WebCT Vista on a pilot basis for evaluation made use of the Resources, Infrastructure, People, Policies, Learning, Evaluation, and Support (RIPPLES) model – which was developed by Surry et al. [11] for analyzing institutional innovations such as the adoption of an LMS – to highlight the factors that needed to be considered in the evaluation of an LMS for adoption in higher institutions of learning. These factors were the accommodations made for the users of the system – both instructors and learners, the system's features that could help identify and implement the institutional policies and procedures needed to enable continual improvement of the system in its use for teaching and learning activities and features that would allow for the monitoring and evaluation of the system's use. According to Benson and Palaskas [10], the RIPPLES model is suitable for evaluating an LMS because it allows for the extension of some aspects of the model while covering significant factors that need to be considered in the adoption of innovations in higher education environments, thus avoiding the limitations of several other smaller models.

Software quality must be well understood to put things in the proper perspective. The LMS is software, and its quality is crucial for delivering quality teaching and examination. Quality is frequently described as "fitness for purpose" to the user's demands [12,13]. Another meaning may be that the 'product meets stated standards' [13]. According to Pressman, software quality is the degree of compliance with particular functional requirements, established software quality standards, and Good Software

Engineering Practices (GSEP)[14]. Various meanings of the term "quality" have been assigned over the years.[15] defined it as "conformance to user needs." Humphrey[16] states that quality is "reaching outstanding levels of fitness for use." However, IBM invented the phrase "market-driven quality," focusing on attaining ultimate customer satisfaction[17].

Technically, Software Quality is defined as cited in[18] as follows:

"Conformance to established software requirements; the capability of a software product to satisfy stated and implied needs when used under specified conditions (ISO 25010 [ISO 11i])."

"The degree to which a software product meets established requirements; however, quality depends upon the degree to which those established requirements accurately represent stakeholder needs, wants, and expectations [Institute of Electrical and Electronics Engineers (IEEE 730)] [IEE 14]."

Putting these definitions in perspective, the level of quality of an LMS does not only depend on establishing that the product meets established requirements (determined by the general requirements for teaching and examination) but also depends on the degree to which those established requirements accurately meet the needs, wants and expectations of the students and lecturers who are the major stakeholders in this particular case. The latter is the focus of this paper.

3.1.1 Software quality models, factors, and sub-factors and their meanings

Software quality factors influence or affect the quality of the software in the end. Generally, we look at factors that determine the quality or otherwise of software. Software quality models define various quality variables or factors related to software quality requirements. Individuals who define software quality requirements are expected to refer to each factor and, as a result, evaluate the need to include the respective requirements in their requirement specification documents[14]. Adopting a quality model to analyze the quality aspects of the software product ensures quality. The software quality models demand implementation–evaluating the quality of software development and maintenance processes and products. In other words, we want to see how well software development and maintenance procedures meet the criteria or requirements of the different quality aspects or factors reviewed in design reviews, software inspections, software tests, and software quality metrics.

We must bridge the gap between generic characteristics and detailed review questions requiring quantitative measurement. Adding explanatory criteria (sub-factors) for each component is one method to close the gap. As a result, each software quality aspect or factor has many quality criteria. Quantitative and qualitative criteria (sub-factors) are used, with quantitative criteria taking precedence. These quantifiable quantitative criteria aid in formulating software requirements, defining review questions, creating test plans, and creating software metrics.

Supplementary Table 1 shows a quality factor model derived from a combination of the quality factor models employed over the years (McCall, Deutsch and Willis, Evans and Marciniak, ISO/IEC 25010, ISO 9126), with bits of information taken from the works of Galin[14], Laporte and April[18], Malhotra and Pruthi[19] and Awan et al.[20]. It is worth noting that most of these individual models overlap, so the factors found in **Supplementary Table 1** are a universal set of all the factors of the models mentioned above.

3.1.2 Ehlers's Model of Subjective Quality Requirements of E-Learning Systems

Ehlers's model of subjective quality requirements of e-learning systems[21] is a learner-focused and comprehensive quality concept rather than just focusing on instructional or technological interface design aspects. This is clearly shown in the survey results that led to the formulation of the requirements in the model. **Supplementary Table 2** summarizes Ehlers's model in a tabular form. It consists of seven quality fields depicting the user requirement areas and thirty dimensions explaining the quality fields. For example, Quality field 1 is Tutor Support with eight dimensions showing the sub-areas explaining Tutor Support.

3.1.3 Matching of Ehlers's model dimensions to quality factors

Referencing **Supplementary Table 1**, the following matchings are achieved and presented in **Supplementary Table 2**.

Using Quality Field 1, Tutor Support, and Dimension 1, which is explained as Interaction Centeredness, we can determine the quality factors that will be necessary or needed to ensure "Interaction Centeredness" is achieved. Interaction Centeredness relates to communication and interaction between the tutor and the learner. Essential in this interaction is a bi-directional interaction: The learner wants to have tutorial feedback and give feedback to the tutor. The following software quality factors are deduced from the description of "Interaction Centeredness" above:

- *Correctness*: The system's ability to show chats, forum discussions, and the like between the tutor and the student.
- *Efficiency*: The hardware requirements for effective communication.
- *Integrity*: To maintain information security between the tutor and the students.
- *Functional suitability/Functionality*: The ability of the system to serve the purpose of interaction.

- *Productivity*: The rate at which the tutor can use the system to perform an interaction with the student/s.
- *Satisfaction*: The perception of both the tutor and the student/s being satisfied.
- *Understandability*: Availability of a library to learn how effective communication between a tutor and student/s is done.

This kind of Analysis is done for all 30 dimensions; the results are in **Supplementary Table 2**.

3.1.4 Analysis of the quality factors in Supplementary Table 2

We first list all the software qualities identified for all 30 Dimensions and then perform a simple count on them, or in other words, find the modal value for each identified factor to help further Analysis. **Supplementary Table 3** below shows the list and modal value of each identified factor in **Supplementary Table 2**.

Supplementary Table 2 shows that except for Survivability and Usability, the remaining software Quality factors are on the high side, with Reliability, Efficiency, Flexibility, Understandability, Satisfaction, Productivity, and Modifiability topping the Chat in descending order of appearance. Reliability is at the heart of all the factors. The reliability of the system and service is vital for all the other factors to work.

3.1.5 Formulation of the LMS Software Quality Factor Model (LMSSQFM) based on Ehlers's user-based e-learning requirement model

The Analysis in section 3.1.4 forms the basis for the LMS Software Quality Factor Model, which is based on Ehlers's user-based e-learning requirement model. The LMSSQFM comprises 12 quality factors, with reliability at the centre, representing its importance and linkage to all the other factors. The model is represented in Figure 1.

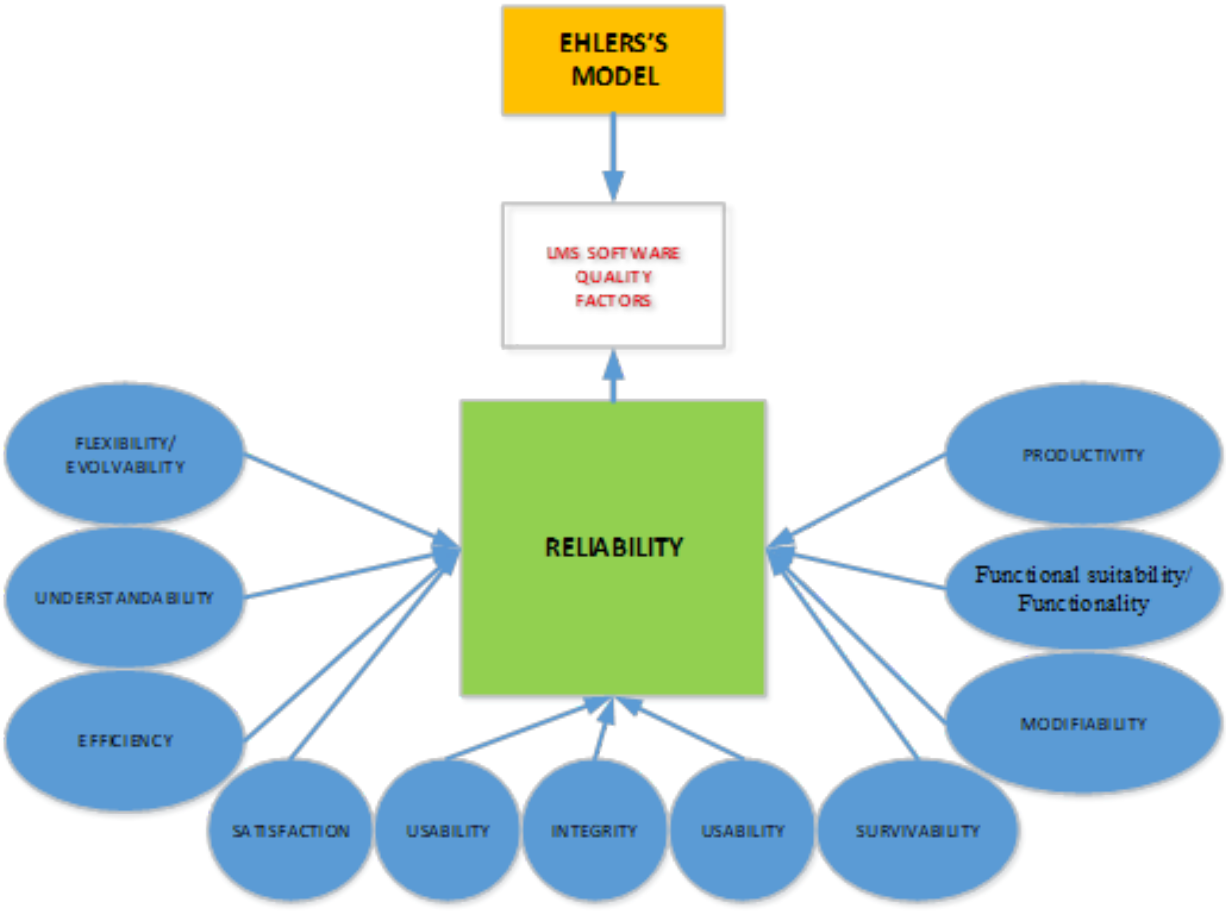

Fig 1. LMS Software Quality Factor Model (LMSSQFM)

4 Conclusion

The research sought to develop an LMS Software Quality Factor Model by matching identified software quality factors from the literature to Ehlers's Model of subjective quality requirements of e-learning systems.

The result is shown in Figure 1. In all, 12 factors were identified to tilt to the user, as is emphasized in Ehlers's model. It was also realized that reliability as a quality factor was crucial for all the other factors. The system and its services needed to be reliable for any other thing to happen. Again, it was revealed that "Efficiency" also had several counts (15 in all), indicating the need for Efficiency of processing, Efficiency of storage, Efficiency of communication, efficiency of power usage (for portable units), time behaviour, and Resource utilization. This covers all the hardware resources needed for the system and the services to run effectively, which is crucial for users. The next factor that also enjoyed several counts following "Efficiency" is "Flexibility/Evolvability", which depends on how flexible the system is to changes and users' needs. This is also significant considering innovations that tutors and students want to bring on board to help in effective teaching and learning. While Thamilarasan et al.[(2)] concluded on "usability", which deals with the scope of staff resources needed to train a new employee and operate the LMS, this paper concludes on "reliability", which deals with failures to provide service; the maximum allowed software system failure rate, the maximum allowed percentage of a software system's downtime, and the maximum allowed recovery times. This can refer to the entire system or one or more of its separate functions.

This research work is not empirical because the factors have yet to be tested quantitatively. Future works can empirically test Ehlers's model with these factors to get a broader view of the relationships. This research is novel from the point of view of determining quality factors for LMS using an existing e-learning model, **Ehlers's user-based e-learning requirement model,** in this particular instant.

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