A Framework for Instantiating Pedagogic mLearning Objects Applications

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Abstract. An increasing desire to port learning objects on mobile phones exists. However, there is limited understanding on how to pedagogically obtain access to and use learning objects on mobile phones. The limited understanding is caused by a dearth in frameworks for underpinning the development of mobile learning objects applications. Following Design Research methodology, we developed a Mobile Learning Objects Deployment and Utilisation Framework (*MoLODUF*) to address this problem. *MoLODUF* is composed of twelve dimensions, including: MLearning Objects, MLearning Device, MLearning Interface, MLearning Connectivity, MLearning Process, MLearning Costs, MLearning Resources, MLearning Context, MLearning Pedagogy, MLearning Ethics, MLearning Policy and MLearning Evaluation. The *MoLODUF* makes significant extensions to existing electronic and mLearning frameworks. It provides a competency set of guidelines for developing and/or evaluating applications for deploying and utilising learning objects on mobile phones.

Keywords: mLearning, mLearning Objects, Framework, mLearning Objects Framework, mLearning Objects Deployment, mLearning Objects Utilization, *MoLODUF*, mLearning Objects Applications, Makerere University.

1 Introduction

Of recent, learner mobility has been enabled by use of mobile devices in their learning processes. This process has been termed ‘mobile learning’ or ‘mLearning’ for short.

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A. Cerone and P. Pihlajasaari (Eds.): ICTAC 2011, LNCS 6916, pp. 194–217, 2011.

Due to its embryonic nature, the practice of mLearning is still insignificant. As such, mLearning requires increasing research attention to let it mature. Research related to mLearning development, practice and evaluation is necessary. More so, little research attention has been accorded to the development of frameworks for instantiating pedagogic application for mLearning objects deployment and utilisation.

In [32], a pedagogic framework for mLearning is given. The framework categorizes educational applications of mobile technologies into four types, namely: 1) high transactional distance socialized mLearning, 2) high transactional distance individualized mLearning, 3) low transactional distance socialized mLearning, and 4) low transactional distance individualized mLearning (p.1). Other researchers [4, 5, 13] have also developed frameworks for theorizing about mLearning. All these frameworks are aloof to issues necessary for instantiating and/or evaluating pedagogic mLearning objects applications and environments. In [21, 34, 43], research that specifically targets development of frameworks for guiding the instantiation of applications for obtaining access to and utilising learning objects on mobile devices is called for.

In this paper, we have developed a Mobile Learning Objects Deployment and Utilization Framework (*MoLODUF*). *MOLODUF* provides process steps for instantiating pedagogic applications that can enable learners in developing countries obtain access to and use learning objects, delivered over the Internet, regardless of their proximity to higher education institutions, through the use of mobile phones. *MoLODUF* can also be used to evaluate mLearning environments in developing countries. Developing countries are faced with a hoard of infrastructural constraints which inhibit conventional eLearning [11] but on the other hand, they are embracing mobile telephony at unprecedented rates [18]. For instance, by the end of 2009, the Compound Annual Growth Rate (CAGR) for mobile telephony stood at 28.7 Percent for Uganda, 92.7 Percent for South Africa, 63.4 Percent for Ghana and 66.7 Percent for Egypt [18]. Such impressive mobile telephony permeation statistics are good recipe for mLearning [28, 41].

MLearning is a subset of eLearning [5]. Research into mLearning should thus be informed by earlier developments in eLearning. To develop a mLearning framework, one has to draw from existing eLearning frameworks. In [13], [20] and others, eLearning frameworks have been developed. A review of these frameworks posts the Global eLearning Framework in [20] as being the most comprehensive of all eLearning frameworks. For this reason, the development of the *MoLODUF* was guided by the Global eLearning Framework in [20]. The Global eLearning Framework [20] suggests implementation of eight dimensions for meaningful eLearning to occur. These are the *Pedagogical, Technological, Interface Design, Ethical, Institutional, Evaluation, Management* and *Resource Support* dimensions. Through *Design Research* [2], the Global eLearning Framework in [20] was extended to include dimensions that allow for learner mobility.

Design research is; "… a systematic but flexible methodology aimed [at improving] educational practices through iterative analysis, design, development, and implementation, based on collaboration among researchers and practitioners in real-world settings, and leading to contextually-sensitive design principles and theories". [48, p.6]. The framework developed in this study provides important guidelines for developing and evaluating mLearning objects applications and environments. It was developed from dimensions adduced from answers to the following six research questions;

i. What are the current learner contexts, practices and prospects for the development and growth of mLearning?
ii. What learning processes can be accomplished through mLearning?
iii. What kinds of learning objects can be used to service the identified learning processes?
iv. What are the issues and factors to obtain access to and use learning objects in mLearning?
v. What are the major dimensions and sub-dimensions of the *MoLODUF*?
vi. How is the *MoLODUF* related with existing mLearning and eLearning frameworks?

The rest of this paper is organized in six sections. In *Section 2*, we review the concept of mLearning, mLearning objects, traditional learning theories and mLearning, mLearning objects frameworks and the Global eLearning Framework in [20]. In *Section 3*, we detail the methodology we used to get the dimensions for the *MoLODUF* and in *Section 4* we present and discuss results of the study with a view of developing the *MoLODUF*. The process steps for instantiating or evaluating mLearning objects applications and environments are given in *Section 5* before drawing the conclusion and future work from the study in *Section 6*.

2 Related Work

2.1 Mobile Learning (MLearning)

Wireless tiny handheld devices are making it possible for learners not to be tethered in orchestrated fixed classrooms for learning purposes. Such "anytime", "anywhere" computing platforms have ignited a paradigm shift from eLearning models to mLearning models [25, p.1]. Hence increasing research attention is unfolding in the area of mLearning from industrialists, researchers, educationist and policy makers [3, 5, 7, 22, 25, 43, 45]. As a consequence, mLearning has been variously defined. While considering a mobile device as an enabler of learner mobility, [43] defined mLearning as learning which takes place at anytime in anyplace using a mobile device. As such, mLearning is more than just the use of mobile devices for learning but the ability for one to electronically learn on-the-go (ibid). In [32, p.79], "mobile learning refers to the use of mobile or wireless devices for the purpose of learning while on the move". A view earlier espoused by [5] emphasized that mLearning is eLearning which uses mobile devices to deliver learning. It is evident from the various definitions that mLearning is a form of eLearning which takes place at anytime in any place using wireless tiny handheld technologies.

MLearning enables learner mobility and as such exposes a learner to different learning environments/contexts [3, 43, 45]. Research has shown that a learner acquires a rich learning experience when exposed to an environment with other learners that have different learning experiences acquired from different contexts [7, 22, 45]. MLearning enables high transactional socialized learning [32] in different contexts. Context relates to information which describes the situation of a learner in a given location [45]. Learning from one's known context increases ones ability to relate what is being learnt to the surroundings, thus increasing learning experience and flexibility in learning.

In mLearning, the accumulation of different learning experiences is brought about by the advantages inherent in mobile devices since they facilitate just-in-time and just-in-place interaction and collaboration in specific contexts through exchange of mLearning objects [45]. In developing countries, contextualized learning is oftentimes lost because of the tethered technologies usually employed in conventional eLearning [5, 26]. A blend of mLearning and eLearning would suffice to bridge the gaps that exist in each of these models. By implementing mLearning, on-the-go, contextualized and flexible learning can be introduced in eLearning. However, the extent of development and use of mLearning in different contexts is still embryonic [41, 45]. Likewise, the development of content for mobile devices cum mLearning objects is also still embryonic [3].

2.2 MLearning Objects

The concept of mLearning objects started way back in 2002 [36]. Since then, little research attention was realized until recently when the Internet became increasingly accessible via mobile devices. It is now possible to deliver content to learners via their mobile phones [3]. However, because of the limitations of mobile devices [15], the content has to be "leaner than content prepared for eLearning systems" [24, p.9]. The content has to be granular, sequenceable, reusable and contextualiseable [3, 45]. These requirements are a perfect match for the characteristics of a learning object. In [49], a learning object is defined as a digital educational resource/content which is granulated into units that are reusable, adaptive, and can be re-purposed to different learning styles, knowledge levels and conditions. In [38, p.2], a learning object is defined as "one or more files or 'chunks' of materials, which might consist of graphics, text, audio, animation, calculator, or interactive notebook, designed to be used as a standalone learning experience". Elsewhere, a learning object is "any entity, digital or non-digital, which can be used, reused or referenced during technology supported learning" [17, p.1].

Whereas resources are abundantly available for desktop computer learning objects, learning objects for mobile devices have to be granulated so that they are viewable and sequenceable on tiny screens via limited bandwidth pipes. Learning objects that can be accessed by and delivered on mobile devices are called mLearning objects [3, 30, 36, 42, 44, 50]. Also a mLearning object can be "an interactive software component, personalized and reusable in different contexts, designed to support an educational objective through a mobile device in situated learning or collaborative learning activities" [3, p.153]. This implies that a mLearning object is not only restricted to content on the mobile device but also the interface to the content or activities related to the use of the content or all of these. An SMS to learners providing them with a URL to content in the WWW could be regarded as a mLearning object.

Research into the development, deployment and utilization of mLearning objects is ongoing [3, 13, 30, 36, 42, 44, 50, 51]. This research is however skewed in favor of developed countries' contexts and is mainly still in trial or prototype phases. Since uptake of mobile phones in developing countries has surpassed industry analyst's predictions, it is important to undertake research into development of frameworks for instantiating applications for deploying and utilizing mLearning objects and evaluating mLearning in those contexts.

MLearning objects could take the form of carefully designed materials that take cognizance of mobile device limitations. However, according to [3], considering mobile devices limitations alone in the design of mLearning objects is being short sighted. Designing for learner personalization, collaboration and interaction completes the picture of a mLearning object (ibid). It means even considering the capability of the mobile device owned by the target learner. It also means taking into consideration exogenous factors that could have an influence on mLearning objects deployment and utilization.

MLearning objects could be delivered in traditional classroom environments, could be used for online performance support to guide a learner working through a task, could be used for augmenting classroom instructions and other learning materials and could be used as instructions for operating a given device [36]. The size, presentation and scope of a mLearning object is dependant upon the capacity of the mobile device in question and how a given institution conceptualizes a learning object. In [3], a software component is regarded as a mLearning object. In developing countries where learners own mainly low end mobile phones, text based learning objects are more feasible than resource heavy learning objects such as software modules [5].

Software modules extending academic and administrative support to students can be run on Java enabled mobile phones. Multiple choice quizzes, exams and lecture calendars, reminders for important events and frequent errors committed by students in a given subject can be developed as Java midlets and delivered on java enabled mobile phones [42]. The success of mLearning lies in the need to recognize the limitation of mobile devices so as to deploy learning objects onto them which address pedagogic assistance. Consequently, mLearning objects should be characterized by appropriate pedagogic values. Just like any other learning delivery model, mLearning is intended to contribute to student learning. Therefore, the pedagogic values inherent in mLearning should as well be underpinned by the traditional learning theories.

2.3 Traditional Learning Theories and MLearning

While learning, learners collaborate, interact and communicate with each other to accomplish group or individual learning activities. Collaboration, interaction and communication are functions that can be accomplished using mobile communication technologies. These learning tenets are inherent in the Social Constructivist Learning Theory [46], Conversational Learning Theory [33], Behaviorist Learning Theory [39], Learning and Teaching Support Theory [29], and Informal and Lifelong Learning Theory [10].

The Social Constructivist Learning Theory is an extension of the Constructivist Learning Theory [46]. The Constructivist Learning Theory recognizes learning as an active process in which a learner constructs new ideas or concepts based on his/her current and past knowledge. The Constructivist Learning Theory takes an individualistic angle that negates the fact that learning occurs in social settings. Consequently, critiques of the Constructivist Learning Theory such as [35] have argued for the Social Constructivist Learning Theory [46]. The Social Constructivist Learning Theory proponents posit that knowledge creation is shared rather than an individual experience. Their position is inline with that of [14] who contends that knowledge is constructed through interaction of a number of minds and not just one. Hence knowledge is a social product [35]. Tools and raw materials for creating this social product can arise from

technologies that encourage interaction and collaboration. The mobile phone is a good example of such technologies. Mobile teleconferencing and SMS can scaffold learning in communities of practice (CoP). Members of a given CoP and their facilitator (s) may use collaborative and interactive tools afforded by mobile technologies to interplay their minds on topical issue so as to generate new knowledge. In this case collaboration and interaction afforded by mobile technologies become key tenets for social learning.

Another traditional learning theory which can underpin mLearning is the Conversational Learning Theory [33]. According to this theory, learning takes place if there is a continuous two-way conversation and interaction between the teacher and learner and amongst the learners themselves. Indeed, learning will take place if two parties participating in a conversation can understand each other. As [29, p.15] observed, learning will take place if "Person A [makes] sense of B's explanations of what B knows, and person B can make sense of A's explanation of what A knows". The Conversational Learning Theory emphasizes the need for continuous conversation with peers and the teacher or a device which subsumes the role of a teacher. Mobile technologies such as mobile phones are well suited at providing this conversational space.

Learning occurs if there is a force in the learning process which reinforces a relationship between a stimulus and a response. This exposition derives from the Behaviorist Learning Theory [39]. This theory emphasizes activities that promote learning as a change in learner's observable actions. In the case of mLearning, an SMS message, for example, invokes a stimulus that may lead to an action as a response. When a message is received on a learner's mobile phone, for example, the learner will be triggered to respond or provide feedback. The message received on the learner's phone presents a problem (stimulus) that requires the learner to solve through a response. In this case, the mobile phone which presented the problem reinforces the relationship between the problem (stimulus) and the solution (response). Moreover, once learners are conditioned to an SMS as a conveyor of educational related messages, they will be conditioned to immediately read them as they are delivered. This abets just-in-time and just-in-place learning.

Provision of learning is not just about providing content and learning activities to learners. It also involves a great deal of coordination of learners and resources [29]. Besides, access, communication and support are the three canonical uses of ICTs in education [5]. The Learning and Teaching Support Theory [29] emphasizes the need for support systems in learning and teaching. The support systems assist in the "coordination of learners and resources for learning activities" [29, p.11]. By using SMS and voice calls, a lecturer can be able to coordinate class activities and organize resources for the class. The lecturer can be able to support learners through reminders of learning events and provide URLs to reading materials. Learners can also support each other using their mobile phones.

As per the Informal and Lifelong Learning Theory [10] learning can take place at any time, in any place and at any age. According to this theory, "learning happens all of the time and is influenced both by our environment and the particular situations we are faced with" [29, p.17]. Informal and lifelong learning can occur as a result of

intentional or accidental learning episodes that are orchestrated by exchange of information and knowledge [31]. Intentional learning episodes occur when learning is planned while accidental learning episodes occur from scenes which have no direct learning intentions, such as experiencing an accident, watching television, engaging in casual conversations, reading a newspapers or even listening to radio talk shows (ibid). It means that accidental learning can occur at anytime in anyplace. Learners carry their mobile phones at all times in anyplace, implying that they can be a source of information for accidental learning.

The above learning theories have been at the forefront of research for formulating mLearning and eLearning frameworks and models. Some of these frameworks and models are reviewed in *Sections 2.4* and *2.5* respectively.

2.4 The Global eLearning Framework

In [20], an eLearning framework addressing global eLearning issues is presented. The framework has eight (8) major dimensions that are instrumental to meaningful implementation of eLearning. These dimensions are presented in the framework shown in *Figure 1* below.

The eight (8) major dimensions in the Global eLearning Framework [20] presented in *Figure 1* below are: *Institutional, Pedagogical, Interface Design, Evaluation, Management, Resource Support, Ethical and Technological* dimensions. Each of the major dimensions consists of several sub-dimensions as is detailed below.

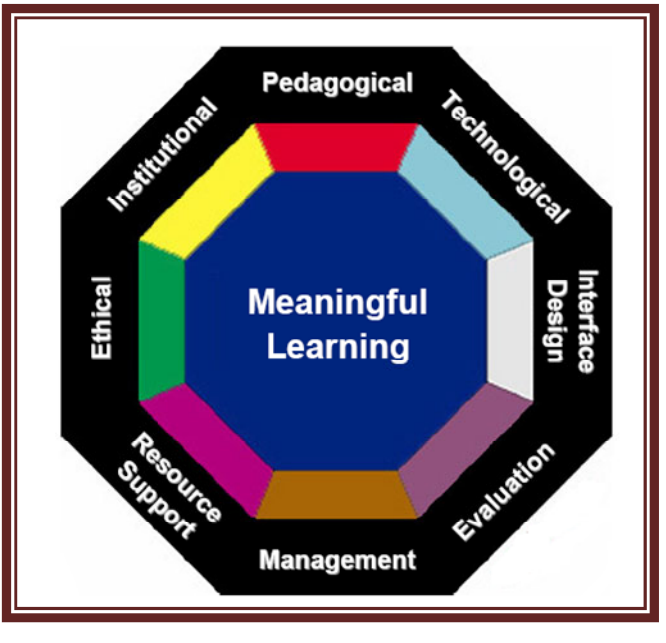

Fig. 1. Showing the Global eLearning Framework [20, p.1]

The *Institutional* dimension implores institutions wishing to adopt eLearning to examine their administrative, academic and student support affairs. In the *Administrative* sub-dimension, an institution should determine whether it is ready to offer eLearning or not. In the *Academic* sub-dimension, the institution should determine whether the quality of programs to be offered via eLearning meet quality standards similar to those offered through traditional programs. In the *Student Support* sub-dimension, the institution should determine that the instructors/administrators are available and ready to support the students during online learning.

The *Pedagogical* dimension consists of the *Content, Audience, Goal and Objectives, Medium, Design, Organization* and *Methods* sub-dimensions. The *Content* sub-dimension requires institutions to determine the type of content that can be delivered over different learning technologies. The *Audience* sub-dimension requires institutions to profile their learners. The *Goal and Objectives* sub-dimension requires institutions to provide clear expectations of what the learners are expected to achieve. The *Medium* sub-dimension requires institutions to determine whether they should utilize multiple media content (text, audio, video, graphics or a combination of these) in their delivery. The *Design* sub-dimension determines the role of the instructor. Is it more facilitative than didactic, more didactic than facilitative or a combination of both? The *Organization* sub-dimension is concerned with whether eLearning provides a sense of continuity in the learning process. It answers questions related to whether in eLearning, one unit of a lesson builds on the previous unit. The *Methods* sub-dimension asks whether the eLearning environment being proposed provides means and mechanisms for collaboration among learners and learners and their tutors and administrators.

In the *Interface Design* dimension are sub-dimensions such as *Page and Site Design, Content Design, Navigation, Accessibility* and *Usability Testing.* The *Page and Site Design* sub-dimension is concerned with the appearance of the web-pages to the learners. Pages must appear good and appealing to learners. The *Content Design* sub-dimension implores content developers to follow a 'one idea per paragraph' rule while designing content. The *Navigation* sub-dimension requires an eLearning program to provide structural aid or site map to guide learner's navigation. The *Accessibility* sub-dimension requires that an eLearning program should be designed in such a way as to be accessed by a wider user population. The *Usability Testing* sub-dimension requires that an eLearning program provides instant feedback to frequently asked questions in the program itself.

The *Evaluation* dimension considers the assessment of learners and evaluation of instruction and learning environment. The *Assessment of Learners* sub-dimension requires the eLearning program to have a mechanism for truly measuring the learner's learning achievements without having loopholes for cheating. The *Evaluation of Instruction* and *Learning Environment* sub-dimension requires that eLearning program should have mechanism to enable learners to evaluate the content, instructor, learning environment, learning resources, course design and technical support.

The *Management* dimension has two sub-dimensions, namely: *Content Development* and *Maintenance*. In *Content Development* sub-dimension, a requirement for a project support site for eLearning production team is placed. In the *Maintenance* sub-dimension, a requirement for constant and timely updates within the eLearning

program is placed. The updates to the learners could be made through e-mail, announcement page, alert boxes, running footer added to a page or phone call.

The *Resource Support* dimension has the *Online Support* and *Resources Support* sub-dimensions. The online support sub-dimension requires that eLearning should have troubleshooting expertise or helpdesk support. The *Resources* and *Support* sub-dimension requires the eLearning program to facilitate learning by providing examples of prior work of the student in digitized formats.

The *Ethical* dimension includes the *Social/Political Influence, Cultural Diversity, Bias, Geographical Diversity, Learner Diversity, Digital Divide, Etiquette* and *Legal Issues* sub-dimensions. In the *Social/Political Influence* sub-dimension, an institution should determine whether there are social/political forces that might curtail the implementation of eLearning. In the *Cultural Diversity* sub-dimension, counsel is provided to reduce or avoid the use of idioms, jargons, ambiguous words or cute humor and acronyms. The *Bias* sub-dimension requires that more than one view point be presented to a controversial issue. The *Geographical* sub-dimension requires that eLearning should be provided to learners located in different geographical areas and must therefore take care of different time zones so as to appropriately schedule synchronous communication. The *Learner Diversity* sub-dimension recognizes that there are slow, medium and fast learners. Therefore an eLearning system must take care of all these learners. The *Digital Divide* sub-dimension is important in that it considers access to technology. The system should not disadvantage learners who lack the necessary learning technologies. The digital divide issue should be considered while designing the eLearning content. The *Etiquette* sub-dimension provides guidance to learners on how to behave during eLearning. It provides the dos and don'ts in eLearning. The *Legal Issues* sub-dimension requires the eLearning program to seek permission to post on the Web, students' photographs and projects.

The *Technological* dimension has *Infrastructure Planning* and *Hardware and Software* sub-dimensions. *Infrastructure Planning* sub-dimension requires the institution to ascertain whether it has the necessary personnel who can assist learners to get onto eLearning. The *Hardware and Software* sub-dimension is important for profiling the necessary hardware and software requirements for the eLearning program (ibid).

The dimensions espoused in the Global eLearning Framework [20] do not cater for mLearning objects deployment and utilization on mobile phones. In the Global eLearning Framework [20] , no dimension(s) is/are included for enabling learning on-the-go. Using *Design Research* [2] approach, this paper has developed a global framework, underpinned by the Global eLearning Framework [20], for instantiating mLearning objects applications.

2.5 MLearning Objects Frameworks

Table 1 below provides a review of some mLearning objects frameworks and models. From *Table 1*, it is worth noting that the models and frameworks therein are not global in nature in as far as mLearning objects deployment and utilization is concerned. They address endogenous factors needed for mLearning objects adaptation and aggregation while putting less emphasis on exogenous factors that have potential influence on the deployment and utilization of learning objects on mobile phones.

Table 1. Some mLearning Objects Frameworks

Model/Framework	Characteristics/Features	Research Gap
Framework for flexible learning using mLearning objects [36]	- Uses the concept of learning objects to personalize learning. - It contextualizes learning	Does not model the limitations of mobile devices Does not consider cost dimension of mLearning Does not consider cognitive overload
Multi-dimensional framework for content adaptation [13]	- Adapts content to different device types and user profiles using five dimensions which include content, user, capability, connectivity and coordination dimensions	Lacks a dimension for learning objects usability and does not take into account mLearning objects acquisition issues. Limits pedagogy to content only yet mLearning pedagogy should be an overarching issue in all aspects of mLearning. Leaves out mLearning policy and strategy.
MLearning content hoarding model [44]	- Picks content from the WWW which it transforms into mobile formats and prepares it for online and offline sessions - Uses PDAs as the mobile devices - Caters for intermittency in network connections - Hoards content in the PDA's memory for use during offline sessions	Whereas the model addresses intermittency in network condition, something common in developing countries, memory limitations on low and mid range mobile phones makes this model inapplicable in developing countries. Has no costs dimension
J2ME midlets/learning objects access model [42]	- A model for offering support services to students in a blended learning environment. - Support services are offered using Java midlets because they offer offline access as opposed to WAP pages - Midlets are accessible either via mobile devices or PCs	No device and learner profiling is evident in the model. Though they offer pedagogic support the midlets are not interactive, collaborative and contextualized.
Adaptive framework for aggregating mLearning objects [50]	- Provides an approach for gathering feasible eLearning content and adapting it for mobile devices - The framework profiles and contextualizes the learner and the mobile device	The model assumes one source of learning content – WWW. It is also concerned more with content transformation than deployment and utilization
Push and pull framework for mLearning objects delivery [27]	- Integrates mobile connectivity with eLearning - Is based on the push and pull model for content delivery - Supports pedagogic approaches for content personalization and collaboration	Does not profile device and network conditions
Adaptive mLearning environment [30]	- Provides an adaptive self-learning environment - It is motivated by the need to use learning objects in mobile and PC based environments - Supports learner adaptation and offline learning using mobile phones - Takes SCORM 2004 to the mobile arena	Limits the source of learning objects only to SCORM based LMS. The mobile web, WWW, enterprise databases, repositories are other sources for learning objects. No pedagogic agents are evident in the model. Also there is no profiling of network condition in the model
Computational models for mLearning objects [3]	- A mLearning object is not simply that which has been adapted for display on a tiny screen of the mobile phone. Rather, it is one with the following characteristics: ▪ Ability to be displayed on the tiny screens ▪ Ability to be personalized ▪ Ability to inculcate collaboration and interaction - Offers computational models based on learning objects personalization, collaboration and interaction	The models lack a component for profiling network conditions, an aspect which is of importance in mLearning in developing countries

3 Methodology

MoLODUF aims at widening the dissemination of knowledge through the mobile phone. Knowledge is a social product [35]. Research into the design, development and evaluation of artifacts for disseminating knowledge is socially responsible [37]. The social responsibility emanates from the belief that such research addresses the needs and aspiration of the masses pursuing an education. It implies that research approaches to be employed in such socially responsible studies must ensure the participation of the masses involved in the knowledge dissemination artifacts design, development, evaluation and use. Since *MoLODUF* was aimed at widening knowledge dissemination; it implies that its development was socially responsible.

Design Research has been fronted as the most suitable approach/methodology for accomplishing socially responsible studies [2, 8, 16, 37, 48]. *Design Research* combines research, design and practice [48] and its outputs include: constructs, models, methods/frameworks, instantiations and better theories [2]. "Constructs are vocabularies or symbols used to define a problem or solution while models are abstractions and representations of the problem or solution and methods/frameworks are algorithms and practices for implementing the artifact. Instantiations are implementations and prototype systems" [16, p.2]. Constructs provide building blocks for models and frameworks. A framework is a supporting structure around which something can be built [ibid]. *MoLODUF* was built following the *Design Research* methodology.

Design Research methodology is an iterative process for developing or evaluating artifacts. It is accomplished through five process steps shown in *Figure 2* below.

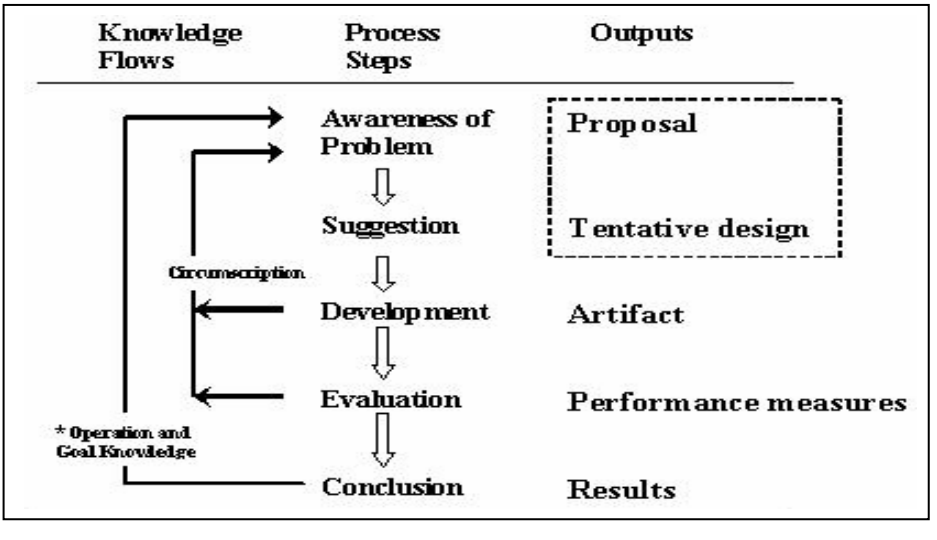

Fig. 2. Showing the *Design Research* Methodology [2, p.13]

The five process steps of *Design Research* as depicted in *Figure 2* above were followed in the development of the *MoLODUF*. The process steps are: the *Awareness of the Problem, Suggestion, Development, Evaluation* and *Conclusion*. At the *Awareness of the Problem* process step, a survey of 446 learners at Makerere University in Uganda was undertaken. The learners were selected using multi-stage sampling method involving cluster sampling at stage one and stratified random sampling at stage two. The learners were distributed as 48.9 Percent (n=218) distance learners and 51.1 Percent (n=228) campus-based learners. Males constituted 62.3 Percent while 37.7 Percent were female. Their minimum age was 18 while the maximum age was 46 with a mean age of 24.7 and mode of 21. The minimum age of 18 was recorded from amongst campus-based learners while the maximum age of 46 was recorded from distance learners. Forty three Percent of the learners surveyed were pursuing science related disciplines while 57.0 Percent were pursuing humanities related disciplines. Learners were drawn from all years of study, including: first year (15.9 Percent), second year (32.3 Percent), third year (35.2 Percent) and fourth year (16.6 Percent). Most of the learners were unemployed (67.5 Percent) and not married (79.8 Percent). They joined university after attaining 'A' Level (70.2 Percent), diploma (26.9 Percent), grade III teacher certificate (1.1 Percent), degree (1.1 Percent) or other qualifications (0.7 Percent).

A semi-structured, self-administered questionnaire was used to capture data. The survey consisted of open and close ended questions. The questionnaire collected data on mLearning context, mLearning activities, mLearning devices and technologies, mLearning resources, mLearning objects, mLearning institutional issues and mLearning environmental issues.

The survey results were triangulated with results from literature review and interviews held with key eLearning and mLearning stakeholders drawn from across Africa.

The *Awareness of the Problem* process step was useful for gathering requirements for suggesting and developing the *MoLODUF* during the *Suggestion* and *Development* process steps respectively. Using deductive reasoning, dimensions and sub-dimensions for constructing the *MoLODUF* were generated from the requirements. In the *Evaluation* process step the *MoLODUF* was compared with existing mLearning and eLearning frameworks with a view of establishing the novelty in our research. In the *Conclusion* process step, we drew conclusions from the novelty revealed in the *Evaluation* process step. The process of suggesting, developing and evaluating the *MoLODUF* and drawing conclusions from it resulted in new knowledge which was used in refining requirements for further development of the *MoLODUF*.

4 Results and Discussions

The results are presented and discussed following the six research questions formulated in this study and within the Design Research [2] framework.

4.1 Raising Awareness of the Problem and Making Suggestions for *MoLODUF* Dimensions

This *Section* is underpinned by the *Awareness of the Problem* and *Suggestion* process steps of Design Research methodology. These process steps were used to gather requirements for deducing dimensions and sub-dimensions for constructing the *MoLODUF*. The *Section* provides answers to four of the six research questions in this study, namely:

i. What are the current learner contexts, practices and prospects for the development and growth of mLearning?
ii. What learning processes can be accomplished through mLearning?
iii. What kinds of learning objects can be used to service the identified learning processes?
iv. What are the issues and factors to obtain access to and use learning objects in mLearning?

Current Learner Contexts, Practices and Prospects for the Development and Growth of MLearning. Distance and campus-based learners faced similar contextual challenges and opportunities in as far as ICTs for learning was concerned. Mobile connectivity was available to all distance and campus-based learners ($p=0.062$). Urban areas were not a preserve for campus-based learners alone but they hosted distance learners as well ($p=0.532$). All the learners faced similar availability or intermittence in power supply ($p=0.199$) and Internet connectivity ($p=0.329$). This confirms the conclusion in [11] that developing countries of Africa are faced with a multitude of contextual constraints that undermine the development and growth of eLearning. Studies have indicated that mLearning has the potential to defy the odds that inhibit conventional eLearning [28]. For instance, there was no significant association between power supply and mobile network connectivity ($p=0.301$), yet Internet connectivity, which powers eLearning, was highly significantly associated ($p=0.000$) with availability of power supply. The implication in these findings is that there is need for equal planning for educational technologies aimed at enhancing learning amongst all learners in all learning contexts, which calls for a *mLearning Context* dimension in a framework for mLearning.

MLearning was practiced in a few instances, albeit inadvertently. In the majority of instances, it was established that learners could not be able to tell whether placing a call or text message for the purposes of learning or education constituted mLearning. These findings are not surprising because in [43], the infancy of mLearning is reiterated. MLearning just like any other infant field of study is likely to face limited epistemology. Consequently, the limited epistemology of mLearning has resulted into its limited practice.

Where mLearning existed, it was mainly practiced through text and audio learning objects in trial and pilot projects for collaborative and interactive learning. MLearning mainly occurred in a push nature with limited bi-directional synchronous and asynchronous collaboration and interaction through text messaging. The one way use of text messages was mainly due to the limitations imposed by low end mobile phones. Also, the use of text messaging in a push fashion was brought about by the high cost of using other media such as video and the prevalence of low end mobile phones which were owned by the majority (68.0 Percent) of learners. Low end mobile phones limitations curtail push and pull synchronous text messaging [15].

Through voice calls, the study showed that pull and push synchronous and asynchronous audio communication was practiced and preferred on low end mobile phones because voice calls imposed no character length limitations inherent in text messages. In [6] and [12], the use of audio mLearning objects on low end mobile phones is reported. In the mLearning project in [6], learners learn how to pronounce and spell English words by listening in to a word from the Hadeda system before being required to type it out. If a learner correctly types the word, the system congratulates him/her, otherwise it gives him/her the correct spelling. In the mLearning project in [12], a mobile audio-wikipedia system is reported. In this system, learners use their mobile phones to dial into it and listen to a definition of a given word. If the definition does not exist, the learner is given a chance to dictate a definition to the system.

Whereas audio learning objects for low end mobile phones were in use, earlier studies [4, 5, 26] on the practice of mLearning in Africa showed that text messaging was the most prevalent way of deploying and utilising learning objects in mLearning. In a report for the Commonwealth of Learning on the use of mobile phones for open schooling, [41] enumerated a number of innovative mLearning projects in which text messaging was the key technology for learning objects deployment and utilisation. One of such projects is the mobile research supervision initiative in Uganda in which lecturers and distance learning students interact with each other for the purpose of accomplishing field research activities. Another project is Dr. Math on Mxit, for collaborative learning in mathematics using instant text messaging [41].

All the projects discussed above considered the capabilities of learners' mobile device and the kind of learning objects that could be deployed and utilised on them. There must therefore be dimensions in the *MoLODUF* for *mLearning Devices* and *mLearning Objects*.

Through text and audio based mLearning objects, 77.7 Percent of the learners were able to collaboratively and interactively work on assignments and receive administrative and academic support. Learner support is one of the three imperatives of ICTs in education [5]. The other two being access to content and communication (ibid). When learners are adequately supported, a lot of their time is freed to participate in other learning activities. They also feel cared for and are motivated to learn. For distance learners who are separated by time and space [1, 7, 43, 47], collaborative and interactive learning can be an avenue for reducing the loneliness usually associated with distance learning. In so doing the 'distance' amongst the distance learners themselves and between the distance learners and their university can be bridged. In the learner support process, mLearning objects were used by learners, lecturers and university administrators which imply the need for *mLearning Pedagogy* dimension for profiling the *mLearning Object Users.*

The study revealed a number of prospects for the development and growth of mLearning. The prospects lay in the existence of possible learning activities that could be ported onto mLearning. MLearning was found to be suitable for out-of-classroom direct learning activities or activities meant to plan and support direct learning activities. While outside the classroom, learners participated in collaborative and interactive learning (41.0 Percent), co-curricular/extra-curricula activities (20.0 Percent), independent research (16.0 Percent), completed theoretical, practical and field courseworks and assignments (8.0 Percent), watched/listened to educative and entertaining music, news and movies (6.0 Percent), engaged in work related activities

(4 Percent), consulted their lecturers (7.0 Percent), acquainted themselves with the university environment (1.0 Percent) and took computer lessons (1.0 Percent). All these learning activities can be variously supported through mLearning to accomplish various learning processes. This calls for a *mLearning Processes* dimension in the *MoLODUF*.

Even if out-of-classroom learning activities can be ported on mobile phones, the tiny mobile phone screen and keyboard can be uncomforting to the mLearning object user. When asked to provide a view on using mobile phones to learn, one of the respondents said, "if it were not for the tiny screen and keyboard of my mobile phone, I would use it to learn". This calls for strategies to mitigate mobile phone limitations. One way could be blending mLearning devices with other eLearning devices and regularly evaluating the learning comfort afforded by the blend with the view of mitigating any discomfort. This suggests the need for a *mLearning Evaluation* dimension in the *MoLODUF*.

MLearning Processes. While considering learning activities that learners participated in while outside the classroom environment, the need to consider learning processes in mLearning was unearthed. Learning processes are value addition learning activities [9]. Since mLearning is of great value to out-of-classroom learning activities, it presents significant benefits to distance learning processes or learners on-the-go with limited access to web-based computers. From traditional learning theories reviewed in this study [10, 29, 33, 39, 46], learning processes related to *Co-Creation of New Knowledge, Knowledge Sharing, Collaborative and Interactive Learning, Reflective Learning, Problem-Based Learning, Academic and Administrative Support* and *Communication/Information Exchange* can be supported through mLearning.

Learning Objects for MLearning Processes. The study revealed that different mLearning objects could be used to service different mLearning processes identified above. MLearning objects could take the form of text messages, voice calls, MMSs, audio and video podcasts, Wapsites, software modules/components or games [3, 5, 19, 42]. The ability to deploy and utilize any of the aforementioned mLearning objects depends on financial, human and technological resources available, costs associated, constraints placed on mobile technologies, the learning processes in question, management/institutional policies and ethical considerations. Within the context of developing countries, text and audio based learning objects were found to be more feasible than any other learning objects. This discussion presents a need for profiling mLearning objects, hence the need for a *mLearning Objects* dimension in the *MoLODUF*. Other dimensions that can be adduced from these results include: *mLearning Processes, mLearning Ethics, mLearning Cost, mLearning Resources, mLearning Device* and *mLearning Policy*.

Issues and Factors for Obtaining Access to and Utilizing MLearning Objects. There are three design issues that can enable easy access to learning objects [40]. These include: designing for device independence, designing for multiple media content and allowing learners to control moving content [ibid]. In addition to these three issues, this research has established that mobile network connectivity/networking technology and intellectual property rights issues are also important factors to consider while obtaining access to learning objects in mLearning.

The interface of the mLearning device is yet another important factor to consider. The cultural appropriateness of using a learning object, the pedagogy chosen by the institution, the relationship between mLearning devices with other delivery devices and the cost of mLearning among others are important issues and factors for deploying and utilizing learning objects on mobile devices. These factors calls for *mLearning Objects, mLearning Connectivity, mLearning Ethics, mLearning Resources, mLearning Cost* and *mLearning Interface* dimensions in the *MoLODUF*.

4.2 Developing the *MoLODUF*

This *Section* is underpinned by the *Development* process step of Design Research methodology. It answers the research question - What are the major dimensions and sub-dimensions of the *MoLODUF*? In the *Development* process step, artifacts are developed from constructs adduced from the *Suggestion* process step [2]. From the awareness raised and suggestions made in *Section 4.1* above, twelve (12) major dimensions are apparent. These are: *mLearning Cost, mLearning Processes, mLearning Objects, mLearning Devices, mLearning Resources, mLearning Connectivity, mLearning Pedagogy, mLearning Interface, mLearning Evaluation, mLearning Ethics, mLearning Policy* and *mLearning Context* dimensions. These major dimensions are explained below and shown with their respective sub-dimensions in *Table 2* below.

***MLearning Cost* Dimension.** The study has revealed that mLearning was practiced mainly in a push nature with limited bi-directional synchronous and asynchronous interaction because of its high cost. Mitigation of mLearning costs is therefore vital for successful mLearning. The *mLearning Costs* dimension is the 'midrib' or 'backbone' in the *MoLODUF*. For effective deployment and utilisation of learning objects in mLearning, there must be mechanisms to mitigate the usually high cost of mLearning. Thus there is need to determine the unit cost of mLearning and put in place a mLearning cost sustainability model.

***MLearning Processes* Dimension.** *MLearning Processes* provide all the learning and teaching models commensurate with the limitations of mobile devices [43]. This research has adduced seven (7) learning processes that can be supported using mLearning. These are: *Co-Creation of New Knowledge, Knowledge Sharing, Collaboration and Interaction, Reflective Learning, Problem-Based Learning, Academic* and *Administrative Support* and *Communication/Information Exchange.* Consequently institutions wishing to effectively deploy and utilize learning objects in mLearning should first profile existing learning processes with the aim of determining those which are appropriate for mLearning. Learning processes can be abducted from the different learning activities partaken of by the learners especially when they are on-the-move or outside the classroom learning environment.

***MLearning Objects* Dimension.** This dimension is responsible for modeling the learning objects for deploying and utilizing on mobile devices. It should have sub-dimensions for *mLearning Objects Organization*, *mLearning Objects Granulation, mLearning Objects Media Types, mLearning Objects Accessibility, mLearning Objects Utilization, mLearning Objects Pedagogy, mLearning Objects Repository* and *mLearning Objects Brokering*. The first three sub-dimensions are also available in the multi-dimensional framework for content adaptation [13].

***MLearning Devices* Dimension.** This dimension profiles the mobile devices being used in mLearning objects deployment and utilization. By profiling the mobile devices in use, their *Generation Order, Properties, Capabilities* and *Limitations* can be determined and mitigated. Mobile devices limitations can constrain mLearning [15], hence they should be mitigated by adopting a device blend.

***MLearning Resources Dimension*.** The *mLearning Resources* dimension has three sub-dimensions which are necessary for the successful implementation of mLearning, namely: *Infrastructural, Human* and *Financial Resources* sub-dimensions. The infrastructural resources needed for mLearning are: servers, fiber optic backbones, computers, fast Internet connectivity, e-mail, high end mobile phones, mobile network connectivity, learning management systems, local area networks (wired and wireless) and mobile applications development software. The human resources needed for mLearning are: flexible managers, administrators, lecturers and students willing to experiment with innovations in core educational practices. Other vital mLearning human resources are: mLearning researchers and systems analysts, mobile applications programmers, technicians, instructional and graphic designers, and content developers. The availability of financial resources is central for the acquisition, installation and maintenance of all the other mLearning resources. Financial resources are also necessary for sustaining mLearning costs. Therefore a budget vote for mLearning is a must for institutions wishing to deploy and utilize learning objects on mobile phones.

Table 2. MLearning Objects Deployment and Utilization Framework (*MoLODUF*)

1. *MLearning Costs*	5. *MLearning Resources*	9. *MLearning Evaluation*
▪ MLearning Unit Cost ▪ MLearning Cost Sustainability Plan	▪ Infrastructural Resources ▪ Human Resources ▪ Financial Resources	▪ MCQ Quizzes ▪ Learning Comfort ▪ Learning Equity ▪ MLearning Object Deployment Feedback
2. *MLearning Processes*	6. *MLearning Connectivity*	10. *MLearning Ethics*
▪ Co-creation of New Knowledge ▪ Knowledge Sharing ▪ Collaboration and Interaction ▪ Reflective Learning ▪ Problem-Based Learning ▪ Academic & Administrative Support ▪ Communication/Information Exchange	▪ Mobile Connectivity State ▪ Mobile Networking Technology ▪ Mobile Network Service Providers ▪ Bandwidth	▪ Cognitive Overload ▪ Cultural Appropriateness ▪ Privacy and Security
3. *MLearning Objects*	7. *MLearning Pedagogy*	11. *MLearning Policy*
▪ MLearning Objects Organization ▪ MLearning Objects Granulation ▪ MLearning Objects Media Types ▪ MLearning Objects Accessibility ▪ MLearning Objects Usability ▪ MLearning Objects Pedagogy ▪ MLearning Objects Repository ▪ MLearning Objects Brokering	▪ MLearning Objects User Role ▪ MLearning Objects User Profile ▪ MLearning Objects User Education	▪ Institutional Policies ▪ Government Policies
4. *MLearning Devices*	8. *MLearning Interface*	12. *MLearning Context*
▪ Generation Order ▪ Mobile Device Property ▪ Capability ▪ Limitations	▪ Mobile Device Interface ▪ PC Interface	▪ MLearning Propellers ▪ MLearning Inhibitors ▪ Learning Environment

MLearning Connectivity **Dimension.** Internet and mobile network connectivity are not always available to all the learners. Also, the ability to deploy and utilize a given media type of a learning object depends not only on the capability of the mobile phone but also on the mobile networking technology at hand. Before embarking on any mLearning instance, it is important to profile the *Mobile Connectivity* State, *Mobile Networking Technology, Mobile Service Providers* and *Bandwidth* available to learners.

MLearning Pedagogy **Dimension.** The *mLearning Pedagogy* dimension profiles the users of mLearning objects. To be able to do so, it profiles the *mLearning Objects User Role, Profile* and *Education*. The actors in mLearning can be learners, lecturers or administrators. Their respective roles must be known before hand so as to deploy the right learning object to the right user. A user profile in terms of learning history, preferences, style and motivation for learning is vital for brokering the right learning objects. For users to be able to effectively utilize the learning objects, mobile phone user education is important.

MLearning Interface **Dimension.** In order to increase learning comfort in mLearning, mLearning devices should be blended with conventional eLearning devices. This implies that interfaces for mLearning are not strictly tied to *Mobile Devices Interfaces* alone. A blended approach means that mLearning objects could as well be deployed and utilised on *PC Interfaces*. This has learning objects design implication in the sense that a learning object should be designed with interoperability capability between mobile devices (*Mobile Device Interface* sub-dimension) and PCs (*PC Interface* sub-dimension).

MLearning Evaluation **Dimension.** "Evaluation is a reflective learning process" [23, p.43]. There must be mechanisms in a mLearning system for self evaluation. The *MoLODUF* has an *mLearning Evaluation* dimension whose functions are to establish: whether a mLearning objects user has understood the content in the object (using *MCQ Quizzes* sub-dimension), whether there is learning comfort in mLearning (using *Learning Comfort* sub-dimension), whether there is learning equity in mLearning (using *Learning Equity* sub-dimension) and whether a deployed learning object actually reached its intended recipients (using *mLearning Object Deployment Feedback* sub-dimension).

MLearning Ethics **Dimension.** This dimension is responsible for spelling out the mLearning etiquettes in a particular organization. It is responsible for protecting mLearning providers from unethical behaviors that may arise from the use of mLearning. It should be responsible for saving mLearning object users from cognitive overloads arising from multiple mLearning objects use and requests. It therefore spells out mechanisms for handling *Cognitive Overload*, *Culturally Inappropriate* communications and *Privacy* and *Security* of information being communicated.

MLearning Policy **Dimension.** This dimension consists of two sub-dimensions, namely: *Institutional Policies* and *Government Policies*. Institutional policies can curtail or propel the development and growth of mLearning. A favorable mLearning policy is therefore necessary. Likewise, if a government has an eLearning policy which takes cognizance of all learning platforms including mLearning, then

mLearning will get support. The policies should be able to give guidelines and strategies for using mLearning in universities and other institutions of learning. The *mLearning Policy* dimension ensures that favorable mLearning policies, strategies, regulations and guidelines are put in place. Policies will inform the mLearning processes and therefore guide all mLearning activities in an institution. They will even provide regulations on the mobile devices to be used for mLearning and set aside resources for sustaining mLearning.

***MLearning Context* Dimension.** In this study, it was established that learners lived and operated in different contexts. According to [45], learning context is an important factor in mLearning. Therefore the *MoLODUF* should have a *mLearning Context* dimension aimed at profiling mLearners' learning contexts. In so doing, *mLearning Propellers* can be established and exploited. Also, *mLearning Inhibitors* can be known and mitigated. The *Learning Environment* where the learner is based must also be profiled to determine the noise levels of the learner's usual learning environment, mobile connectivity in the area, availability of resources such as desktop computers and power connectivity and so on. The environment should be favorable for mLearning or if not, attempts must be made to make it favorable.

4.3 Evaluating the *MoLODUF*

This *Section* is underpinned by the *Evaluation* process step of *Design Research* methodology. It answers the research question - How is the *MoLODUF* related with existing key eLearning frameworks? Therefore the *MoLODUF* was evaluated by

Table 3. Summary Comparison of *MoLODUF* with mLearning and eLearning Frameworks

	Dimensions												
Frameworks	mLearning Cost	mLearning Resources	mLearning Processes	mLearning Evaluation	mLearning Connectivity	mLearning Devices	mLearning Interface	mLearning Pedagogy	mLearning Policy	mLearning Objects	mLearning Context	mLearning Ethics	Coordination
MoLODUF	■	■	■	■	■	■	■	■	■	■	■	■	■
Global eLearning Framework [20]		■		■	■	■	■	■	■			■	■
Multi-dimensional Framework for Content Adaptation [13]					■	■	■	■		■	■		■
Framework for Flexible Learning Using mLearning Objects [36]					■	■	■	■		■	■		■
Framework for Personalized mLearning Content [51]		■			■	■	■	■		■	■		■
mLearning Content Hoarding Framework [44]		■			■	■	■	■		■	■		■
Adaptive Framework for Aggregating mLearning Objects [50]		■			■	■	■	■		■	■		■
Push and Pull Framework for mLearning Objects [27]		■			■	■	■	■		■	■		■
Adaptive mLearning Environments [30]		■			■	■	■	■		■	■		■
Computational Models for mLearning Objects [3]		■			■	■	■	■		■	■		■

comparing it with existing mLearning and eLearning Frameworks in [3, 13, 20, 27, 30, 36, 44, 50, 51]. The differences and similarities of these frameworks with respect to the *MoLODUF* dimensions are presented in *Table 3* below.

A shaded box in the dimensions column indicates the existence of the corresponding dimension in the respective framework on the right. In the *Table*, it can be seen that existing mLearning frameworks do not have dimensions for *mLearning Costs, mLearning Processes, mLearning Evaluation, mLearning Policy* and *mLearning Ethics*. All the aforementioned dimensions are present in the *MoLODUF*. When the *MoLODUF* is compared with the Global eLearning Framework in [20], it can be deduced that the *mLearning Cost, mLearning Processes, mLearning Objects* and *mLearning Context* dimensions are *MoLODUF's* extension to that framework. The *Coordination* and *mLearning Pedagogy* dimensions are present in all frameworks. The *MoLODUF* has extended exiting mLearning frameworks with the *mLearning Costs, mLearning Processes, mLearning Evaluation, mLearning Policy* and *mLearning Ethics* dimensions. In the conventional eLearning arena, *MoLODUF* has contributed towards integrating mLearning with eLearning by suggesting the addition of *mLearning Cost, mLearning Processes, mLearning Objects* and *mLearning Context* dimensions into the Global eLearning Framework in [20].

5 Instantiating MLearning Objects Deployment and Utilization Applications

Whereas the *MoLODUF* process steps are not necessarily sequential in nature, we suggest that implementation of the *MoLODUF* guidelines/dimensions be based on the loose sequence provided in the process steps in *Figure 3* below.

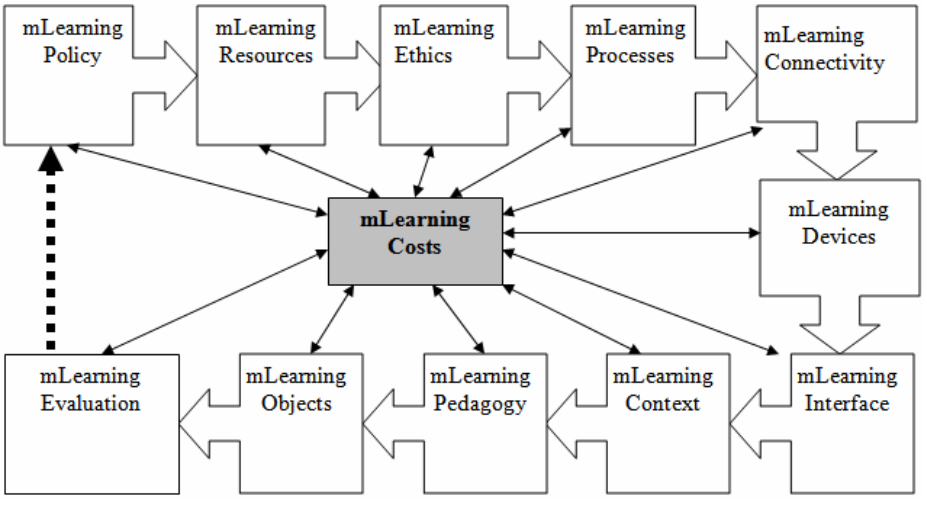

Fig. 3. Showing the Process Steps for Instantiating mLearning Applications using the *MoLODUF*

Loosely speaking, organizations wishing to create applications for deploying and utilizing learning objects on mobile phones should implement the guidelines/dimensions given in the *MoLODUF* dimensions following the sequence provided in *Figure 3* above. However, as can be seen in the *Figure*, mLearning costs present a central challenge that must be dealt with at all process steps. Further, sustainable deployment and utilization of mLearning objects will only be achieved if there is an appropriate mLearning policy. This is the reason why an mLearning policy must be put in place first before implementing any other dimension. Though formative mLearning evaluation is important to evaluate the mLearning applications development process, *Figure 3* above suggests the need for summative evaluation to measure the learning outcomes, learning comfort and learning equity emanating from the learning objects deployed and utilized by any mLearning application. *Figure 3* further shows that as a result of an mLearning summative evaluation, recommendation can be made to revise the mLearning policy and so on.

6 Conclusion and Future Work

This Section was underpinned by the *Conclusion* process step of Research Design methodology. The *MoLODUF* provides a competence set of dimensions and sub-dimensions for instantiating and/or evaluating mLearning objects applications and/or environments. By introducing four mobility dimensions, namely: *mLearning Cost, mLearning Processes, mLearning Objects* and *mLearning Context* into the Global eLearning Framework in [20], the *MoLODUF* provides a method for integrating mLearning with conventional eLearning. It also enhances research into adoption and implementation of mLearning. Further, *MoLODUF* offers guidelines for the pedagogic use of mobile phones. Future work emanating from this study include: a practical implementation of the *MoLODUF*, developing mLearning cost sustainability model and mobile phones limitation mitigation plan.

Acknowledgement. This work was part of the corresponding authors PhD research. Many thanks go to Makerere University, SIDA/SAREC and NUFFIC for funding this PhD Project.

References

1. Aderinoye, A.R., Ojokheta, O.K., Olojede, A.A.: Integrating Mobile Learning into Nomadic Education Programmes in Nigeria: Issues and perspectives. The International Review of Research in Open and Distance Learning 8(2), 1–17 (2007)
2. Association of Information Systems: Design Research in Information Systems (2007), http://www.isworld.org/Researchdesign/drisISworld.htm
3. Ayala, G., Castillo, S.: Towards Computational Models for Mobile Learning Objects. In: The Fifth IEEE International Conference on Wireless, Mobile, and Ubiquitous Technology in Education (WMTE 2005), Tokushima, Japan, March 23-26 (2008)
4. Barker, A., Krull, G., Mallinson, B.: A proposed Theoretical Model for M-Learning Adoption in Developing Countries. In: The 4th World conference on m-learning (MLearn 2005), Cape Town, SA, October 25-28 (2005)

5. Brown, H.T.: Towards a Model for m-Learning in Africa. International Journal on E-learning 4(3), 299–315 (2005)
6. Butgereit, L., Botha, A.: Hadeda: The Noisy Way to Practice Spelling Vocabulary using a Cell Phone. In: The IST-Africa 2009 Conference, Kampala, Uganda, May 6-8 (2009)
7. Caudill, G.J.: The Growth of m-Learning and the Growth of Mobile Computing: Parallel developments. The International Review of Research in Open and Distance Learning 8(2), 1–13 (2007)
8. Design-based research collective: Design-Based Research: An Emerging Paradigm for Educational Inquiry. Educational Researcher 32(1), 5–8 (2003)
9. Doos, M., Wilhelmson, L., Backlund, T., Dixon, N.: Functioning at the edge of knowledge. A study of learning processes in new product development. Journal of Workplace Learning 17(8), 481–492 (2005)
10. Eraut, M.: Non-formal learning, implicit learning and tacit knowledge in professional work. In: The Necessity of Informal Learning. The Policy Press, Bristol (2000)
11. Farrell, G., Isaacs, S.: Survey of ICT and Education in Africa. A Summary Report Based on 53 Country Surveys (2007), http://akgul.bcc.bilkent.edu.tr/egitim/ict-africa-survey.pdf
12. Ford, M., Botha, A.: MobiLED – Mobile-Led and Leading via Mobile. In: The IST-Africa 2009 Conference, Kampala, Uganda, May 6-8 (2009)
13. Goh, T., Kinshuk, D.: Getting Ready for Mobile Learning - Adaptation Perspectives. Journal of Educational Multimedia and Hypermedia 15(2), 175–198 (2006)
14. Goodman, N.: Mathematics as an objective science. In: Tymoezko, T. (ed.) New Directions in the Philosophy of Mathematics, pp. 79–94. Barkhauser, Boston (1986)
15. Grant, J., Lynch, K., Fisher, J.: Looks Can Cost; Especially On A Small Screen. In: The 7th IFIP International Conference on e-Business, e-Services, and e-Society (I3E 2007), Wuhan, China, October 10-12 (2007)
16. Hevner, R.A., March, T.S., Park, J., Ram, S.: Design Science in Information Systems research. MIS Quarterly 28(1), 75–105 (2004)
17. IEEE: WG12: Learning Object Metadata, http://ltsc.ieee.org/wg12/ (2010)
18. International Telecommunications Union: Mobile cellular subscribers (2009), http://www.itu.int/ITU-D/icteye/Reporting/ShowReportFrame.aspx?ReportName=/WTI/CellularSubscribersPublic&ReportFormat=HTML4.0&RP_intYear=2009&RP_intLanguageID=1&RP_bitLiveData=False
19. Ketterl, M., Heinrich, T., Mertens, R., Morisse, K.: Enhanced Content Utilization: Combined Re-Use of Multi-Type e-Learning Content on Mobile Devices. IEEE Multidisciplinary Engineering Education Magazine 2, 61–64 (2007)
20. Khan, B.: Elements of e-learning (2001), http://BadrulKhan.com
21. Kurubacak, G.: Identify Research Priorities and Needs for Mobile Learning Technologies in Open and Distance Education: A Delphi Study. College of Open Education, Anadolu University, Anadolu (2007)
22. Laurillard, D.: Pedagogical forms for mobile learning. In: Pachler, N. (ed.) Mobile Learning: Towards a Research Agenda. WLE Centre, London (2007)
23. Lin, X., Hmelo, C., Kinzer, K.C., Secules, J.T.: Designing Technology to Support Reflection. Educational Technology Research and Development 47(3), 43–62 (1999)
24. Low, L.: M-learning standards report. Background, discussion and recommendations for usable and accessible m-learning (2007), http://e-standards.flexiblelearning.net.au/docs/m-standards-report-v1-0.pdf

25. Luis de Marcos, H.R.J., Gutiérrez, A.J., Pagés, C., Martínez, J.J.: Implementing Learning Objects Repositories for Mobile Devices (2006), http://ftp.informatik.rwth-aachen.de/Publications/CEUR-WS/Vol-208/paper04.pdf
26. Masters, K.: Low-key m-learning: a realistic introduction of m-learning to developing countries, http://www.fil.hu/mobil/2005/Masters_final.pdf (nd)
27. Motiwalla, F.L.: Mobile learning: A framework and evaluation. Computers & Education 49(3), 581–596 (2007)
28. Muyinda, B.P., Lubega, J., Lynch, K.: Unleashing mobile phones for research supervision support at Makerere University, Uganda: the lessons learned. International Journal of Innovation and Learning 7(1), 14–34 (2010)
29. Naismith, L., Lonsdale, P., Vavoula, G., Sharples, M.: Literature Review in Mobile Technologies and Learning (No. 11). University of Birmingham, Birmingham (2006)
30. Nakabayashi, K., Hoshide, T., Hosokawa, M., Kawakami, T., Sato, K.: Design and Implementation of a Mobile Learning Environment as an Extension of SCORM 2004 Specifications. In: The Seventh IEEE International Conference on Advanced Learning Technologies (ICALT 2007), Niigata, Japan, July 18-20 (2007)
31. Nie, M.: The Pedagogical Perspectives of Mobile Learning (2007), https://lra.le.ac.uk/bitstream/2381/407/1/The%20Pedagogical%20Perspectives%20of%20Mobile%20Learning%20-%20A%20Literature%20Review.pdf
32. Park, Y.: A Pedagogical Framework for Mobile Learning: Categorizing Educational Applications of Mobile Technologies into Four Types. The International Review of Research in Open and Distance Learning 12(2), 78–102 (2011)
33. Pask, G.: Minds and media in education and entertainment: some theoretical comments illustrated by the design and operation of a system for exteriorizing and manipulating individual theses. In: Trappl, R., Pask, G. (eds.) Progress in Cybernetics and Systems Research, Hemisphere, London, pp. 38–50 (1975)
34. Pettit, J., Kukulska-Hulme, A.: Going with the grain: Mobile devices in practice. Australasian Journal of Educational Technology 23(1), 17–33 (2007)
35. Prawat, S.R., Floden, E.R.: Philosophical perspectives on constructivist views on learning. Educational Psychology 29(1), 37–48 (1994)
36. Quinn, N.C.: Flexible Learning: Mobile Learning Objects. Knowledge Anywhere (2002)
37. Reeves, C.T., Herrington, J., Oliver, R.: Design Research: A Socially Responsible Approach to Instructional Technology Research in Higher Education. Journal of Computing in Higher Education 16(2), 97–116 (2005)
38. Schibeci, R., Lake, D., Phillips, R., Lowe, K., Cummings, R., Miller, E.: Evaluating the use of learning objects in Australian and New Zealand schools. Computers & Education 50(1), 271–283 (2008)
39. Skinner, B.F.: The Technology of Teaching. Appleton-Century-Crofts (reprinted by the BF Skinner Foundation in 2003), New York (1968)
40. Smith, S.R.: Guidelines for Authors of Learning Objects (2004), http://archive.nmc.org/guidelines/NMC%20LO%20Guidelines.pdf
41. South African Institute for Distance Education: Using Mobile Technology for Learner Support in Open Schooling. Project report for: Commonwealth of Learning (2008), http://www.col.org/SiteCollectionDocuments/Mobile%20Technology_Final%20Report.pdf
42. Toledano, M.C.M.: Learning objects for mobile devices: A case study in the Actuarial Sciences degree. Current Developments in Technology-Assisted Education 2006, 2095–2099 (2006)

43. Traxler, J.: Defining, Discussing, and Evaluating Mobile Learning: The moving finger writes and having writ.... International Review of Research in Open and Distance Learning 8(2), 1–12 (2007)
44. Trifonova, A., Ronchetti, M.: Hoarding content for mobile learning. International Journal of Mobile Communications 4(4), 459–476 (2006)
45. Uden, L.: Activity theory for designing mobile learning. International Journal of Mobile Learning and Organization 1(1), 81–102 (2007)
46. Vygotsky, L.S.: Mind in Society: The Development of Higher Psychological Processes. Harvard University Press, Cambridge (1978)
47. Wang, C., Liu, Z.: Distance education: basic resource guide. Collection Building 22(3), 120–130 (2003)
48. Wang, F., Hannafin, J.M.: Design-Based Research and Technology Enhanced Learning Environments. ETR&D 53(4), 5–23 (2005)
49. Wiley, D.A.: The Instructional use of Learning Objects. Association for Educational Communication and Technology, Bloomington (2001)
50. Yang, M.: An Adaptive Framework for Aggregating Mobile Learning Materials. In: The Seventh IEEE International Conference on Advanced Learning Technologies (ICALT 2007) Los Alamitos, California, July 18-20 (2007)
51. Zhang, D.: Delivery of personalized and adaptive content to mobile devices: a framework and enabling technology. Communication of the Association for Information Systems 12, 183–202 (2003)