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Assessing the Quality of M-Learning Systems using ISO/IEC 25010

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Abstract

Mobile learning offers several advantages over other forms of learning like ubiquity and idle time utilization. However for these advantages to be properly addressed there should be a check on the system quality. Poor quality systems will invalidate these benefits. Quality estimation in M-learning systems can be broadly classified into two categories: software system quality and learning characteristics quality. In this work, a M-Learning frame work is first developed. Software System quality is then evaluated following the ISO/IEC 25010 Software Quality model by proposing a set of metrics which measure the characteristics of a M-Learning systems. The applications of these metrics were then illustrated numerically.

Keywords

M-Learning, ISO/IEC 25010, Quality Characteristic, Requirements, Measurement, Framework, Mobile.

1. Introduction

There are an estimated 6 billion mobile phones in the world today. This is about six times the number of Personal Computers (PC) available [15]. In fact the processing power that is available in certain high range mobile phones is similar to those of low end PCs available in today's market. These facts make us speculate that in near future top range mobile devices will replace the PCs in most applications. Coupled with this, there has been a lot of advancement in the field of mobile communication. M-learning enables learning independently of place and time, is ubiquitous through the use of wireless networks and mobile devices, such as personal digital assistants (PDA), cellular phones, smart-phones, and mp-3 devices [6]. These changes make us believe that M-learning could signal the end of classroom learning in the near future [1].

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In this work, we first develop a M-learning framework which can be adapted to the design requirements and factors that are critical to the success of a M-learning application. However, for all the advantages of M-learning to be addressed successfully, the quality of the system developed should be high. To this end, we derive a set of metrics which measure the quality of M-learning systems. For this we extend the characteristics and sub characteristics of ISO/IEC 25010 Software engineering - Software product Quality Requirements and Evaluation (SQuaRE) model [13] that are relevant to M-learning. The derived metrics are then measured using a set of relevant attributes and suitably interpreted. The uses of these metrics were then illustrated numerically.

2. A framework for M-Learning

Mobile devices along with wireless connections are central to the concept of M-Learning system giving access to the learning environment (Table 1). This environment in turn generates a set of learning characteristics. The involvement of the system developers, tutors and learners should validate these characteristics.

2.1 Devices and infrastructure

The first and foremost advantage of M-learning over traditional class room learning and E-learning is anytime anyplace learning. Thus a busy company executive who needs to travel a lot can utilize this idle time by giving a test or taking a course; this is not possible in traditional learning. This can be achieved in several ways. Tutors may mail the course materials to the learners. Learners in turn may SMS test answers to the tutors. The location of the learner during the learning phase also affects the learning process. If the learner is in remote location network connectivity may be poor due to obstacles. Thus bandwidth availability is an important factor influencing the success of M-learning. Gafani[4] has identified a set of properties that are typical to handheld devices. These devices in general have a poor user interface, small memory size, low processing power, short battery life, small screens. Georgieva [9] in her comparative study has identified two types of M-learning systems: offline and online. In offline systems domain data is loaded in the device memory before the system is used. These systems do not depend on network connectivity. Online systems can access the learning environment at any instant of time using web services.

Table 1: A framework for M-Learning

	Components Involved	**Implementation Requirements**	**Desirable Outputs**
Mobile Device and Connectivity	PDA, Cellular phones, Smart phones, Tablets, MP3 Devices	Bandwidth Availability, Device Quality, Secure Network	Ubiquitous Learning
Learning Characteristics	Learning Contents, Learning Methods, Learning Impact	Reusable Learning Objects, Personalized and Collaborative learning tools	SMS, Alerts, Instant Message, Schedule Calendars, Chat forums, Discussion Boards
Development and Use	Learners, Tutors and Developers	Software Management	Course materials, Tests, Assignments, Feedback
	M-Learning System		

Pocatilu [3] has identified several security concerns in M-learning applications. Online exams, assessments and user management have high security requirement whereas content management, quizzes have low security requirement. The importance of the mobile device itself cannot be overemphasized: the device may be lost or stolen. There are various types of devices which can be used for m-learning: Personal Digital Assistants (PDA), Mobile phones, MP3 devices, tablets along with a host of other devices. In our work we concentrate on mobile phones.

2.2 Learning Characteristics

BenMoussa[19] has identified several advantages of M-learning in addition to those discussed in the previous section. Filtering information according to personal needs is personalized or individualized learning. Instant interactivity is achieved by collaborative learning. Motiwala[14] suggests use of alerts and scheduling calendars for personalized learning and Instant Messaging , Discussion boards and chat forums for collaborative learning. According to Henry[11], there should be continuous assessment of learning. This could be in the form of unit tests, submission of assignments and term end exams. The evaluative reports of these should be sent to the learners for self correction. Also learning should be in short bursts. Liu's[2] finding in a survey that most learners prefer a course length less than six hours justifies this. His survey also concludes that 8-12 am is the best time for M-learning. Designing and identifying the necessary learning materials is another important goal of M-learning. Courses and Learning Objects can be designed specifically keeping the weak students in mind. Greg [10] has suggested two methods for doing this. Tutors can assemble learning materials themselves keeping the needs of their learners in mind. Also a vast resource of learning materials is available in the web. Tutors can use these materials instead of creating new ones. Thus learning object reusability helps to optimize the study material development time. Finally the impact created by M-learning courses on the learners should also be evaluated.

2.3 System development, use and support

Three major players are involved in the development and use of M-learning environment [15]. The learner has to attend courses, take online tests, send assignments before due date and send course feedback. The tutors have to create and identify course contents, assess the exams and assignments, send suitable feedback to the students. The system developer has to define and implement the databases required for storing M-learning contents, details relating to learner and tutor management, messages received and sent to learners. They also need to identify suitable web services and servers to interface mobile devices with the database. Finally, the learner may not be very conversant with the use of mobile devices for learning purpose. Suitable training should be imparted to them to avoid disillusionment with such type of learning [15].

3. M-Learning Systems quality measurement

The above framework illustrates several advantages of M-learning application, namely ubiquity, personalized and collaborative learning, enhanced student satisfaction. However, as discussed earlier a substandard system developed will nullify these advantages. The framework proposed in the previous section suggests that quality in M-learning systems can be measured at two ways. One way is to measure software and system quality from the technical point of view. Another way is to measure the quality of learning characteristics. We focus on the first aspect. In this section we first specify the factors that affect quality of M-Learning. There are several models proposed for quality definition such as Boehm's Model[18] and McCall's Model[17]. The most recent of these is ISO/IEC 25010 Software engineering - Software product Quality Requirements and Evaluation (SQuaRE)model [13] which was developed in 2008.We can then evaluate a M-learning system with the parameters developed from this model. The research methodology used is illustrated in Fig 1.

3.1 Factors affecting quality in M-learning environment

Some of the factors pertaining to hardware requirement like low processing power, small keypad are already discussed in Section 2. Factors relating to infrastructure include high cost of implementation(due to the use of mobile devices, suitable learning object preparation and internet connectivity), diverse types of devices and networks, locational diversity leading to varied communication support. Finally factors relating to learning characteristics include small units of information transfer between the tutors and the learners, poorly organized contents, small course lengths. We summarize these problems below for use in section 4:

i. Small Keyboard.
ii. Small memory size.
iii. Low processing power.
iv. Low battery power.
v. High cost of implementation.
vi. Diverse devices and networks.
vii. Locational diversity.
viii. Small units of information transfer.
ix. Poorly organized learning contents.
x. Small course lengths.
xi. Small screen

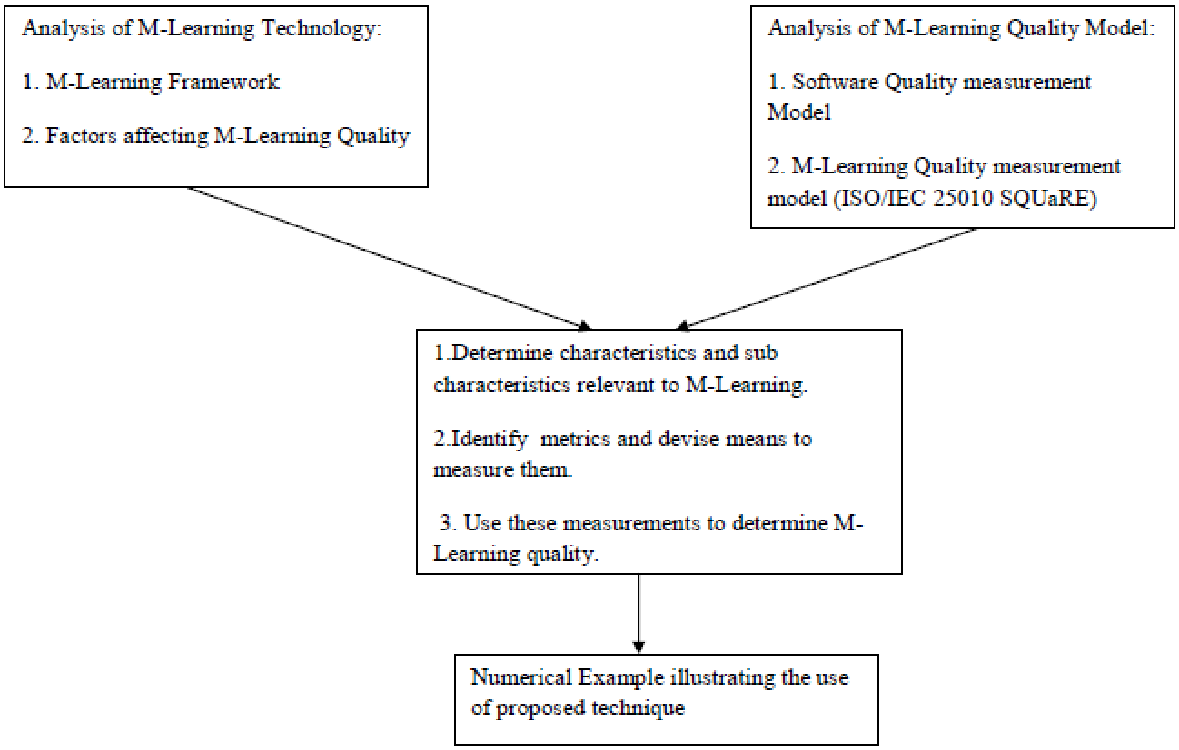

Fig 1: Research Methodology used in this paper

3.2 ISO/IEC 25010 model

We have argued in the previous section that developing high quality system is of prime importance to realize all the benefits of M-learning. This can be achieved by defining appropriate quality characteristics which are suitable to evaluate the M-learning system. We use ISO/IEC 25010 Software engineering - Software product Quality Requirements and Evaluation (SQuaRE) model [13] for this purpose. This standard consists of two parts: A software product quality model composed of eight characteristics, which are further subdivided into sub characteristics and a system quality in use model composed of three characteristics, which are further subdivided into sub characteristics. We evaluate the M-Learning system on the basis of software product quality model as it should be used when setting quality requirements for software products [13]. Below we show the diagram (Fig 2) of Software product quality model and discuss *only those* characteristics and sub characteristics that are relevant to M-learning environment.

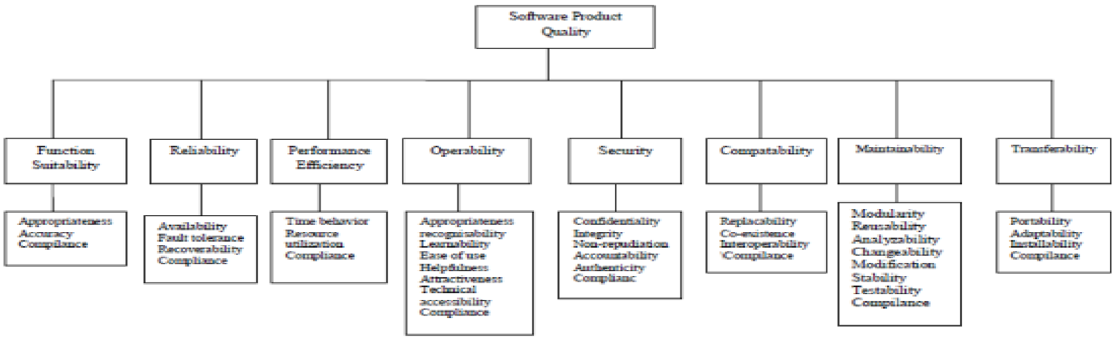

Fig 2: Software Product Quality Model

Function suitability includes appropriateness, accuracy and functional suitability compliance. Appropriateness here means that the M-learning system so developed should meet all the needs of the learner and the tutor.

Reliability includes availability, fault tolerance, recoverability, and reliability compliance. By fault tolerant we mean that the M-learning system should be able to maintain a certain level of performance in spite of poor network coverage, device malfunction and other factors. Recoverability is required because the system should be able to return to the previous state even if there is a network failure.

Performance efficiency includes time behavior, resource utilization, and performance efficiency compliance. The communication time between the server and the client in M-learning system should be as less as possible for fast downloads and hence the need of time behavoiur.

Operability includes appropriateness recognizability, learnability, ease of use, helpfulness, attractiveness, technical accessibility, operability compliance. Ease of use means that the learners and the tutors should be able to master the system without any external help. The system also should be attractive to use for the users in spite of poor interface, small screen and keypad.

Security includes confidentiality, integrity, non repudiation, accountability, authenticity and security compliance. M-learning database contains a lot of information about learners which should not be accessed by all users. Thus suitable authentication mechanism is required for the students and tutors alike. Confidentiality is also needed in case of evaluations.

Compatibility includes repacability, co-existance, interoperability, compatibility compliance. Co-existence is important because the learner should be able to execute other applications on the mobile device while executing a learning application.

Maintainability includes modularity, reusability, analyzability, changeability, modification, stability, testability, maintainability compliance. We have already discussed about the need of reusability of learning objects in the previous sections.

Transferability includes portability, adaptability, installability, transferability compliance. Installibility is important because the application should run on a wide range of devices, operating systems and mobile devices.

Several researchers have concentrated on quality estimation in M-Learning applications. Spriestersbach et al[5] in their work has developed an "adjusted" ISO 9126 model that can ensure the quality of mobile web application. They also discuss how various challenges in mobile web application development may be solved using this model. Gafani[4] has designed a set of metrics form the characteristics of ISO/IEC 9126. These metrics were measured by a set of formula derived from the relevant attributes and an interpretation of these was developed. These interpretations were then empirically and mathematically validated using the "PDA Experiment".

4. Quality metrics in M-learning systems derived from ISO/IEC 25010

In this section we develop the metrics that determine the quality of M-learning. The metrics are first defined and then measured using related attributes. Finally an interpretation of these was developed. We follow the notation adopted by Kitchenham [20].

Table 1 lists the metrics derived from the characteristics of ISO/IEC 25010. It also shows the factors that affect the corresponding quality characteristic. These factors were specified in section 3.1.

Table 2: Metrics derived from quality characteristics and the factors affecting them

Characteristic	Sub Characteristic	Corresponding metric in M-learning context	Factors (defined in Section 3.1) that affecting quality
Function Suitability	Appropriateness	Feature completeness	(v)
Reliability	Fault Tolerance	Average prob. of retrieving information from device memory	(ii),(iii),(iv)
	Recoverability	Average resume time after disconnection	(vi),(vii)
Performance Efficiency	Time behavior	Average server response time	(vi),(vii)
Operability	Ease of use	Friendly user interface	(i),(xi)
	Attractiveness	Message compaction	(i),(ii),(iv),(xi)
Security	Authentication, Confidentiality	System Security	(vii)
Compatibility	Application co-existence	Multiple application co-existence	(ii),(iii),(iv),(v),(vi)
Maintability	Reusability	Learning content reusability	(viii),(ix)
Transferability	Installability	Installation Success	(ii),(iii),(iv),(vi)

We now define these parameters and measure them by stating the relevant attributes and interpret these results.

(A) Average probability of retrieving information from device memory

Definition: The degree to which certain data generated during learning process that could not be transmitted due to network problems still exists in device memory.

Attributes Measured:
Number of disconnections occurred during transmission =I
Number of times information available in device memory=A
Computation: X=A/I.
Interpretation: Values closer to 1 indicates most of the data lost during transmission still exists in device memory.

(B) Feature Completeness

Definition: The degree to which all the features proposed in design can actually be implemented.
Attributes Measured: Number of features proposed in design=P
Number of features actually implemented=I
Computation: X=I/P.
Interpretation: Values closer to 1 indicates most of the proposed features were actually implemented.

(C) Average resume time after disconnection

Definition: The degree to which the M-learning system can reestablish connectivity in the event of network failure due to poor bandwidth.
Attributes Measured: Time interval for which mobile device remains disconnected for task i $=t_i$
Total number of disconnections=n
Serial number of the disconnection=i
Computation: $X = (\sum_{i=1}^{i=n} t_i)/n.$
Interpretation: Lower Value indicates lesser disconnection time.

(D) Average server response time

Definition: The degree to which the M-learning system provides appropriate response to the learner's queries irrespective of location and time.

Attributes Measured: Time taken to get response to the query from the server for task i $=t_i$

Total number of tasks=n

Serial number of the task=i

Computation: $X = (\sum_{i=1}^{i=n} t_i)/n$.

Interpretation: Lower value indicates lesser response time.

(E) Friendly user interface

Definition: The degree to which the constraints of inputting data like small screen and keypad can be overcome.

Attributes Measured: Number of data inputs with radio buttons=Radioflds

Number of data inputs with check boxes=Chekbox

Number of data inputs with list boxes=Listbox

Total number of fields=Totflds

Computation: X= (Radioflds+ Chekbox+ Listbox)/ Totflds

Interpretation: Value closer to 1 indicate most field are input with radio buttons, check and list boxes and hence have friendly interface.

(F) Message Compaction

Definition: The degree to which the M-learning system enables easy exchange of SMS among learners and tutors irrespective of location and time.

Purpose: The learner needs to send test answers, assignments to the tutor in the form of SMS. Similarly the tutor also needs to send schedules and feedback to the learner. Due to the lack of bandwidth these SMS should be as compact as possible.

Attributes Measured:

Length of message in characters to perform task i= MassLi

Maximum message size supported by the editor=MesssM

Total number of messages used for computation=n

Computation: $X = (\sum_{i=1}^{i=n} MassL_i)/n * MesssM$.

Interpretation: Lower value indicate shorter messages and hence better.

(G) Application co-existence

Definition: The degree to which several other applications like attending a phone call, listening to music etc can be executed in a mobile device while executing an M-learning application without any detrimental impacts.

Attributes Measured:

Maximum number of applications that can be executed simultaneously while running a M-Learning application=M

Total number of applications=A

Computation: X=M/A.

Interpretation: Value closer to 1 indicates more applications can be executed while running a M-Learning application.

(H) Learning content reusability

Definition: The degree to which a learning object can be used by more than one learner.

Attributes Measured: Number of times LO i is accessed=$LOcount_i$

Total number of learning objects=n

Serial number of the LO=i

Computation: $X = (\sum_{i=1}^{i=n} LOcount_i)/n$.

Interpretation: Higher values indicate greater degree of LO reuse.

(I) Installation Success

Definition: The degree to which the M-learning software can be successfully installed or uninstalled across various networks and device types.

Attributes measured: Number of device types=InstalDev

Number of network types=InstalNet

Number of device types where application successfully installed=IDev

Number of network types where application successfully installed=INet

Computation:

X=(IDev+INet)/(InstalDev+InstalNet)

Interpretation: Values closer to 1 indicate greater degree of installability .

(J) System Security

Definition: The degree to which authentication, encryption and confidentiality mechanism exist in the system.

Attributes measured:

$$A,E,C = \begin{cases} 1 & \text{, if authentication, encryption and confidentiality check mechanism exist respectively.} \\ 0 & \text{, otherwise.} \end{cases}$$

Computation: X=(A+E+C)/3.

Interpretation: A value of 1 indicates all the three features are present in the system.

5. An Example

The above section provides a set of metrics which could be used as an indicator to measure the quality of M-Learning. In this section we propose to illustrate these numerically. We assume two M-Learning systems namely A and B. We further assume a set of realistic values for the attributes of each metric. Based upon the formula proposed above we compute the values of X. In order to scale these in [0,1] we apply the transformation Y=1/X. In some cases when this transformation yields values that are too small we apply the transformation Y=(MAX-X)/MAX. For simplicity we call these values X.

We note the nature of the transformations indicate higher value of X enhances quality. The sum totals of X_A and X_B indicate that system A is marginally better than system B qualitatively.

The details are shown in the table below.

Table 3: Mathematical validation of the derived metrics

	Attributes of A	**Attributes of B**	**Transformation applied**	X_A	X_B
Feature completeness	I=50, A=27	I=50, A=22	None	0.54	0.44
Average prob. of retrieving information from device memory	P=15, I=12	P=13,I=9	None	0.80	0.69
Average resume time after disconnection	$\sum t_i$ =540, n=15	$\sum t_i$ =712, n=18	Y=(MAX-X)/MAX	0.28	0.20
Average server response time	$\sum t_i$ =377, n=15	$\sum t_i$ =412, n=15	Y=(MAX-X)/MAX	0.25	0.27
Friendly user interface	Radioflds=12 Listflds=10 Checkflds=11 Totflds=52	Radioflds=09 Listflds=11 Checkflds=13 Totflds=62	None	0.63	0.53
Message compaction	∑MessLi=1876 MessM=140 n=20	∑MessLi=2173 MessM=140 n=31	Y=(MAX-X)/MAX	0.67	0.50
Security	A=1 E=0 C=1	A=1 E=1 C=1	None	0.67	1.00
Multiple application co-existence	M=7 A=11	M=6 A=10	None	0.64	0.60
Learning content reusability	∑LOcounti=73 N=15	∑LOcounti=82 N=13	Y=1/X	0.20	0.16
Installation Success	InstallDev=5 InstallNet=6 Idev=3 Inet=5	InstallDev=6 InstallNet=5 Idev=3 Inet=4	None	0.73	0.64
Total Score				5.41	5.38

6. Conclusions and Future Work

This work evaluates a M-learning framework with the help of ISO/IEC 25010 model. The output is a set of metrics which were illustrated numerically. However this evaluation was done purely from the technical point of view. In our view ISO/IEC 25010 model alone is insufficient to measure M-Learning quality because it measures the software and system quality only. It does not measure the learning characteristics like the effectiveness of the learning objects in learner's context, personal and collaborative learning and the learning outcome.

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