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ISO 9126 external systems quality characteristics, sub-characteristics and domain specific criteria for evaluating e-Learning systems

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ABSTRACT

Universities and technical institutes in a developing country like South Africa are faced with the challenge of adopting and embracing a course management system (CMS) to implement e-learning. Course management systems are interactive systems that enable educators, with minimal technology expertise to design, develop and deliver e-learning content as well as measure the outcome of e-learning courses [26]. This class of software will allow these higher education institutions to stay abreast of latest educational technologies, to be competitive in the higher education domain and to afford their stakeholders new innovative ways of teaching and learning. Much of the research on CMSs has had a technology focus or has been limited to studies of adoption. Little attention has been paid to evaluating users' views of quality of CMSs with the aid of a software quality model. This paper considers the adoption of the ISO 9126 model for selecting generic external systems quality characteristics and sub-characteristics appropriate for user evaluation of CMSs. To this end, domain specific quality criteria have been created that relate to selected characteristics and sub-characteristics of the ISO model. These quality criteria can be used to evaluate the association between end-user satisfaction ('quality of use' characteristic) and individual external quality sub-characteristics for CMSs. External systems quality is operationalised by 6 quality characteristics: functionality, reliability, effectiveness, usability, maintainability and portability namely and 22 sub-characteristics. The construct of 'quality in use' is operationalised by characteristics namely effectiveness, productivity, security and satisfaction.

Categories and Subject Descriptors

K.5.1 [Software Engineering]: General- standards;

K.3.1 [Computers and Education]: Computer Use in Education
– computer-assisted learning.

General Terms

Measurement, Design, Reliability, Security, Human Factors, Standardization.

Keywords

e-learning, external systems quality characteristics, quality in use, ISO 9126 quality model, course management systems

1. INTRODUCTION

In higher education institutions, electronic teaching and learning environments have been adopted and are becoming increasingly popular among academics. These environments are popularly known as course management systems. Course management systems are interactive systems designed to enable subject matter experts, with little or no technology expertise to design, create and deliver e-learning content as well as measure the results of e-learning courses [26]. There has been limited attention given to assessing 'quality of use' for course management systems despite the importance of software quality and its impact on end user satisfaction.

Literature on ISO /IEC 9126 quality model was reviewed to identify quality characteristics and sub-characteristics for measuring external quality of software products. ISO/IEC 9126 categorizes quality from a user perspective as functionality, reliability, usability, efficiency, maintainability and portability. ISO/IEC 9126-2 provides 22 subcharacteristics as an operationalisation of the construct of external quality. The ISO/IEC 9126 model suggests that higher external systems quality is an indicator of higher 'quality in use'.

'Quality in use' is the combined effects of the six categories of software quality when the product is used [12]. ISO/IEC 9126 defines 'quality in use' as 'the capability of the software product to enable specified users to achieve specified goals with effectiveness, productivity, safety and satisfaction in a specified context of use' [14].

'Quality in use' is hence the user's view of the quality of software operating in an environment, and is measured by the results of using the software in the environment rather than properties of the software itself. User satisfaction as a measure of software quality is often used to ascertain software success. Its common usage can be attributed to its ease of application in many areas [17].

The purpose of this paper to establish a theoretical framework comprising domain specific quality criteria relating to selected ISO /IEC 9126 systems quality characteristics and sub-characteristics pertaining to a class of software namely course management systems used in higher education institutions. This theoretical framework would be used to evaluate 'quality in use' of available CMSs from an educators' perspective in a subsequent empirical study.

The first four external quality characteristics of the ISO9126 model namely functionality, reliability, usability and the time behaviour sub-characteristic of efficiency are suitable since they are easily recognisable or observable by educators while interacting with the software [7]. Quality characteristics and sub-characteristics that are difficult to measure and report on by educators would not be considered as they can best be assessed by trained systems professionals. The domain specific quality criteria could then be used in a separate empirical study to demonstrate whether individual external quality sub-characteristics of the ISO 9126 quality model are positively associated with user satisfaction as an operationalised measure of 'quality in use' [17] for available course management systems. Empirical evaluations of this nature would highlight various design flaws which in turn would serve to inform systems designers on the need to address both internal and external system qualities with the ultimate goal of improving 'quality in use' for e-learning systems.

The remaining sections of this paper discusses software quality issues, the ISO/IEC 9126 quality model, domain specific quality criteria related to sub-characteristics of ISO/IEC 9126, and concluding comments.

2. SOFTWARE QUALITY ISSUES

Quality has to do with feeling comfortable and satisfied with the user product [28]. High quality software is an important goal for software developers [23]. Quality is a key determinant of success with regards to the software development effort [5], and hence due cognizance should be taken of software quality characteristics derived from ISO/IEC 9126.

Quality is conceptual whilst measurement is operational [30]. Software quality can be measured internally (by static measures of the code), or externally (by measuring the behavior of the code when executed) [4]. For example, reliability can be measured externally by observing the number of failures in a given period of execution time during a trial of the software, and internally by inspecting the detailed specifications and source code to assess the level of fault tolerance.

An approach to software quality has been proposed where the objective is for the product to have the desired effect in a particular context of use [4]. 'Quality in use' is a term denoting the user's view of quality. External properties (such as suitability, accuracy, fault tolerance or time behavior) will impact on the observed 'quality in use'. A failure of 'quality in use' (e.g. the user is unable to complete a task) could be linked to external quality (e.g. suitability or operability) and the associated internal attributes which have to be modified. Achieving 'quality in use' is thus dependent on adhering to criteria for external measures of the behavior of the software, which in turn is dependent on satisfying related criteria for the associated internal measures [4]. This approach to software quality is depicted in Figure 1.

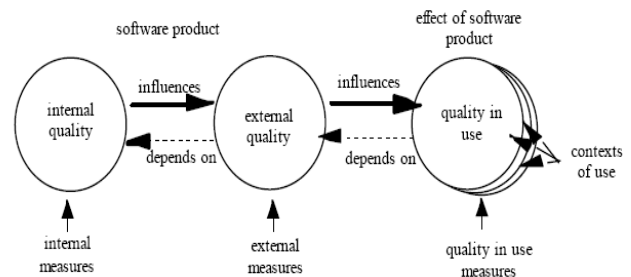


Figure 1: Approach to Software Quality [4]

User satisfaction as an measure of 'quality in use' is more difficult to measure as it is a subjective measure in contrast to accuracy and speed, which are objective measures [8]. Several user satisfaction questionnaires have developed and are available for usage, one of the more popular ones being the Questionnaire for User Interaction Satisfaction (QUIS) [6]. However these questionnaires are general in nature and do not consider the unique characteristics of e-learning systems. The following metrics could be used to measure user satisfaction: the percentage of user statements while performing tasks that are positive versus negative towards the system; the number of times users express frustration or satisfaction; the proportion of users who would prefer using a system over other competing systems [22].

3. ISO 9126 MODEL

The ISO/IEC 9126 defines quality as 'the totality of characteristics of an entity that bear on its ability to satisfy stated and implied needs.' The ISO/IEC 9126-1 defines a quality model with six characteristics namely, functionality, reliability, usability, efficiency, maintainability, and portability which are further subdivided into 22 characteristics. Table 1 provides descriptions of the respective ISO/IEC 9126 quality characteristics.

Table 1: Characteristics of the ISO 9126-1 quality model [20]

Characteristic	Description
Functionality	The capability of the software to provide functions which meet the stated and implied needs of users under specified conditions of usage (what the software does to meet needs)
Reliability	‘The capability of the software product to maintain its level of performance under stated conditions for a stated period of time.’
Usability	The capability of the software product to be understood, learned, used and provide visual appeal, under specified conditions of usage (the effort needed for use)
Efficiency	The capability of the software product to provide desired performance, relative to the amount of resources used, under stated conditions.
Maintainability	The capability of the software product to be modified which may include corrections, improvements or adaptations of the software to changes in the environment and in the requirements and functional specifications (the effort needed for modification)
Portability	The capability of the software product to be ‘transferred from one environment to another. The environment may include organizational, hardware or software.’

None of the quality factors/ characteristics discussed above can be measured directly, but must be assessed in terms of objective sub-characteristics. The quality characteristics defined in the ISO 9126 standard may be classified with respect to the domain “specificity” coordinate [27]. Functionality, for instance, is highly dependent on the educational domain to which course management systems belong. On the other hand, maintainability is a characteristic that can be only evaluated either by the developer or by a third party having access to the technical documentation of the project and the source code. A third class is represented by the quality characteristics that are independent of the specific domain. Portability, for instance, falls into the third category [27].

Sub-characteristics corresponding to the six quality characteristics are depicted in Figure 2.

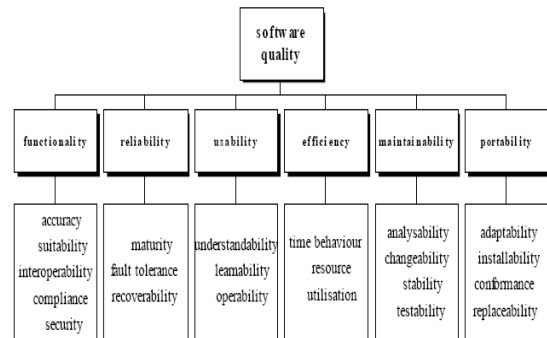


Figure 2: Software quality ISO 9126 [4]

The objective of this suite of standards is to provide a framework for the evaluation of software quality [1]. ISO/IEC 9126 does not prescribe specific quality requirements for software, but instead describes a quality model, which can be applied to any software. This ISO standard includes the user's view and introduces the concept of ‘quality in use’.

The ISO/IEC 9126-1: Software Engineering -- Product quality -- Part 1: Quality model [15].

This standard specifies two distinct models for software quality:

- ‘Internal and external quality is modeled with the same set of six characteristics: functionality, reliability, effectiveness, usability, maintainability and portability.’
- ‘Quality in use characteristics are modeled with four other characteristics: effectiveness, productivity, security and satisfaction.’

The ISO quality model is more complete and does not have the same weaknesses with comparable models such as McCall’s model, the Boehm model etc [2].

Explanations of the 22 sub-characteristics are summarized in table 2.

Table 2: ISO 9126Characteristic and sub-characteristics [7]

Characteristic	Sub Characteristics	Explanation
Functionality	Suitability	‘Can software perform the tasks required?’
	Accurateness	‘Is the result as expected?’
	Interoperability	‘Can the system interact with another system?’
	Compliance	‘Is the system compliant with standards?’
	Security	‘Does the system prevent unauthorized access?’
Reliability	Maturity	‘Have most of the faults in the software been eliminated over time?’
	Fault tolerance	‘Is the software capable of handling errors?’
	Recoverability	‘Can the software resume working & restore lost data after failure?’
Usability	Understandability	‘Does the user comprehend how to use the system easily?’
	Learnability	‘Can the user learn to use the system easily?’
	Operability	‘Can the user use the system without much effort?’
	Attractiveness	‘Does the interface look good?’
Efficiency	Time Behaviour	‘How quickly does the system respond?’
	Resource utilization	‘Does the system utilize resources efficiently?’
Maintainability	Analyzability	‘Can faults be easily diagnosed?’
	Changeability	‘Can the software be easily modified?’
	Stability	‘Can the software continue functioning if changes are made?’
	Testability	‘Can the software be tested easily?’
Portability	Adaptability	‘Can the software be moved to other environments?’
	Installability	‘Can the software be installed easily?’
	Conformance	‘Does the software comply with portability standards?’
	Replaceability	‘Can the software easily replace other software?’

4. e-Learning systems quality criteria relating to selected (sub)characteristics of ISO/IEC 9126 model

Quality criteria (see Tables 3a – 3h) corresponding to the first four quality characteristics listed in table 2 were developed to aid in evaluating users’ view of quality for e-Learning systems. These quality criteria will be used to

obtain feedback from educators in higher education using questionnaires and interviews in a future study to validate the effectiveness of the ISO 9126 quality model for evaluating the quality of e-learning systems.

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Table 3a: e-Learning systems quality criteria relating to functionality sub-characteristic of ISO/IEC 9126 model

Characteristic	Sub-Characteristic	Domain specific quality Criteria
Functionality	Suitability	<p>Educators perceptions of the extent to which the available e-learning system provides an appropriate set of functions for required pedagogic tasks and user objectives such as [9]; [10], [13], [26]:</p> <ul style="list-style-type: none"> • Learning content creation with templates • Content delivery • Management of student records • Tracking students' progress • Communication and collaboration • Organizing students into groups for projects • Managing group discussion on topics • Conducting assessments • Maintaining records of assessment • Maintaining records of teaching materials, aids etc • Assigning tutors to courses • Other tasks...

Table 3b: e-Learning systems quality criteria relating to functionality sub- characteristic of ISO/IEC 9126 model

Characteristic	Sub-Characteristic	Domain specific quality Criteria
Functionality	Accurateness	<p>Educators perceptions of the extent to which the available e-learning system provides expected results or effects for specified tasks and user objectives such as [9]; [10], [13], [26] :</p> <ul style="list-style-type: none"> • making announcements • creating and updating course information • uploading course material • Managing group discussion • Uploading course material • E-mail • File exchange • Calendar • Drawing tools • Chat room discussions • Updating grade books • Conducting online testing • Producing course statistics • Other tasks.....

Table 3c: e-Learning systems quality criteria relating to functionality sub- characteristic of ISO/IEC 9126 model

Characteristic	Sub-Characteristic	Domain specific quality Criteria
Functionality	Interoperability Data Compatibility	<p>Educators' perceptions about capability of the e-learning system to :</p> <ul style="list-style-type: none"> • 'access content from, and provide content to digital libraries and other e-learning systems' [18] • export data (i.e making data like marks available to other systems) • import data (e.g class lists from SMS & curricula materials developed by educational and academic publishers [9]

Table 3d: e-Learning systems quality criteria relating to functionality sub- characteristic of ISO/IEC 9126 model

Characteristic	Sub-Characteristic	Domain specific quality Criteria
Functionality	Compliance	<p>Educators perceptions about the capability of e-learning system to adhere to standards [21] viz:</p> <ul style="list-style-type: none"> • Defines a common format for information about learners' i.e. 'including preferences, details, objectives, competencies, activities, interests, etc.' which can be freely exchanged among systems(IMS Learner Information Packaging specification) • It describes 'how to sequence activities within a course' (IMS Simple Sequencing specification) • 'It models different aspects of a Unit of Learning of a course. Such aspects are the different roles, activities or resources, the synchronization of different user actions, the activity or resource sequencing depending on conditions, etc.' (IMS Specification Learning Design) • Describes 'how digital resources can be organized into logical learning units called content packages e.g. how smaller units of learning (e.g. lessons, activities) should be arranged' (IMS Specification Content Packaging) • Define generic ways of specifying tests, assessments and questions that can be realized in many different systems. (IMS Specification Question and Test Interoperability) • Complies with information security Standard - ISO 27001[16]. • Complies with WAI WCAG 1.0 AAA guidelines to facilitate Content Sharing/Reuse • Enables sharable, durable, and reusable Web - based learning content(Sharable Content Object Reference Model (SCORM)) [25] • Complies with standards such as that of underlying technologies such as HTML and XML (W3C standards) [29]. • Complies with standards for accessibility of Web content (W3C)[29] • Complies with instructional Standards for sharing instructional materials with other online learning systems [13]

Table 3e: e-Learning systems quality criteria relating to functionality sub- characteristic of ISO/IEC 9126 model

Characteristic	Sub-Characteristic	Domain specific quality Criteria
Functionality	Security	<p>Educators perceptions about security mechanisms of e-learning system to maintain the confidentiality of information about learners especially marks [19], [24]:</p> <ul style="list-style-type: none"> • Identification and authentication of staff & students where username and passwords will be used. • SSL for login procedures and encryption of critical data • HTTPS for web pages displaying or transmitting sensitive data • Encryption for encoding data as it travels over the network • Password protection of all courses, events and resources • A secure set of user privileges (role-based access control), which determine permission levels (creation and updating learning materials for teachers) that users need to control, manage, and update content. • Private messaging or lecturer-to-student messaging [11] • Screening of student posts to prevent distribution of undesirable material • Security mechanisms for chat rooms

Table 3f: e-Learning systems quality criteria relating to reliability sub- characteristics of ISO/IEC 9126 model

Characteristic	Sub-Characteristic	Domain specific quality Criteria
Reliability	Maturity	Educators' perceptions about the reliability of the system [23] wrt: <ul style="list-style-type: none"> Frequency of system failure(failure rate) Error-free system functions Presence of faults/software bugs
	Fault tolerance	Educators' perceptions about the fault tolerance capability of the system [23] wrt : <ul style="list-style-type: none"> the ability to maintain a specified level of performance or continue functioning in the event of software fault(s) system response to invalid input data level of service availability
	Recoverability Error Handling	Educators' perceptions about the recoverability of the system [23] wrt: <ul style="list-style-type: none"> Allowing users to take corrective action once an error has been recognized by the system Recovering quickly from a failure Resuming work soon after a failure

Table 3g: e-Learning systems quality criteria relating to usability sub- characteristics of ISO/IEC 9126 model

Characteristic	Sub-Characteristic	Domain specific quality Criteria
Usability	Understandability	Educators' perceptions of the understandability of e-learning system with respect to [8]: <ul style="list-style-type: none"> Consistent use of terms throughout the system Consistency of layout Functions of buttons System terminology related to pedagogic tasks Consistent positioning of error messages on the screen Clear prompts for input Informing users of systems progress Match between task in interface and task as understood by user and supported by system Ease of understanding information (and documentation) provided by the system
	Learnability	Educators' perceptions of learnability of e-learning system with respect to [6]: <ul style="list-style-type: none"> The level of difficulty when learning to operate the system The level of difficulty when exploring new features by trial and error The level of difficulty when remembering names and use of commands The ease and straightforwardness of performing tasks The usefulness of help messages on the screen The clarity of supplemental reference materials (online help, onscreen messages and other documentation)
	Operability	Educators' perceptions with regards to operating the e-learning system: <ul style="list-style-type: none"> The level of ease with which tasks can be performed such as uploading resources; organizing students into groups etc..... The clarity with which information is organized The logic and clarity in which sequence of screens presented The level of ease when correcting errors Effectiveness of help systems in use Ease of finding required information
	Attractiveness	Educators' perceptions with regards to viz.: <ul style="list-style-type: none"> Pleasantness of systems interface Attractiveness of systems interface

Table 3h: e-Learning systems quality criteria relating to efficiency sub- characteristic of ISO/IEC 9126 model

Characteristic	Sub-Characteristic	Domain specific quality Criteria
Efficiency	Time Behaviour	<p>Educators' perceptions wrt to the capability of the system to [23]:</p> <ul style="list-style-type: none"> • provide appropriate response time, processing time and throughput rates when performing the various functions (e.g uploading/ downloading files, online testing) under stated conditions • have an acceptable level of performance when large numbers of students are accessing the system at any one time • handle large documents • locate operations & information quickly • perform a sequence of operations (data input) with economy of motion

The domain specific and independent criteria contained in table 3 would be used to develop a survey instrument to measure user satisfaction for each corresponding ISO/IEC 9126 sub-

5. Conclusion

This framework of external quality system (sub) characteristics and corresponding quality criteria can be used to test the theoretical proposition that higher external quality implies higher quality in use for users of e-Learning systems. Quality criteria corresponding to external quality (sub) characteristics can be used to test the (sub) characteristics that strongly influence user satisfaction for e-learning systems.

Measuring external quality to examine its effect on 'quality in use' would help systems designers to make necessary additions and or revisions to design content and features to improve users' views of quality. Evaluators, testers and developers will be able to evaluate software external product quality and address external quality issues. Educators, educational administrators, and higher education institutions adopting CMSs to implement e-learning

characteristic. This survey would be administered in the second phase of the study.

have a vested interest in evaluating 'quality in use' as they inform the decision making process with regards to the choice of CMS.

One of the limitations of this paper is that it focuses only on one characteristic of quality in use namely user satisfaction. Further research is required to investigate how external quality sub-characteristics influence the effectiveness, productivity, and safety characteristics of the 'quality of use'.

Recommendations for future work would be to conduct an empirical study to ascertain whether external quality as epitomized by quality characteristics/sub characteristics is associated with 'quality in use' for e-learning systems.

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