Information Quality Characteristics for M-Learning Applications

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***Abstract*—This research study investigates the potential to apply a quality analysis process for mobile learning (M-learning) software applications in accordance to a defined set of information quality characteristics in attempt to increase the level of quality in the mobile learning systems. This empirical study is conducted on widely accepted and used M-learning application form both close source and open source systems comprising a known reasonable amount of MLOC, medium-scale. Four M-learning applications were selected for conducting this study including Moodle, Blackboard, Edmodo and Schoology. The systems are statically analyzed and examined to determine if it meets the proposed quality characteristics or not. For each system the features and techniques used with respect to the defined characteristics are determined and tabulated. This study focuses mainly on particular information quality characteristics include maintainability, reusability, testability, and security. The data shows that the approach is applicable and effective but needs further formalization and improvement to be effectively implemented. New ideas are additionally proposed for future work to include other dimensions of the M-learning application quality characteristics such as availability, reliability, performance, usability, and functionality. This empirical study is part of funded research project investigating the development, adoption and dissemination of M-learning in Oman.**

***Index Terms*—Mobile learning, M-learning, Mobile Application, Information Quality Characteristics, Quality Management.**

I. Introduction

With the recent development and improvement in wireless network technologies and devices mobility, different types of learning and educational approach has been reported, e.g. learning using short messages, SMS registration, parents reporting using SMS and emails, learning vocabulary and practice questions [1, 2]. Mobility added the ability to access information while on the go using different general purpose mobile devices e.g. laptops, smart phones, tablets and PDAs. That is, the improvement in information and communication technologies and mobile computing have led to the development of new learning approached called Mobile learning or M-learning. M-learning is defined as the use of general purpose mobile devices for learning purpose and process. The priceless, lightweight and portability of the mobile devices have a played a major role in its popularity, and usage for general purposes compared to other regular devices like desktops.

In spite the fact that most of today's schools and even homes have an access to desktop machines, studies have shown that students express more desire to use lightweight mobile devices and find it more enjoyable and practical with their everyday life style and for the learning process [3]. Most of modern Mobile devices are designed to offer a promising and effective approach of communication and flexible method of learning. They introduce a potential promise to improve the current educational and learning styles and techniques to become more collaborative, interactive, interesting and widely available in an effective cost. Despite a long history and huge amount of benefits associated with M-learning, it is still considered as a new learning approach and has some limitations some of which were already defined such as screen size, battery live, storage capacity, transmission rate, performance, architecture pattern, and most importantly the lack of standard of selection criteria [4]. Additionally, some usage drawbacks were reported such as the regulations of some schools that inhibit the usage of mobile devices during formal education process including class time.

As in every software and automation process, it is necessary to provide a quality management process in order to promote effective adoption and wide dissemination of M-learning initiatives, and to insure a certain degree of quality for M-learning services. Specially, when this type of software systems deals with very sensitive information that demands more privacy and governed availability in order to offer reliable services. This article attempts to propose and develop significant and practical information quality criteria that should guide learners and learning providers in the development, selection, adoption, and evaluation of effective M-learning applications. M-learning quality is a combination of characteristics that have to be met which deal with all the service architecture that required by the applications to function properly with liability and robustness, which may include many aspects starting from the software development, ending with network availability and system interoperability, since they are expected to work on different platforms. In this study, we are interested in highlighting the most relevant

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information quality characteristics that affects both individual learners and organization in selecting their M-learning products.

Good quality characteristics in M-learning area lead to an increased level of quality in the learning and educational system. The M-learning services are intended to be used in all educational systems, at all levels, having a complementary not replacement role. The study presented in this paper focuses information quality characteristics on M-learning tools. Which were drawn mainly from the background studies, users' manuals and feedbacks, and analyzing standards for software quality. This work contributes in several ways. First, it is one of the only few studies on the potential to propose new standards that can be used to develop some criteria for measuring the quality of mobile learning systems that can be used by both the learners and the providers for choosing a reliable mobile learning systems that meets their expectations. Our findings show that the characteristics we used can be applicable and practically used for intended purpose. Our study also shows that function most of the mobile learning applications used in this study meets the initial characteristics proposed in this study. This knowledge will assist researchers in formulating and directing their work to address this problem.

The remainder of this paper is organized as follows. Section II presents a definition of the M-learning environment and architecture and defines problem and related work on the topic of mobile learning and its challenges. Section III presents the insight on the Information quality characteristics should be considered in any process concerning the quality of mobile learning applications. Section IV describes the methodology we used in the study along with the different quality characteristics used along with how we performed the analysis to identify each aspect and analyze each related system feature. Section V introduces some facts about the chosen systems in this study. Section VI presents how the study is conducted and the findings of our study of four software systems. There is a discussion of results in section VII followed by conclusions.

II. M-LEARNING

The recent developments in information and communication technology specially the Internet technology supports the improvement in distance learning (D-learning) using electronic learning (E-learning) and virtual learning (V-learning) tools. These also improve the overall learning and educational process, and supports learners and instructions interaction. Which tend to encourage the participation in different learning activities such as discussion groups, collaboration and problem solving. The prompt improvement in mobile technologies has enhanced the learning platforms to be more enjoyable, interesting, interactive and collaborative using M-learning software apps. Mobile technologies are usually supported by built-in web page browsers, voice recognition systems and/or global positioning sensors. Mobile technologies also have high abilities of photo and video stream processing, and advanced Internet wireless connectivity [5, 6, and 7]. This helped in the development of new trend in learning processes called M-learning. M-learning is a mobile application that offers different learning activities and uses the advantage of wireless and mobility technologies in the learning process [8]. M-learning has also been defined as the consumption of learning materials using any type of mobile devices. Some researcher has defined M-learning as E-learning using mobile devices [9, 10, and 11]. M-learning approach is concerned with supporting of learners and instructors to access information, knowledge and learning materials anywhere and at any time. M-learning endeavors to provide flexible, interactive, and robust learning approach as complementary to the traditional and E-learning systems. Although M-learning provides many benefits, it encounters many obstacles and challenges [12, 13, and 14].

III. QUALITY CHARACTERISTICS

Information quality characteristics refer to the desirable features of the M-learning application, such as maintainability, reusability, testability, robustness and, security. The selected criteria differ from the set of criteria's in the empirical study of software quality characteristics based on open source software OSS selection [15] to select adoption criteria for OSS [16], features about information quality, system quality and service quality were found to be critical. This study focuses mainly on particular information quality characteristics include maintainability, reusability, testability, and security. This study is conducted in order to contribute to the success of M-learning development and adoption among potential developers and users.

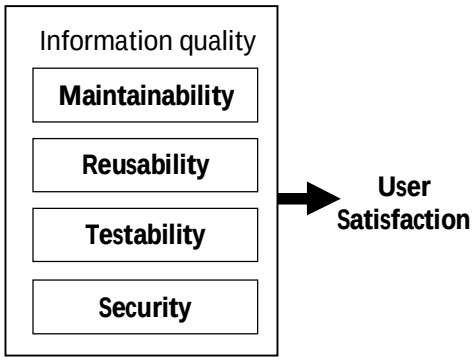

Fig. 1. Information quality characteristics for M-learning applications

IV. METHODOLOGY

Four M-learning applications are selected and weighted based on criteria that has been built from different research literature review, system documentations, user manuals, standard for software quality and guidelines, personal knowledge and user feedback. The second step defines a set of information quality characteristics, the analysis of each criterion for different M-learning application, considers that all resources are not taken into account since not all listed resources are available for each and M-learning application.

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The methodology third step was focused on extracting the required information.

The forth step summarized qualitative valuation for all selected applications. In addition, quantitative representations are used for additional analysis, such as averaging the quality characteristics of the individual M-learning application. All steps are carried out in a sequential manner for all selected M-learning applications (Moodle, Blackboard, Edmodo and Schoology). The following are the methodology steps:

1. Select M-learning applications.
2. Specify information quality characteristics
3. Extracting the required information
4. Summarizing qualitative valuation (weights)

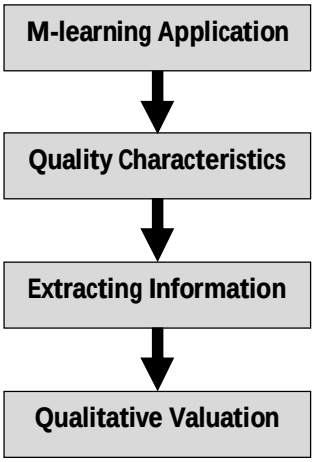

Fig. 2. The methodology steps

V. Selected M-learning applications

With the current huge number of M-learning applications used today, four of the most popular M-learning applications are selected for this study to be used as a case study to demonstrate the effectiveness and feasibility of the proposed information quality characteristic approach. That is, selecting M-learning applications for conducting the study was very critical to reflect sufficient evaluation assessment of the proposed approach. The selected applications are: Moodle, Blackboard, Edmodo and Schoology.

A. Moodle

Moodle learning system is a free open source learning management system Moodle Mobile MM is the official mobile application for Moodle system. Moodle Mobile is an HTML5 application that uses common web technologies which is a client web services. Moodle Mobile learning is realized as a plugin for open source Learning Management System (LMS) Moodle. MLE-Moodle enhances and improves E-learning system to M-learning. MLE- Moodle is available on different mobile platforms i.e. iOS and Android. Learners and their instructors can easily access their required course materials virtually anywhere. [17].

B. Blackboard

Blackboard M-learning is a mobile learning application available to be downloaded and installed on different mobile devices to support learners and instructors access to different features of courses on a variety of mobile platforms including Android, iPhone OS and BlackBerry. The Blackboard M-learning offers learners and instructors easily access to their course materials Blackboard M-learning solution makes it easy to implement M-learning system that has the power to improve learners learning process steps farther than expected [18].

C. Schoology

Schoology is a learning management system available as free native mobile application that extends learning process beyond the restrictions of the classroom. Schoology leverages iOS and Android platforms. Schoology extends the CODiE-award-winning LMS to Apple, Android and Kindle Fire mobile devices. Schoology redefined the learning management system to offer online education as a collective effort to improve the impact of all learners involved in the learning process. Whereas, learners can send course material, private messages, learners ' feedback, and organize events using Schoology's intuitive interface on mobile devices. With its flexible collaborative interface, Schoology robust M-learning applications empower engaging learners in more interactive and collaborative learning process on any device [19].

D. Edmodo

Edmodo is a learning platform as online and mobile social learning platform often described as a Facebook for education and learning providers. Edmodo moves learning process to be beyond the traditional classrooms, offering a free, safe place for instructors and learners to connect, interact, collaborate, share learning content, and access learners' work in an online environment anytime and anywhere. Edmodo attracts learners and instructors with a social element that resembles Facebook and its great value in the learning applications. Edmodo was designed by instructors' enables exceptionally secure cloud-based collaboration. Instructors are fully managing, controlling and can limit learners to read only status if desired [20].

VI. The study

The provided study focused on analyzing information quality characteristic of selected M-learning applications. With the currently available M-learning applications today, having the right M-learning application choice, can be quite overwhelming. Thus, only four different M-learning applications were selected to conduct this research study and to demonstrate the feasibility and effectiveness of the proposed approach. To demonstrate the applicability of the used information quality characteristics in different M-learning applications, the most popular and well known M-learning application were evaluated in this study, including Moodle, Blackboard, Schoology and Edmodo. Thus, the research in this paper focused on discussing various M-learning applications and evaluated them according to the selected information quality characteristics. The selected M-learning information

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quality criteria are independent of the application type. Next subsections provide brief introduction to four selected information quality criteria [21].

A. Maintainability

The ease of maintenance of M-learning apps is very important. Where, it should be considered in design phase as that minimum time and less effort are required to maintain efficient operations. M-learning applications should be prevent and recognize any faults errors. Any errors that cannot be disallowed should be easily fixed with less time, effort and

limited resources. In addition, there should not be any data or recourses lost in response to faults and bugs [22].

B. Reusability

Reusability is primary characteristic of M-learning app quality. The main attribute of M-learning app reusability is the extent to which the app components can be used in other applications. M-learning app reuse is a process of implementing or updating of M-learning app using existing application components. A better M-learning app reuse process facilitates the decrease of costs and development time and, the increase of reliability, quality, and productivity. The reuse of M-learning process development and repository produces a knowledge that enhances the quality after every reuse [23].

C. Testability

Testability is the degree to which the M-learning app testing is difficult .M-learning app testability determines the limit to which the dangerous bugs and risk of costly can be decreased to an acceptable level. What makes the test of M-learning app easier or harder? In general, are the observability and controllability. M-learning app observability determines the work to set up and perform test cases and the degree to which the response of the app under test to test cases can be verified. However, the controllability determines the work to set up and perform test cases and the degree to which M-learning app features and individual functions under test can be made to respond to test cases [24, 25].

D. Security

M-learning app has many factors those may affect the app security. M-learning app can restrict access via single sign-on (SAML, OAuth, AD, LDAP, VPN). Restrict access by device context – time, date, or location (Prevent access after certain-time, remote access, and network conditions -3G vs. 4G vs. Wi-Fi). Limit access to unique device ID (IMEI, UDID, MAC). M-learning app can protect data via Encryption (Core Data, HTML5 data, passcodes, and policies). Can also use firewall logging, VPN and authentication [26, 27, 28].

VII. Discussion

The following tables provide description of how the selected application differs across the selected criteria. Table 1 shows that all four applications support maintainability. They differ a little in the application modularity as some of them supports object oriented programming and Schoology supported both procedural and object oriented programming.

TABLE I. Mobile LMS Maintainability

M-LMS	Maintainability
Moodle	Moodle is structured as an application core, in addition with plugins to provide specific functions. It designed as customizable version without modifying the core. Yahoo User Interface framework is the library for Moodle. It is an extremely capable, powerful, fast and well-documented library.
Blackboard	Blackboard is continuing its commitment to modularity. This is reflected in the new software update feature. It uses new development environment for Java called Spring. Blackboard provides several services. One of these services such as authentication and authorization that means configurable security processes to support range of standards, protocols, and practices via Spring Security sub-project.
Edmodo	Edmodo is written as object oriented program which give the application modularity feature. On the other hand, it cannot be modified by any user, the main company can do that only because its closed source.
Schoology	Schoology is both procedural and object oriented programming. In that, modularity is desirable. In procedural programming also using another technique to keep procedure strongly modular called scoping. It is closed source so, it doesn't have the modifiability because any modified will be done on the application by application providers.

Table 2 shows the Reusability features across the four selected applications. Moodle differs little comparing with other application as its interface design does not offer enough options for rebranding and customizing the look or ship without extensive coding work.

TABLE II. Mobile LMS Reusability

M-LMS	Reusability
Moodle	Moodle has its detractors, however. Some power LMS users complain that its interface design doesn't offer enough options for rebranding and customizing the look and feel without extensive coding work.
Blackboard	Java spring provides service called Aspect oriented programming. That aims to increase modularity by allowing the separation of cross cutting concerns. Which, mean Blackboard can be reusable.
Edmodo	Edmodo has well organized good code structure. Whereas, it can be reuse and extend easily.
Schoology	Depending on its modularity it can be reuse and extend easily and with less effort.

Table 3 describes the testability feature in all four applications. It is clear that the Moodle, Blackboard and Edmodo supports unit test and Schoology does not have official way for reporting bugs. Despite that, Moodle usually testable more than other tools as it is open source software application.

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TABLE III. MOBILE LMS TESTABILITY

M-LMS	Testability
Moodle	PHP unit testing is the technique used by Moodle in testing step. This technique done by dividing the program into smaller parts and ensures that each part is correct. It is an important step because it guarantees that the codes are work probably without any problem.
Blackboard	As long as Blackboard is written in spring java, so it supports classes for writing unit tests and integration test.
Edmodo	Edmodo team use automated testing for browser performance and they monitor the server side performance using a number of popular metrics at the same time.
Schoology	Schoology does not have official way for reporting bugs. But helpdesk can be contacted through "submit request" link and explain the issue to them.

Table 4 summarizes that different security level offered by each application. All of the applications offer common security related features but blackboard uses static and dynamic analysis for application security testing.

TABLE IV. MOBILE LMS SECURITY

M-LMS	Security
Moodle	There are three factors of authentications: Knowledge (password, PIN code … etc), Ownership (security token, phone … etc), Inherence (fingerprint, signature, various biometric identifiers). Depending on this username and password, permission will be given. This step known as Authentication that done by comparing the user used to access the platform with the data located in the Authoritative data. Moodle supports 13 different types of authentication which means it supports the consulting of 13 different types of Authoritative Data Sources.
Blackboard	Blackboard performs continuous internal security testing at the code-level (static analysis) and application level (dynamic analysis) to meet customer's expectations. It obtains security penetration testing from third party security vendors. In static and dynamic application security testing, it leverages open source and commercial static analysis scanners to assess Blackboard Learn source code continuously. These tools allow Blackboard to identify potential vulnerabilities in source code as the system evolves through integration with build environments. Blackboard couples automated source code analysis for security vulnerabilities with manual code reviews.
Edmodo	Edmodo has numerous employees focused on privacy-related issues, including: a Chief Privacy Officer; a User Trust and Safety Team, made up of employees from almost every aspect of the company; and a team of security engineers, whose everyday responsibilities are to continually monitor and improve the safety and security of Edmodo's services. Even though XSS (Cross-site scripting) and CSRF (Cross-site request forgery) vulnerabilities were discovered by hacker known as Gambit. Then, they passed both vulnerabilities up to one of the lead engineers.
Schoology	Schoology secures two-way API automates data transfers between Schoology and other technologies to ensure the right information is sent to the right places without your lifting a finger. Schoology uses industry standard technology called SSL (Secure Socket Layer). SSL encrypts information transmitted across the internet to and from Schoology. Moreover, it asks for some authentication process. i.e. there are three sign up levels to create new account teacher, student, or parent. Then choose username and password.

VIII. CONCLUSION AND FUTURE WORK

Most of the currently available learning and educational software applications are developed for the formal learning, training and education environments. Those environments are characterized by the improvement in the interaction process between learners and their instructors to offer flexible learning process. It is of general agreement that the quality issues of M-learning application should be considered in earlier stage of M-learning application development process, to avoid risks and facilitate the overall application operations. As, there is not complete and well defined set of M-learning application characteristics different M-learning quality management process is required including information, software and services qualities. This paper presented an empirical study that examined the potential to apply a quality analysis process for M-learning software applications in accordance to a well-defined set of information quality characteristics to increase the level of quality in the M-learning systems.

The information quality characteristics include maintainability, reusability, testability, and security. The study was conducted on four different M-learning application representing both preparatory source and close source systems. Each system was analysed to determine if it met the proposed quality characteristics. The data showed that the approach is applicable and effective but needs further improvement and formalization to be practically implemented. New ideas are additionally proposed for future work to include other dimensions of the M-learning application quality characteristics e.g system quality characteristics including availability, reliability, performance, usability, and functionality as well as service quality characteristics including commercial support, community support, and documentation and developer skills.

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