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PROPOSING A NEW TECHNICAL QUALITY REQUIREMENTS FRAMEWORK FOR MOBILE LEARNING APPLICATIONS

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ABSTRACT

Most of mobile learning applications might fail and not effectively used just because of bad selection of appropriate technical requirements, which affects the quality and increases the production cost of mobile learning applications. For the development of effective and successful mobile learning applications, it is important to identify set of technical quality requirements for mobile learning applications. With this work, we developed a new framework to capture most crucial technical quality dimensions and requirements for the development of mobile learning applications. To better understand and identify the list of technical quality dimensions and requirements a Delphi study was carried out. This method allowed us to reach a consensus in three rounds and counted with the participation of 30 experts in the Software Engineering, Information Systems and mobile learning fields. As a result of the Delphi study, a specific framework comprised by 19 technical quality requirements divided in six quality dimensions was developed for the development of mobile learning applications. This framework is expected to guide the designers and developers for a successful development process of mobile learning applications.

Keywords: *Technical Quality Requirements; Mobile Learning Applications; Delphi Study ;Software Engineering*

1. INTRODUCTION

In the recent years, mobile learning applications have become essential tool for learners in higher education institutions [1]. In particular, learners increasingly benefit from mobile learning applications that enables access learning materials remotely anywhere and anytime. This new technology has gained significant interest from many researchers as a suitable tool that presents effective solutions to e-learning challenges [8]. Despite of that, mobile learning faced a number of challenges such as availability of learning resources, low quality of system functionalities, design of system interface, interactivity, accessibility, security issues, and limited resources [9,10]. These challenges can be addressed by determining the necessary technical quality requirements for mobile learning applications. Mobile learning system integration in teaching and learning processes is a key component of many educational reform agendas worldwide [2]. A crucial factor for the successful implementation of new mobile learning applications is the preparation set of technical quality requirements for mobile learning development [11]. Yet, research shows a gap of how to implement a successful mobile learning system in the university environment and what are expected factors that could lead to develop high quality mobile learning applications that meet learners' requirements [3]. One of the reasons for this gap is that mobile learning is still in the beginning stage of implementation in the university environment [4, 12]. Researchers are expected to develop effective models to provide future designers with the necessary specifications for mobile learning system development. Professional models and frameworks are therefore needed to identify the most important technical requirements for mobile learning development. Quality factors have been shown to contribute to the identification of requirements necessary to develop a successful information systems [13, 14). Although previous studies have developed several models and frameworks into mobile learning [15, 16 and 17], there are no clear and well defined technical quality requirements and specifications for mobile learning applications. In order to address this

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gap, the current study aimed at establishing framework to identify the most critical technical quality requirements for mobile learning that aid the development of mobile learning applications. By identifying the most significant technical quality dimensions and requirements, there exists a better opportunity to success the implementation of a mobile learning applications.

Therefore, this study contributes to the literature through answering the following two main questions:

1. What are the appropriate technical quality requirements for mobile learning applications?

2. What are the technical quality requirements from question one that lead to the development of mobile learning applications successfully?

2. BACKGROUND OF THE STUDY

For the successful development of technical quality requirements framework, several software quality models need to be taken into account. Table 1 presents an overview of the literature on software quality models, information system quality models and service quality models that play a role for the development quality standards, factors and characteristics of software, systems and applications [7,18]. Therefore, the quality models are used as a foundation for constructing the proposed framework for this study, which will be presented in the following sections.

2.1 Software Quality Models

In terms of software quality dimensions, several models and frameworks were analysed, starting from the McCall's quality model comprised by 11 dimensions namely (reliability, usability, correctness, efficiency, interoperability, integrity, maintainability, testability, flexibility, portability, and reusability) developed by McCall, Richards, and Waiters [19]. The McCall's model led to the development of Boehm model by Boehm, Barry, John, and Hans Kaspar [20], which included seven dimensions (portability, utility, reliability, efficiency, maintainability, understandability and modifiability). After that, Software and Systems Engineering of International Organization for Standardization developed ISO 9126/IEC model [21]. This model contains six quality dimensions are: functionality, usability, reliability, efficiency, maintainability, and portability. These models were used as a basis for several new methodologies, methods and studies.

2.2 Information System Quality Models

In the information system quality factors context, we analysed the updated DeLone and McLean model developed by DeLone and McLean [22], with a huge focus on three main dimensions namely system quality, information quality and service quality. Each one of these dimensions is divided into sub dimensions as the following: system quality (usability, functionality, interface design, accessibility, ease of use, interactivity), information quality (content adequacy, content usefulness and content design) and service quality (availability, personalization, reliability, trust and responsiveness). These became the indices to predict the quality and success many types of information systems.

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Table 1 : Review Of Previous Quality Models And Their Dimensions

Type	Quality Models	Quality Dimensions	Authors
Software quality models	McCall's quality model	reliability, usability, correctness, efficiency, interoperability, integrity, maintainability, testability, flexibility, portability, and reusability	[19]
	Boehm model	portability, utility, reliability, efficiency, maintainability, understandability and modifiability	[20])
	ISO 9126/IEC model	functionality, usability, reliability, efficiency, maintainability, and portability	[21]
Information system quality models	The updated DeLone and McLean model	system quality (usability, functionality, interface design, accessibility, ease of use, interactivity), information quality (content adequacy, content usefulness and content design) and service quality (availability, personalization, reliability, trust and responsiveness)	[22]
Service quality models	E-S-Qual	efficiency, compliance, availability and privacy	[23]
	WebQual model	informational fit-to-task, tailored communications, trust, response time, ease of understanding, intuitive operations, visual appeal, innovativeness, emotional appeal, consistent image, on-line completeness, and relative advantage	[24]
	WebQual model	usability, information and interaction	[25]

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2.3 Service Quality Models

Finally, in the service quality dimensions context, we analysed the E-S-Qual model developed by [23], which contained 22 items for four dimensions (efficiency, compliance, availability and privacy). Loiacono, Watson, and Goodhue [24] developed the WebQual model, which uses a basic scale of twelve dimensions. Subsequently, we studied an approach that shared the same name: the WebQual model by [25], with a mainly focus on three dimensions (usability, information and interaction). We reviewed also the service quality attributes (availability, personalization, reliability, trust and responsiveness) in the updated DeLone and McLean model developed by [22].

2.4 Research Contribution

After conducting a systematic review in the literature as shown in Table 1 and presenting the comparison between different models of software quality factors, we proposed a preliminary list of technical quality dimensions for mobile learning applications. These dimensions could be used as guidelines to develop high quality mobile learning applications that meet users' requirements. Also, these dimensions may contribute to a successful development of mobile learning applications. Based on that, this study proposes a technical quality framework for mobile learning applications based on quality models such as McCall's quality model, Boehm model, ISO 9126/IEC model,the updated DeLone and McLean model, E-S-Qual and WebQual model. The next section presents the method used in this study in order to achieve the research objectives.

3. METHODOLOGY

Any research process must explain in detail the methodological principles and methods adopted. In this sense, the development process underlying this research work was structured and divided in stages, according to the following order:

1. Systematic literature review;
2. Preparation of a set of interviews to 30 experts in the software engineering, information system and mobile learning fields;
3. Development of a preliminary list of technical quality dimensions obtained from our literature review and the analysis the interviews to experts;
4. Conduct of the Delphi study;
5. Identification the final technical quality dimensions and requirements
6. Presentation of a technical quality dimensions and requirements framework

3.1 Delphi Study

To build consensus about the crucial technical quality dimensions for the successful development of mobile learning applications, a Delphi study was set up. A Delphi study includes (1) consulting a mature field of experts (2) in an anonymous manner (3) in different rounds, (4) with feedback of the results and (5) the opportunity for participants to reconsider their position [26]. The Delphi method was chosen because it is specifically directed towards generating consensus in a group of respondents [26,27]. Developing a framework may be another outcome of a Delphi study [28]. In the current study, the researcher strove for a consonant framework of the technical quality dimensions necessary for the development of mobile learning applications that induce consensus.

For this Delphi study, both qualitative and quantitative methods were used. The Delphi study consisted of three rounds of data collection and analysis. These are discussed in depth in the results section. The estimated time span of the iterative data collection rounds was seven months, starting with the first round in February 2017 and ending with the last round in September 2017.

3.2 Experts Selection

In the Delphi study, expertise is considered to be the most important criterion for selecting a Delphi participant [27]; that is, a participant in a Delphi study must be a proven expert in the field of the study. It should be noted that the selected respondents included a group of experts with responsibilities and technical profiles in the Software Engineering, Information Systems and mobile learning fields at Jordanian universities.

For conducting the Delphi study, 30 respondents distributed across three groups participated in the study. The first and second groups included 24 experts in the fields of Software Engineering and Information Systems and six experts in Mobile

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Learning in the third group, as shown in Table 2. They all joined the first round but, because of changes in jobs or temporal leave, not all moved on to the second and third round.

Table 2 : Participants Of The Delphi Study

Group	Field	Num in the 1st round	Num in the 2st round	Num in the 3st round
1	Software Engineering	14	10	10
2	Information Systems	10	9	9
3	Mobile Learning	6	6	6
Total of participants		30	25	25

4. CONDUCT OF THE DELPHI STDY AND ANALYSIS OF THE RESULTS

As mentioned before, the Delphi study consisted of three rounds of data collection and analysis. For each round, instruments were developed and pilot-tested by ten to twenty fellow researchers and experts. In this section, we describe the development and implementation of each instrument per round. The Delphi study started with a literature review that served as foundation for the first questionnaire. Data from the first open-ended questionnaire was analyzed in order to develop the second round survey. The results of the second round served as the basis for the next one. The results of the third and last round are described extensively as the final results of this study.

4.1 First round

Design of the preliminary quality dimensions and requirements based on the literature review

To develop, validate and complete the preliminary list of technical quality dimensions requirements for mobile learning applications, found in our literature review and submitted to a Delphi study, 30 interviews were carried out via open-ended questionnaire to experts of Software Engineering, Information Systems and Mobile Learning field. The open-ended questionnaire was developed based on these dimensions to ascertain whether and why each dimension was perceived as important for the development of mobile learning applications. For the first round we deliberately chose an open-ended questionnaire so that respondents could have a greater role in setting dimensions than is possible with conventional surveys [29]. The survey started with a general question 'Which quality dimensions are important for the development of mobile learning applications?. They were also asked to assign a domain to each dimension. Additionally, the respondents could indicate new dimensions and requirements.

Results of the first round

Based on all collected and analysed data from 30 respondents the preliminary list of quality dimensions derived from the literature review were identified through inductive analysis of survey data. It comprised from 21 technical quality requirements divided into six quality dimensions (Table 3 - preliminary list of dimensions), this list served as basis to the first round of the Delphi study.

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Table 3: Preliminary List Of Technical Quality Dimensions And Requirements

Quality Dimensions	Technical Requirements items
Interactivity	1. The application enables learners to interact with instructors via online messages.
	2. The application enables learners to exchange and share the learning content.
	3. The application enables learners to discuss with learners and faculty by using discussion board.
Functionality	4. The learners can easily navigate between tasks.
	5. The application gives learners alerts for new notifications.
	6. Access to the application for both students and instructors.
	7. The application gives learners sufficient features.
	8. The application offers an interface with a good size and resolution.
Interface Design	9. The application provides a simple and flexible user-interface with a good icons design.
	10. The learners can easily identify the particular functions of the application.
	11. The application offers good organization of course content and activities.
Accessibility	12. Instructors can create courses and learning content items.
	13. Instructors and learners can access the documents of learning content in multiple formats.
	14. Upload and download attachments.
	15. Learners can submit assignments and home works.
Learning Content Quality	16. The learners can find the complete learning content when using the application.
	17. The learners can find the various activities of learning content when using the application.
	18. The learners can find the detailed contact information when using the application.
Content Design Quality	19. The application provides learners different formats of learning content such as text, audio and video.
	20. The application provides learners up-to-date content.
	21. The application provides learners accurate content.

4.2 Second round

Identification of important technical quality dimensions and requirements for mobile learning applications

With the aim of reaching consensus about which technical quality dimensions and requirements are regarded as most important, the 21 technical quality requirements resulting from the first round were brought together in a quantitative survey in the second round. The respondents were asked to score each dimension on a six-point Likert scale from not important at all to necessary. Also, they could add additional comments if desired.

Consensus in Delphi studies is defined in a variety of ways (Powell, 2002). In this study, the median and interquartile range (IQR) were used to identify technical quality dimensions regarded as important by multiple experts and to determine the level of consensus for each dimension. The median denotes the middle point of a frequency distribution with half the scores falling above and half the scores falling below it (Doughty, 2009). A median ≥5 (very important or necessary) was used as basic criterion to take a condition to the next round.

The median is an appropriate measure to determine consensus with small groups, but the interquartile range (IQR) is also often used to determine the degree of consensus in a Delphi study (Doughty, 2009). The IQR represents the middle half of responses within a distribution of scores, whereby a small IQR indicates a higher level of consensus and a large IQR indicates a lower level of consensus (Doughty, 2009). For each dimension with a median ≥5 we calculated the IQR and we differentiated among three levels of variation in responses. A high level of

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consensus is reached when there is an IQR≤0.5 which indicates that half of the opinions fall within 0.5 point around the median [30]. We talk about a moderate level of consensus when the IQR is higher than 0.5 but smaller or equal to 1. This IQR shows that half of the opinions are placed within 0.5 to 1 point around the median. Lower level of consensus is reached with an IQR>1, because more than 50% of all opinions fall without 1 point around the median [30].

Results of the second round

Table 4 gives an overview of the 21 technical quality requirements resulting from the second round. After this round, one out of five technical quality requirements items was left within the dimension of functionality. Also, at the learning content quality dimension one out of three items was removed. Notably no technical quality requirements items were left within the quality dimensions interactivity, accessibility, interface design and content design quality, suggesting that there is consensus regarding the importance of technical quality requirements related to these quality dimensions for the successful development of mobile learning applications. There is high consensus for 14 technical quality requirements and moderate consensus regarding the importance of 5 technical quality requirements. Based on the second round results, 19 technical quality requirements with a median ≥5 and IQR≤0.5 were retained because majority of the respondents agreed that these dimensions are very important for the development of mobile learning applications.

Table 4: Results Of The Second Round

Quality Dimensions	Technical Requirements	IQR Score	Degree of Consensus*
Interactivity	1. The application enables learners to interact with instructors via online messages.	0.6	Moderate
	2. The application enables learners to exchange and share the learning content.	0.3	High
	3. The application enables learners to discuss with learners and faculty by using discussion board.	0.8	Moderate
Functionality	4. The learners can easily navigate between tasks.	0.2	High
	5. The application gives learners alerts for new notifications.	0.3	High
	6. Access to the application for both students and instructors.	0.1	High
	7. The application gives learners sufficient features.	0.4	High
	8. The application offers an interface with a good size and resolution.	1.3	Low
Interface Design	9. The application provides a simple and flexible user-interface with a good icons design.	0.3	High
	10. The learners can easily identify the particular functions of the application.	0.3	High
	11. The application offers good organization of course content and activities.	0.5	High
Accessibility	12. Instructors can create courses and learning content items.	0.4	High
	13. Instructors and learners can access the documents of learning content in multiple formats.	0.7	Moderate
	14. Upload and download attachments.	0.3	High
	15. Learners can submit assignments and home works.	0.9	Moderate
Learning Content Quality	16. The learners can find the complete learning content when using the application.	0.3	High
	17. The learners can find the various activities of learning content when using the application.	0.3	High
	18. The learners can find the detailed contact information when using the application.	1.2	Low

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Content Design Quality	19. The application provides learners different formats of learning content such as text, audio and video.	0.6	Moderate
	20. The application provides learners up-to-date content.	0.2	High
	21. The application provides learners accurate content.	0.4	High

***high level of consensus if IQR<0.5, moderate level of consensus if 0.5<IQR≤1 and low level of consensus if IQR>1**

4.3 Third round

Consensus confirmation of the final technical quality dimensions and requirements

In order to give respondents the opportunity to revise their answers, the 21 technical quality requirements resulting from the second round were used in the survey for the final round. In this round, respondents were provided with information about the degree of consensus in the previous round. Respondents were asked to score these 21 requirements again on the same six-point Likert scale from not important at all to necessary. This provided respondents with the opportunity to rescore technical quality requirements. After this last round, we also calculated medians and IQR, using the same criteria as that of the data analysis of the second round.

Results of the third round

Majority of the respondents agreed about the importance of nineteen technical quality requirements (median≥5 and IQR≤0.5) for the development of mobile learning applications after the third round (see Table 5). Interestingly, there was more consensus in the third round (a shift from moderate to high for two technical quality dimensions), the first is about the need for applications that enable learners to interact with instructors for the interactivity dimension and about the need for applications that provides learners different formats of learning content such as text, audio and video for the content design quality dimension is the second.

Table 5: Results Of The Third Round (Final List Of Technical Quality Dimensions And Requirements)

Quality Dimensions	Technical Requirements	IQR Score	Degree of Consensus*
Interactivity	1. The application enables learners to interact with instructors via online messages.	0.3	High
	2. The application enables learners to exchange and share the learning content.	0.3	High
	3. The application enables learners to discuss with learners and faculty by using discussion board.	0.8	Moderate
Functionality	4. The learners can easily navigate between tasks.	0.2	High
	5. The application gives learners alerts for new notifications.	0.3	High
	6. Access to the application for both students and instructors.	0.1	High
	7. The application gives learners sufficient features.	0.4	High
Interface Design	8. The application provides a simple and flexible user-interface with a good icons design.	0.3	High
	9. The learners can easily identify the particular functions of the application.	0.3	High
	10. The application offers good organization of course content and activities.	0.5	High
Accessibility	11. Instructors can create courses and learning content items.	0.4	High
	12. Instructors and learners can access the documents of learning content in multiple formats.	0.7	Moderate
	13. Upload and download attachments.	0.3	High
	14. Learners can submit assignments and home works.	0.9	Moderate

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Learning Content Quality	15. The learners can find the complete learning content when using the application.	0.3	High
	16. The learners can find the various activities of learning content when using the application.	0.3	High
Content Design Quality	17. The application provides learners different formats of learning content such as text, audio and video.	0.4	High
	18. The application provides learners up-to-date content.	0.2	High
	19. The application provides learners accurate content.	0.4	High

***high level of consensus if IQR<0.5, moderate level of consensus if 0.5<IQR≤1 and low level of consensus if IQR>1**

Based on that, there is high consensus for 16 technical quality requirements and moderate consensus regarding the importance of 3 technical quality requirements compared with the second round. Finally, the results of our study allowed us to identify the final technical quality requirements for the development of mobile learning applications with high consensus of respondents.

5. DISCUSSION

To the best of our knowledge, this is the first study that focuses explicitly on consensus across multiple stakeholders about important technical quality dimensions and requirements for the development of mobile learning applications. Table 5 shows the respondents' consensus from three rounds of the Delphi study with regards to a framework that identifies most necessary technical quality requirements for mobile learning applications development. This study presents new framework of technical quality dimensions and requirements for mobile learning applications.

To develop this framework, a Delphi study was conducted that included three rounds. In the first round, the main objective was to develop a preliminary list of technical quality dimensions and requirements. To achieve that, a literature review was initially carried out which allowed us to identify general perception about quality dimensions in the software quality models, information system quality models and service quality models. To complete the list of preliminary dimensions compiled from our literature review, we also carried out an empirical study based on a set of interviews to 30 experts in the fields of Software Engineering, Information System and mobile learning. Based on all collected and analysed data, a preliminary list, composed by 21 technical quality requirements divided in six quality dimensions and submitted to the second round of the Delphi study, was drawn up. In the second and third round of this Delphi study, a quantitative survey was carried out to reach consensus about which most important technical quality dimensions and requirements for mobile learning applications development resulting from the first round. Based on the second and third round data analysis, 19 technical quality requirements with a median ≥5 and IQR≤1 were retained because more than half of the respondents agreed that these dimensions are very important for the development of mobile learning applications.

In short, the current Delphi study developed new framework of 19 technical quality requirements divided into 6 quality dimensions regarded as very important by majority of the respondent groups. Figure 1 gives an overview of these technical quality dimensions and requirements in the proposed framework. All these dimensions and requirements are discussed below. Subsequently, we discuss the limitations of this study and make recommendations for further research.

5.1 Technical quality dimensions and requirements framework for mobile learning applications

5.1.1 Important technical quality requirements at the interactivity dimension

Interactivity in mobile learning is defined as the quick and real interaction between learners and teachers as well as among learners themselves by using the mobile applications [1]. If learners can be able to interact and communicate effectively with teachers and peers via mobile applications, this will make these applications the better and useful option for learning. Mobile learning applications should accommodate of both synchronous and asynchronous communications. This communication through mobile learning applications can lead to create effective collaborative learning environment between learners and support the quick respond in real time. Interactivity factor plays a critical role in the success of mobile learning applications because it

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improves instant respond, collaboration and interaction in real time regardless of time and place. Mobile learning applications should accommodate all technical characteristics and mechanisms of interactivity such as online chat room, discussion room, online message board and instant messenger. These requirements should be taken in the consideration of designers in order to develop a high quality of mobile learning applications. Therefore, designers should develop mobile learning application that enable learners to interact with teachers, and create mobile learning application discussion boards that allow them easily exchange and share learning content and give them the chance to discuss their ideas with learners and faculty instructors, which leads to improve quality of a mobile learning applications.

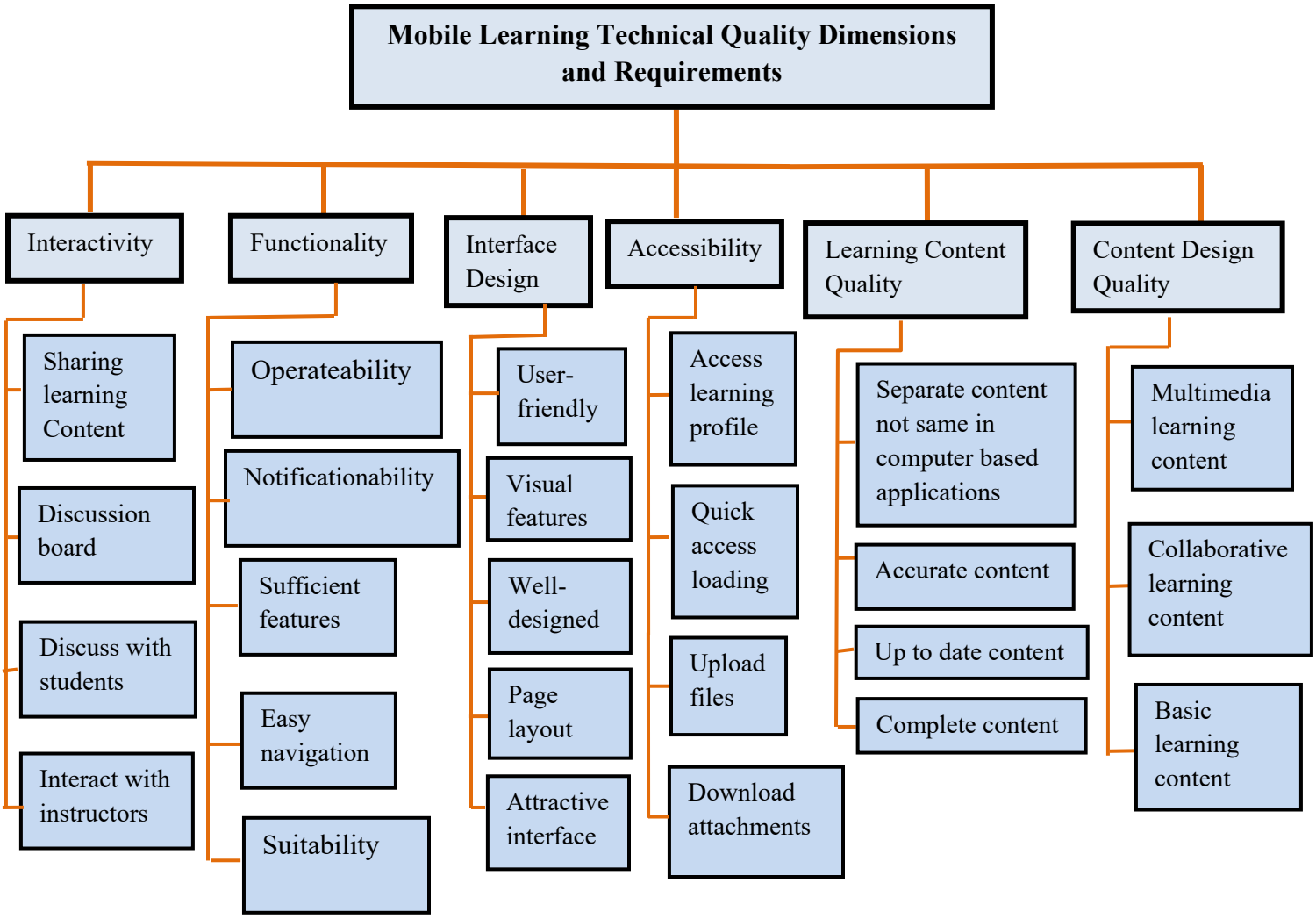

Figure 1: Technical Quality Dimensions And Requirements Framework For The Development Of Mobile Learning Applications

5.1.2 Important technical quality requirements at the functionality dimension

Functionality of mobile learning application refers to the necessary and effective features and functions of application that meet learners needs and perform their learning activities effectively [1]. The application should include all important features in order to provide useful and effective learning experience for both learners and instructors using mobile devices. Functionality can be divided into a number of attributes including operateability, navigability, suitability, notificationability and accuracy. These functionality requirements must be taken into

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account during the development of mobile learning applications. Operateability refers to the capability of application to adapt with different mobile application platforms and devices. Designers should develop mobile learning applications that support multiple mobile platforms such as Android, IOS and Windows, which leads to improve the use of application by all learners regardless of the type of mobile devices. Navigability refers to the easy navigation and access of functions and tasks of application. Mobile learning applications should include all technical features and mechanisms of navigability such as links, scroll bars and buttons that enable learners to easily navigate between learning tasks and activities. Suitability refers to the ability of mobile learning system to provide appropriate features and functionalities to fulfil learners' requirements. Notificationability refers to the ability of mobile learning applications to give learners alerts for new notifications. This new feature enables learners to keep in touch with all updated actions from instructors such as add new courses, new announcements, new assignments and others. Accuracy refers to the ability of mobile learning applications to provide appropriate information and results.

5.1.3 Important technical quality requirements at user the Interface design dimension

User interface design is an crucial factor for a successful application. Thus, designing and developing an efficient interface within a learning environment is still a challenge for most developers, facilitators, and designers [31]. Udell [32] stated that the interface for mobiles must be consistent and straightforward than those of e-learning. He believes that if the mobile navigation must be learned to use, then that is a failure [32]. Similarly, Elias (2011) stated that mobile learning applications must be simple and intuitive [33]. Furthermore, Kukulska-Hulme et al. [34] urged developers of mobile learning applications to design attractive and easy to use interface, a pleasant visual design, and effective interaction styles [34]. In addition to instructional and interface design, the organization of visual elements and media on the mobile screen will influence the ease and quality of learning, and has an important impact on learners' cognitive load. It is also important to consider the number of pixels available on users' device, to provide the best quality of images on users' screens. Furthermore, designers should consider screen size and screen orientation (Horizontal and Vertical), knowing that learners sometimes need to be able to use both orientations.

5.1.4 Important technical quality requirements at the accessibility dimension

In this study, mobile learning accessibility refers to the degree of ease access of students to the learning content via mobile learning application. Accessibility refers to the degree of ease of how a user can access and use the information and extracted from the system [13]. Park [8] expressed that system accessibility refers to the degree of ease that enables students to access and use e-learning system. Practically, when mobile learning provides students online access and download the learning materials when and where they need via mobile learning application, they will perceive that the mobile learning is an easy to use and useful tool for learning.

5.1.5 Important technical quality requirements at the learning content quality dimension

Stakeholder considers quality of learning content as a critical factor that motivates learners to use mobile learning applications. Mobile learning applications should enable learners to easy access to appropriate learning content. Content quality refers to the quality and accuracy of content which is provided by the information system [22]. Learning content quality is very important in mobile learning applications in order to make fully engage of learners in the learning process. According to Almaiah et al. [1] learning content quality is an crucial factor in supporting the success of mobile learning applications because it demonstrates the actual use of mobile learning applications among learners. Mobile learning can make the learning process very interesting by giving learners the chance to access learning materials through their mobile devices such as smartphones, this leads to enhance flexibility of learning and participation regardless of place and time. Learners expect mobile learning applications offer the appropriate learning contents such as lectures, courses, assignments, images and quizzes. Various learning contents should be considered in the design of mobile learning applications. Mobile learning application designers should create various learning activities and styles to

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accommodate learners requirements and interact to learning contents in different ways. If learners do not find the required learning contents in the mobile learning applications offered by universities, this may lead to failure in the use of mobile learning advantages. Mobile learning application designers should develop separate learning content and should not be the same learning content that is used in the computer-based applications [11].

5.1.6 Important technical quality requirements at the content design quality dimension

The success of mobile learning applications basically depends on how the learning content is designed in order to meet learners' perceptions, this may lead to improve the learning process via mobile applications [5]. Content design quality in mobile learning is defined as the format and type of learning content that is presented by the application. The mobile learning application should accommodate multiple styles and formats of learning contents that are necessary to provide an effective learning experience. Practically, the design quality of learning content depends on the users' perceptions, and thereby, the mobile learning application must be able to support different learners' preferences of learning content styles and formats [6]. These styles and formats should be taken into account during the design phase of an mobile learning application. The design quality of mobile learning content should be acceptable by learners. To meet that, designers should develop mobile learning applications as collaborative learning platform that enable learners to share and send learning content files with instructors, as well as, should design multiple learning styles such as multimedia learning contents (audio, video and animation) and basic learning contents (text, graphics and charts).

6. CONCLUSION

The present work tried to answer the proposed objectives, which involved the development of a framework to identify technical quality requirements for mobile learning applications and help those responsible for the development mobile learning applications identify and evaluate which necessary technical quality requirements for mobile learning applications development. A Delphi study was set up to identify technical quality dimensions and requirements perceived to be important for the successful development of mobile learning applications from the perspective of multiple stakeholders. After three rounds of data collection there was consensus about the importance of nineteen technical quality requirements divided to six quality dimensions. We believe that the framework developed in the present research can support those responsible to develop mobile learning applications.

7. LIMITATIONS AND FUTURE WORK

This research does not end with the present paper, as there are lines of development that can be followed in future investigation works. As the framework was developed in an academic context and under time restrictions, we intend to continue the study and carry out an in-depth validation of the framework. We want to use the developed framework in an extended case study, it is necessary to investigate the components of the proposed framework in different mobile learning applications empirically. In addition, it will be important to test and validate its applicability in learning context.

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