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Original

Integrated design model for mobile learning pedagogy and application

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Abstract: Mobile Learning (M-Learning) has added a new dimension to the traditional system of education. The importance of M-Learning has been acknowledged by industrialized countries and therefore these countries have implemented it in the educational institutions. The Software developer, Software analyst, and Software test engineer face challenges in requirements elicitation, design, development, testing, and deployment of M-Learning application. It's because the Software engineering domain of M-Learning has not yet attended maturity. The design and development of M-Learning application is still a challenge. This study explores and analyses existing approaches in the design phase of M-Learning application development, reports the limitations, and propose a new solution. M-Learning has two basic components: pedagogy and software application (application). M-Learning pedagogy describes learning content in terms of instructional and learning design while software application provides platform for accessibility of learning content. The integration of these two components while designing, development, and testing play crucial role in the successful implementation of M-Learning. However, review of the existing literature has revealed lack of integrated approach for designing M-Learning pedagogy and application. There are researchers who have proposed design approaches for M-Learning pedagogy and application however separately. The significance of these approaches cannot be ignored but M-Learning application design and development suffers from compatibility issues, lack of design and testing mechanisms, identified stakeholders and their roles, lack of defined step and procedures. Therefore, this article presents an integrated design model for M-Learning pedagogy and application. The proposed model consists of pedagogy, application, and testing as important components. The application design is concerned with architectural level, high level, and detailed design. The pedagogical design is related to instruction and learning content. The test case design is concerned with formulation of conditions for testing the pedagogy and application. The proposed integrated design model has been compared with the existing approaches and ISO/IEC 12207:2008 and ISO/IEC 19796-1 standards. Also, the model has been reviewed by IT experts. The outcome is positive in both the cases.

Keywords: M-Learning Design, M-Learning Development, M-Learning Application Design, Software Development, M-Learning Content Design, Design Phase, Mobile Learning

1. INTRODUCTION

A software application is the product of completion of many phases such as planning, analysis, requirements, design, development, testing and deployment. The development phase which includes design, actual coding, and testing has own importance in the software development life cycle (Kantorowitz & Lyakas, 2005). Software design is defined as the interface between the analyzed requirements and actual software development.

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E-Learning and M-Learning are technology based learning systems. M-Learning is defined as learning using mobile devices (Fermoso, Mateos, Beato, & Berjón, 2015). M-Learning provides flexibility of learning at anytime, anywhere, and by anyone (Khan, Al-Khanjari, & Sarrab, 2016; Sarrab, Elgamel, & Aldabbas, 2012; Sarrab, Elbasir, & Alnaeli, 2016).

The proliferation of mobile devices such as PDA, smart phones has created opportunities as well challenges in design and development of application (Ogbuji, Onuoha, & Izogo, 2012). The GPS navigation and location tracking are used for learning during museums visits (Duran-Limon, Siller, Hernandez-Ochoa, Quevedo, & Robles, 2014; Iqbal-Faruque, Aisyah-Husni, Ikbal-Hossain, Tariqul-Islam, & Misran, 2014). The accessibility of Internet based mobile applications is affected due to network (Kandadai, Sridharan, Parvathy, & Pitchaimuthu, 2017)

Design is an important aspect in software development (Chu & Lo, 2013) but the content based application such as M-Learning leads to the complexity in design phase. The arrival of multimedia applications has further increased the complexity (Chen, L. et al., 2013). The learning domain are facing design and development challenges due to evolutionary nature (Päivärinta & Smolander, 2015).

This research proposes an integrated design and development model for M-Learning application development. The model has two parts: pedagogy and software application. The pedagogical design is a systematic approach which uses methods, models, theories in order to enhance the learning outcome (Conde, García-Peñalvo, Alier, Mayol, & Fernández-Llamas, 2014). The pedagogical design defines plan, scenario, format, content, structure, environment, delivery system, and implementation strategy (Romiszowski, 2016). The pedagogical design contains instructional and learning design. The learning design is concerned with designing the learning content using different styles of learning such as visuals, aural, read/ write, kinesthetic (Reigeluth, 2013). Learning design is related to students for tasks/ opportunity such as lesson, a unit of learning or a course (Khanghah & Halili, 2015; Soflano, Connolly, & Hainey, 2015; Yang, Huang, Gao, & Liu, 2014). Instructional design is related to instructors for systematic management of the systematic management of learning process and learning plan such as lecture format. Learning theories are Learning theories are descriptive and make general statements about how people learn. For example, Constructivism, Cognitive and Behaviorism. The software application design consists of architectural level design, high level design, detailed design, and usability design. Architectural design defines the overall structure of the system or module and relationship between them (Clark & Mayer, 2011).

The proposed model presents a structured and integrated approach for utilizing technology, context, usability, and pedagogy in the design and development of M-Learning content and application. The model involves identification of stakeholders, modeling and classification of requirements, design of learning content and software, creation of test cases, development of learning content and software, finally testing and evaluation.

The paper is structured as follows. There are seven sections. Section 2 is about the methodology adopted for the research. Section 3 relates to the literature review and existing problems. Section 4 describes the proposed model. Section 5 involves the discussion. Section 6 illustrates the feasibility of the model, and the last section summarizes the findings.

2. METHODOLOGY

This study has used literature reviews in order to explore the possible pedagogical and application design solution for M-Learning. The steps used in the process are shown in Figure 1. The first step defines the problem, followed by discovering, filtration, and finally reporting. The digital databases explored for problem analysis, relevancy, and possible solutions includes: Science Direct, IEEE xplore, Scopus, and Springer using simple and advanced search. Searching has been conducted individual as well as in combination of search terms. The search terms include: M-Learning application design, learning design, M-Learning design, model etc. Boolean Operators such as AND, OR, *, has been used to retrieve articles from databases. For example, the keywords include “M-Learning design”, “learning design”, and “model”, and application of Boolean search is as follows: (model* OR approach*OR method*OR process*) AND (M-Learning application design * OR learning design *OR M-Learning design*). Although the searching leads to a number of articles however, articles published between 2005 and 2016 with relevance to M-Learning application design have been studied thoroughly.

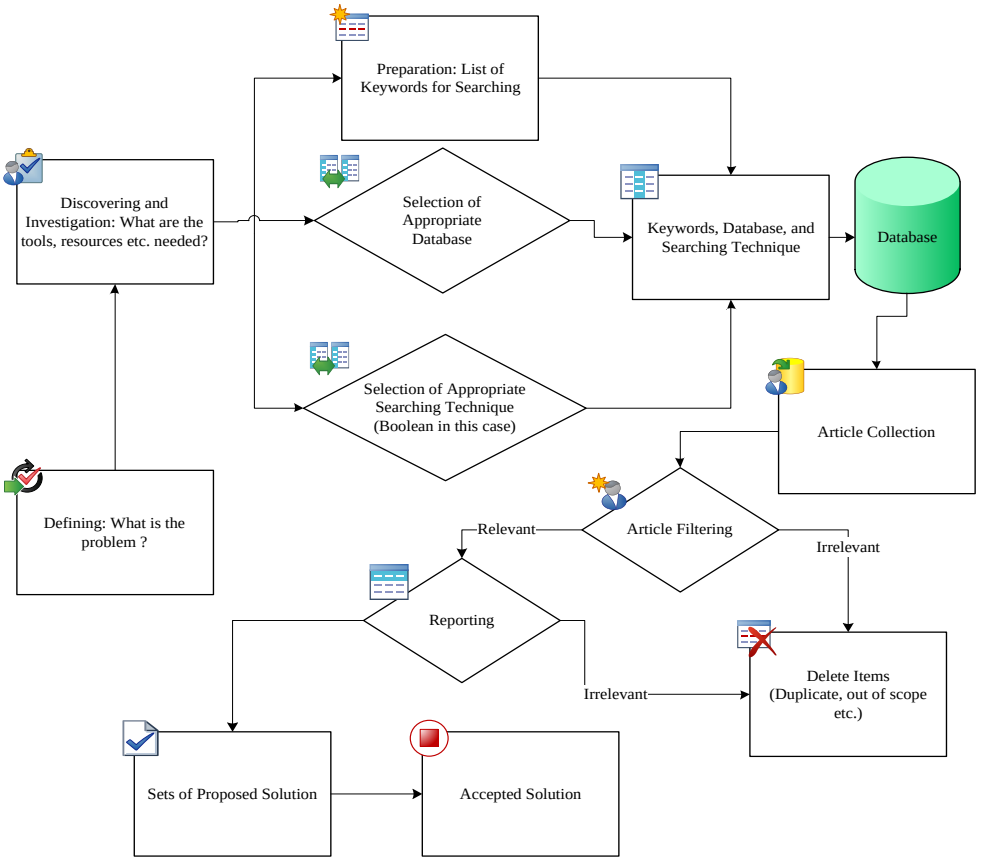

Fig. 1. Methodology followed in the research.

3. LITERATURE REVIEW AND PROBLEM IDENTIFICATION

The research in mobile application development is still theoretical and limited in scope (Kim, 2015). M-Learning is a type of mobile application which exerts considerable influence on education (Muyinda, 2007) but designing M-Learning is a complicated process. M-Learning design needs attention (Alden, 2013) due to contextual nature of mobile applications and limitations of mobile devices (e.g., screen size, low processing power, and energy limitation). Software engineering has numbers of design methods (Danado & Paternò, 2014; Marinho et al., 2013) however these methods cannot be applied to M-Learning due to uniqueness (Zhu, 2005). For instance, E-Learning design models ADDIE (Analysis, Design, Development, Implement, and Evaluation) (Chittaro, 2011; Naismith, Lonsdale, Vavoula, & Sharples, 2004), ASSURE (Analyze learners, State objectives, Select media and material, Utilize media and materials, Require learner participation, Evaluate and revise) (Seels & Richey, 2012).

M-Learning materials require a detailed and systematic planning of design and development process (Heinich, Molenda, & Russell, 1989). There are technological and pedagogical challenges such as user interface design, multiple devices (Mahazir, Norazah, Rosseni, Arif, & Ridzwan, 2015) variation in networks (wireless home area networks (HAN) and wireless wide area networks (WAN), business area networks(BANs)) (Develi & Kabalci, 2017). The designing of course bring challenges to the course designers (Wu, Lee, Chang, & Liang, 2012). Integration of infrastructure and application is another challenge in ubiquitous application (Stanton & Ophoff, 2014). The summarized output of extensive analysis of the articles on M-Learning design is shown in Table 1 and 2.

Table 1. M-Learning content and application design constraints.

Researchers	Opinion/ Suggestion/ Conclusion
(Santos & Boticario, 2015)	Design phase of M-Learning should consider interface as well as the learning content
(Khanghah & Halili, 2015)	For different kinds of mobile application cross platform design is an issue
(Heitkötter, Kuchen, & Majchrzak, 2015)	The educational module once developed should integrate learning content such as text and images, presentations etc.
(Fouh et al., 2014)	Game based learning encounter problem in designing of application. The researcher pointed out while designing M-Learning for learning history using game
(Martín-SanJosé, Juan, Gil-Gómez, & Rando, 2014)	Advocated the importance of user-centered design for interactive mobile application. They proposed a design approach combining agile characteristics, model-driven development, and user-centered techniques.
(Losada, Urretavizcaya, & Fernández-Castro, 2013)	Although there are many design methods for software development however they have limitations in designing Ubiquitous system application
(Ruiz-LóPez, Noguera, RodríGuez, Garrido, & Chung, 2013)	Design phase of M-Learning application needs research
(Hanson & Shelton, 2008)	Design phase should include active learning, collaborative learning, authentic learning and multiple perspectives
(Banavar & Bernstein, 2002)	Design phase in M-Learning is mainly concerned with developing learning materials only

Pedagogical design should be taken care while developing learning applications such as understanding different learning style (Visual, Verbal, and Inductive etc.) (Parsons, Ryu, & Cranshaw, 2007). Additionally, the design phase if not handled properly would affect the M-Learning development and implementation (Franzoni-Velázquez, Cervantes-Pérez, & Assar, 2012). It has been observed that there are researchers who are concerned only about instructional design of M-Learning. Moreover, as far as the M-Learning is concerned the existing design methods do not address the design of both pedagogy and software application in parallel which often results in compatibility and integration issue. Using the existing approaches design become complex and fail to fulfill the objectives resulting adverse effects on learners (Hsu, Ching, & Snelson, 2014; Zhu, 2005).

Table 2. M-Learning pedagogy and software application design approaches.

Researchers	Brief Description	Key Findings	Coding for Comparisons
(Karagiorgi & Symeou, 2005)	Proposed a methodology to design robot-oriented generative learning objects (GLOs) for computer science course.	No description of integrated design of learning content and application.	A
(Štuikys, Burbaitė, Bespalova, & Ziberkas, 2016)	Analyzed the problems in the design and development of M-Learning application through existing literatures.	Only identification of problems in the design of M-Learning.	B
(Khanghah & Halili, 2015)	Proposed a process of planning and creating a course for M-Learning rather than the content and structure. Considered the aspects such as technology, context, usability, and pedagogy	Integrated design of learning content and application successfully performed however no description of the evaluation	C
(Stanton & Ophoff, 2014)	Proposed a design model for the inclusion of cultural aspects in M-Learning application.	No integrated design of learning content and application	D
(Mohamad & AlAmeen, 2014)	Proposed a design approach for the intelligent tutoring systems based on the stateless client–server architecture and utilization of web services.	No integrated design of learning content and application	E
(Heeren & Jeuring, 2014)	Proposed a design approach for educational software consisting of user centered design and learning life cycle	No integrated design of learning content and application. Main concern E-Learning, and in brief.	F
(Santos, Boticario, & Pérez-Marín, 2014)	In the project "Open DSA" designed the architecture and learning content of the course Data structures and Algorithms	No proposed approach for the integrated design of learning content and application. The article aimed to promote open source tools	G
(Fouh, et al., 2014)	Illustrated use of Software Product Line (SPL) paradigm in the design of mobile and context-aware software	No integrated design of learning content and application.	H
(Marinho, et al., 2013)	Proposes four design principles for M-Learning: Connect, contextualize access, capture and multimodal.	Main focus on the interface between classroom and M-Learning	I
(Ryokai, Agogino, & Oehlberg, 2012)	Proposed six principles for instructional designing: a simple and intuitive interface, interactive multi-media, short and modular lessons, engaging and entertaining activities, contextually relevant and meaningful content, and just-in-time delivery	Main concern is instructional design principle	J
(Dillard, 2012)	Proposed a set of practices such as objectives, feedbacks, structured content, Time frame for lessons and inclusion of active learning for designing M-Learning.	Main area of concern is content design	K
(Killilea, 2012)	Applied the universal instructional design principles of distance education in the design of M-Learning	Main area of concern is content design	L
(Elias, 2011)	Proposed a conceptual framework for the design of M-Learning application. The framework is based on the factors and design requirement collected from the literature.	The framework is incomplete and has been left as future work.	M

4. PROPOSED MODEL

The proposed design model has two important components: pedagogy and software application. The pedagogy defines the educational part while the software application defines the actual application supposed to run on mobile devices. The design model is break down into modules: a. Requirements modeling and identification of stakeholders b. Design of learning content, software application, and test cases c. Development and testing of learning content and software application e. Evaluation and feedbacks. Figure 2 illustrate the proposed integrated design model for M-Learning software application and pedagogy.

a. Requirements modeling and identification of stakeholders

The system analyst collects the elicited and prioritized requirements for M-Learning software development. The system analyst then separates requirements as functional, non-functional, and pedagogical. The system analyst identifies stakeholders who would be directly or indirectly involved at different steps of the design model. The stakeholders are classified into as part of pedagogy and software application. The pedagogical stakeholders are related to learning content design and development such as Instructional designer, Subject matter expert, Language editor, and Educational technologist. The software application stakeholders are concerned with design and development of actual application such as User interface designer, HCI expert, Software developer, and Software test engineer.

The requirements are modeled by system analyst using modeling technique as UML diagrams. The system analyst also assigns tasks to pedagogical stakeholders and software application stakeholders during requirements modeling.

b. Design of learning content, software application, and test cases

Next step is to create instructional design for the course. The Subject matter expert and Educational technologists (selection and identification of mobile devices suitable for delivery of learning content) selects courses depending upon the importance of learning content and availability of mobile devices. Once the course is selected along with mobile devices the Instructional designer starts instructional design and learning content design steps. In the instructional design and learning steps the Instructional designer consults Subject matter expert for suitable learning styles, instructional strategies (tactics that help people learn), instructional theory (better way to learn), and learning theory (how learning takes place such as behaviorism, constructivism, and situated learning theory). The learning content media such as text, audio, video etc. as well as size is also clarified.

Similarly, the architectural, detailed, and high level design high level design is executed in parallel in parallel with instructional design and learning content design. The system analyst prepares architectural, detailed, and high level design in consultation with User interface designer (design the application interfaces for the end users), HCI expert, and Instructional designer. In the detailed design, the data structure, algorithm etc. are created.

The test cases created during learning content design and software application are placed in common repository accessible to Software developer, Software test engineer, and Instructional designer.

c. Development and testing of learning content and software application

The Software developer starts coding of application using suitable programming language. The Instructional designer develops the learning content. During the development testing is conducted in parallel. The Software test engineer tests the application and learning content compatibility across multiple platforms and networks using already designed test cases. The testing is done on emulator and cloud. The Language editor verifies the language of contents i.e. free from grammatical errors and formatting.

d. Evaluation and feedbacks

Once the module is ready after testing on emulator and cloud, it is sent to Instructors as crowd testing steps to get the feedbacks. The feedback is received in feedbacks repository which is accessible to Software test engineer and Language editor. The prepared reports on the feedbacks are sent to Software developer for change (if any). In case of positive feedbacks, the module is added to the existing application else changes are made and steps are repeated.

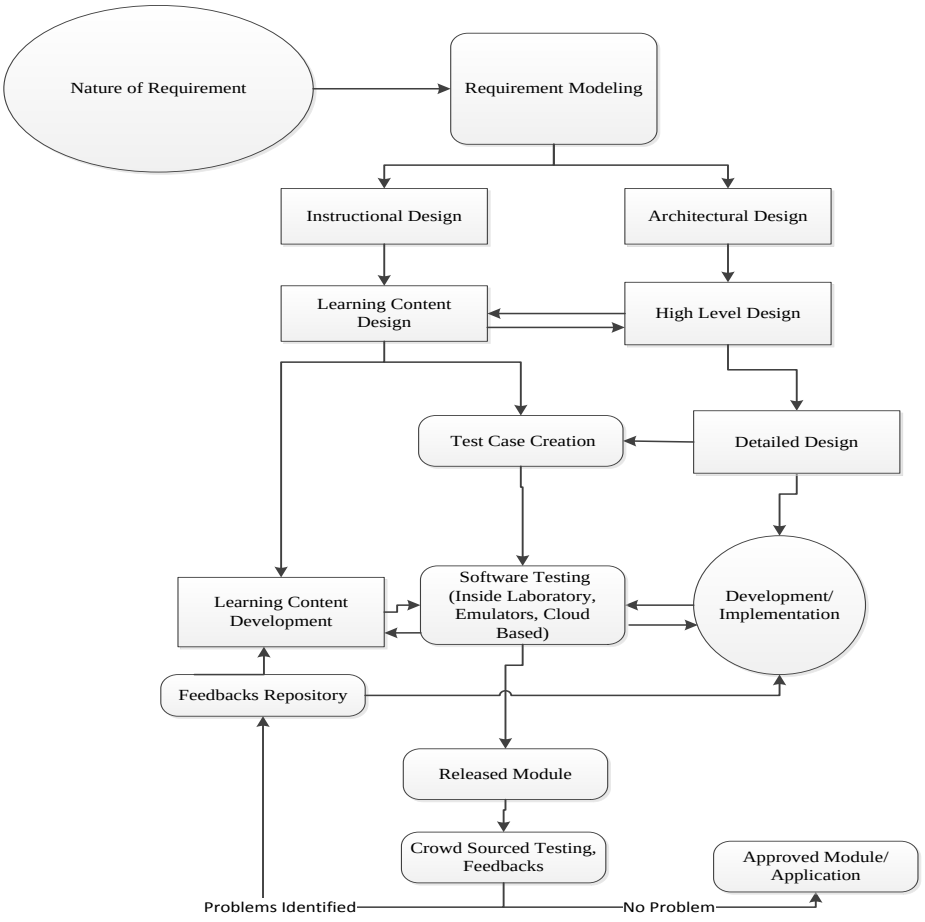

Fig. 2. Integrated Design Model for M-Learning Pedagogy and Application.

5. DISCUSSION

The design phase of M-Learning software development life cycle affects the subsequent phases such as development, testing, and deployment. Therefore, it's necessary to consider all the constraints and criteria while designing the pedagogy and software application for M-Learning. The proposed design approach has considered the limitations of the existing approaches by advocating integrated design model. These limitations would be discussed one by one.

First of all, the proposed model has considered the pedagogical design and application design as a one task with subtasks undergoing in parallel. The common design issues in M-Learning is communication and interactivity between different components (Alvarez, Alarcon, & Nussbaum, 2011).

Likewise, several researchers performed case study in M-Learning and concluded that the instructional design should be aligned with the objectives and technology (Capretz, Ali, & Ouda, 2012; López, Royo, Laborda, & Calvo, 2009; Naismith & Corlett, 2006). Not all kind of learning material can be uploaded in an application (Chou, Block, & Jesness, 2012) . In an article (Cheon, Lee, Crooks, & Song, 2012; Williams, 2009) defined a design approach for Augmented Reality with emphasis on pedagogy and software application together.

Starting with software application design, this design model has considered three levels: architectural, high level and detailed. For instance (Chen, D., Chen, Huang, & Hsu, 2013) claimed that software design is composed of architectural design, interface design, detail design. At the architectural level design, the software designer identifies the design solution of the problem. The sub systems, constraints, interacting interfaces, and architectural styles (Batch sequential, Client-server, communicating processes, Event systems, Object-oriented etc.) are explored. At the high level design breaking of architectural

level design into modules is performed. The sub systems are now represented as modules. During the detailed design level module details (data structures and algorithms) are designed which would be further used in the development phase.

As far as pedagogical design is concerned the proposed model has addressed instructional design and learning design. Most of the M-Learning design and development fails to consider these two important areas. M-Learning software development suffers from good pedagogical designs (Zhu, 2005). M-Learning software development process should follow clearly defined pedagogical design principles depending on the learner type, context of use, and interactivity (Laru, Naykki, & Jarvela, 2015; Looi, Sun, & Xie, 2015).

In the proposed model the pedagogical design starts with the instructional design which is equivalent to architectural design of software application. (Lehner & Nösekabel, 2002) after reviewing M-Learning articles from 2007 to 2014 on the design of science apps pointed out that instructional principles are rarely implemented during the design and suggested that instructional designers and researchers should pay considerable attention. Instructional design and development should incorporate pedagogical principles and theories (Zydney & Warner, 2016) specially proposed for M-Learning (Lim, Oakley, & Liu, 2013). Instructional materials should be presented in granular fashion (Huang, Lin, & Cheng, 2010) and use of micro lecture format (Lowenthal, 2010). Designing digital contents for M-Learning require analyzing cognitive skills of students (Gu, Gu, & Laffey, 2011) and presenting learning content logically (Chiu & Churchill, 2014).

Next step is learning design. The proposed model dictates to consider the learning styles and learning theories such as behaviorist (instruction oriented), constructivist (construction of knowledge or task-based activities), collaborative (group work, dialogue, and discussion) in learning design. It is important to consider learning styles and learning theories (Yang, Li, & Lu, 2015). The learning design is equivalent to high level design of software application. The detailed designs have to be in congruence with the learning design. For any discrepancy necessary changes have to be included into practice. There should be alignment of learning content, learning context, and the adjustment of instructional strategies (Schwabe & Göth, 2005). The design should be tested to make sure that design and instruction principles are implemented (Tsai, Young, & Liang, 2005). A pedagogical design should adopt a theory of learning Mayes (2004). Learning theory, instructional design theory, and instructional design are interlinked (Zydney & Warner, 2016).

The instructional as well as learning design job is performed by Instructional and Learning designer. The common tasks are: look and feel, organization and functionality of instruction, blueprint for the course, outline of subjects etc.

The last important component of the proposed model is testing. The testing of product is important for acceptance (van Rhyn & Hancke, 2017). There are three types of testing performed in the proposed model: emulator, cloud, and crowd sourced. The test cases are generated for validation of the application at stages during high-level design. Even though the development of application starts with requirements elicitation however including the testing processes from very early stage is required (Moraes, Andrade, & Machado, 2016). Software testing is an important step in development process for building a reliable and correct software (Belli, Budnik, Hollmann, Tuglular, & Wong, 2016). Hence in the proposed model once the application has been tested well it's accepted for use.

6. COMPARISONS WITH ISO/IEC 12207:2008 AND ISO/IEC 19796-1 STANDARDS, EXPERTS REVIEW, AND RESULTS

The existing design approaches for M-Learning pedagogy and software application from Table 2 (coded as A, B, C, D, E, F, G, H, I, J, K, L, M and the newly proposed approach is coded as N) is compared with ISO/IEC 12207:2008 and ISO/IEC 19796-1 standards. These comparisons are shown in the Table 3 and Figure 3. Out of seven process groups in ISO/IEC 12207:2008 standard five have been taken for comparisons. The comparison with ISO/IEC 19796-1 covers five processes out of seven. ISO/IEC 19796-1 is a standard that help educational organizations to develop quality systems and improve the quality of their processes, products, and services (Pawlowski, 2007).

The comparison of existing design and development approaches and proposed Integrated Design Model with

ISO/IEC 12207:2008 and ISO/IEC 19796-1 (Table 3 and Figure 4) shows that all the five criteria are not satisfied by any of them except "N". Also, most of them have not considered integration of learning content and software application, evaluation, and testing steps. None of them have identified the stakeholders and their roles during design, development, and testing steps. In the proposed model architectural design, detailed design, continuous integration and testing of learning and software application modules have been emphasized.

Table 3. Comparison of existing M-Learning design approaches with ISO/IEC 12207:2008 and ISO/IEC 19796-1.

ISO/IEC 12207:2008 design process	**Existing M-Learning Design Approaches and Comparisons**													
	A	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**	**L**	**M**	**N**
Architectural Design	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Detailed Design	Yes	Yes	No	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Construction	Yes	No	Yes	Yes	Yes	Yes	No	Yes	No	No	Yes	Yes	No	Yes
Integration	No	No	Yes	No	No	No	No	No	No	No	No	No	No	Yes
Qualification & Testing	Yes	No	No	No	Yes	Yes	No	Yes	No	No	No	No	No	Yes

Process Model of ISO/IEC 19796-1	**Existing M-Learning Design Approaches and Comparisons**													
	A	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**	**L**	**M**	**N**
Design of an educational process	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Development	Yes	No	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Implementation of technological components	No	No	No	No	No	No	No	No	No	No	No	No	No	Yes
Learning Process	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	No	Yes	Yes	Yes	No	Yes
Evaluation	No	No	No	No	No	No	No	No	No	No	No	No	No	Yes

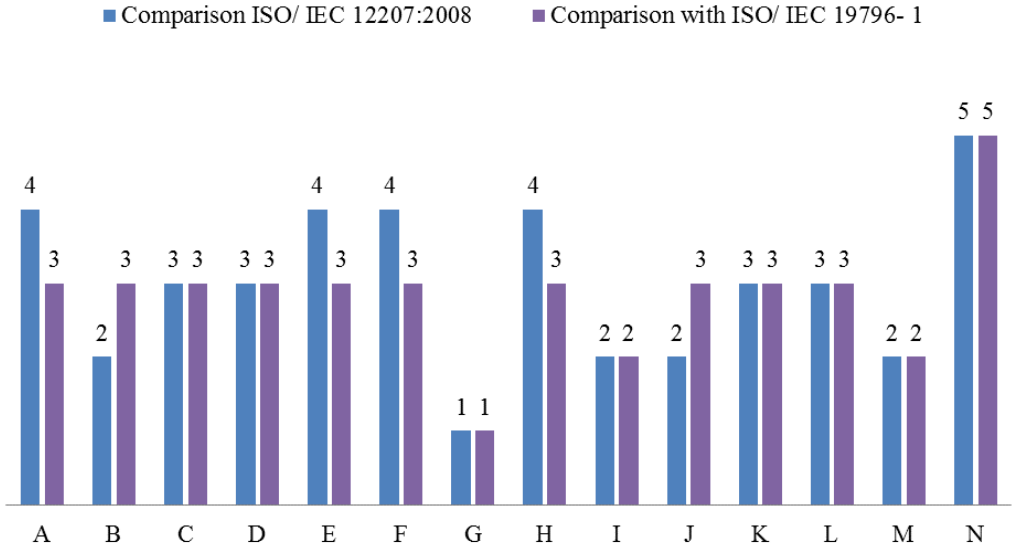

Fig. 3. Comparison of existing M-Learning design approaches with ISO/IEC 12207:2008 and ISO/IEC 19796-1.

Experts Review

IT experts examined the the proposed design model from April 2017 to July 2017 to provide feedbacks on the suitability in the context of learning. Out of twelve experts 41% have 2-3 years and 25% have more than four years' experience in M-Learning design and development.

The experts have positive perception towards stakeholders' identifications, requirements classification and modeling before actual design starts. Eight of them view it's important to go for parallel design and development of learning content and software while two of them disagree. When the reasons for their disagreement were investigated it's found that the disagreement is due to less experience in M-Learning. The experts have positive opinion for including the learning styles and learning theories during instructional and learning design as shown in Table 4. This further supports the pedagogical design steps in the proposed model.

The experts are of the view that the end users should be involved in testing and testing should be performed at both learning content, and learning software which supports the proposed model steps of testing. Table 5 shows the experts feedbacks on testing.

Lastly, the experts were asked an open ended question to provide feedback on the overall integrated design model. Out of twelve, nine of them accepted the steps of the design model. The experts have found design, development, and testing steps appropriate and acceptable.

The SWOT (Strengths, Weaknesses, Threats, and Opportunities) analysis of the proposed model is shown in Figure 4.

Table 4. Instructional design with learning theories and learning style.

Design Step	Strongly Agree (=1)	Agree (=2)	Neutral (=3)	Disagree (=4)	Strongly Disagree (=5)
Learning theories	4	5	2	1	0
Learning Styles	4	5	2	1	0
Total Frequency	8	10	4	2	0

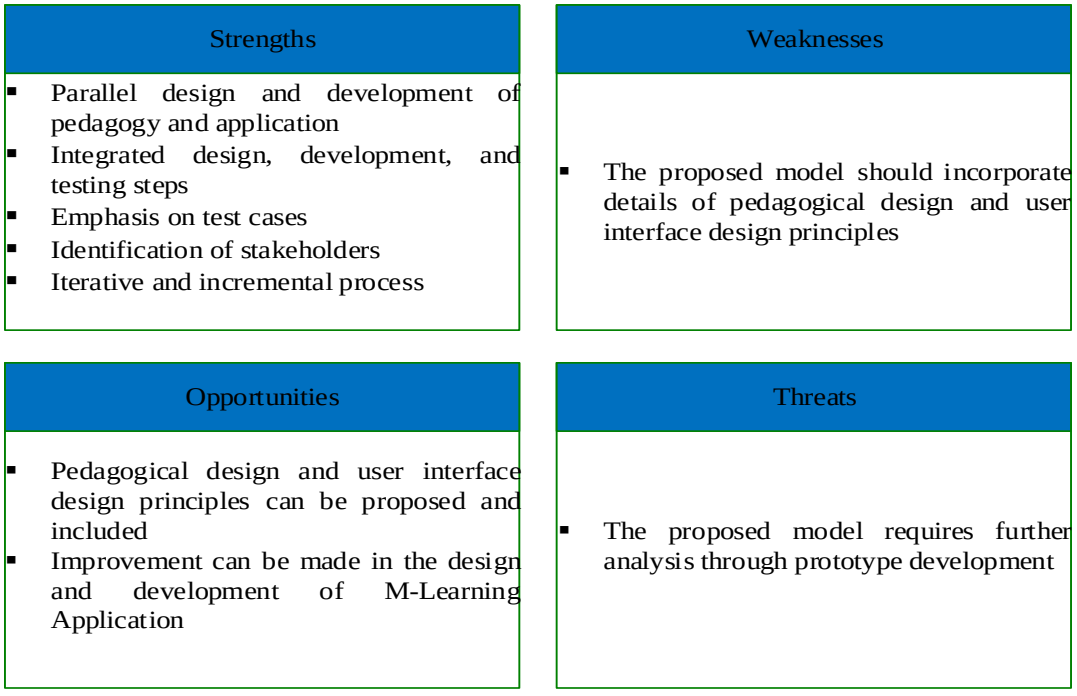

Fig. 4. SWOT analysis of the proposed Integrated Design Model for M-Learning Pedagogy and Application.

Table 5. Testing during design and development.

Testing activity	Strongly Agree (=1)	Agree (=2)	Neutral (=3)	Disagree (=4)	Strongly Disagree (=5)
Testing of learning content	8	1	2	1	0
Testing of learning software	7	2	3	0	0
Involvements of End users	4	5	2	1	
Total Frequency	15	3	5	1	0

7. CONCLUSION

Successful implementation of M-learning is influenced by design approach followed for pedagogy and application. The proposed model is based on the critical analysis of the existing literatures. The proposed design model is the first of its kind where the designing of both pedagogy and application takes place in parallel. The proposed model emphasizes requirements classification and modelling, identification of stakeholders, pedagogical design and development, application design and development, designing test cases, and testing of the developed application.

The requirements are classified into functional, non-functional, and pedagogical. The stakeholders are categorized as software application and pedagogical stakeholders. The model considers three level of application design: architectural, high, and detailed design level. The pedagogical design consists of instructional design and learning design. The pedagogical stakeholders are involved in pedagogical design.

The test cases are designed during software application and pedagogical design. The test cases are used to find out compatibility between learning and application design, suitability of learning content and application, and alignment of the developed M-Learning application with the elicited requirements.

Lastly, the proposed model has been verified by comparing with ISO/IEC 12207:2008 and ISO/IEC 19796-1 standards and IT experts review. The feedback is positive in both cases. In future M-Learning application would be developed following the steps of proposed model and application design principles would be proposed

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CONFLICT OF INTEREST

The authors have no conflicts of interest to declare.

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