Aspects of Content, Context and Adaptation Modeling in Mobile Learning Application Design

http://dx.doi.org/10.3991/ijim.v7i2.2338

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***Abstract*—Mobile leaning application development has been influenced by the e-learning models, methods and a variation of these for the better understanding and accommodation of additional elements that prop up in m-learning scenarios and applications. Here uniquely designed models for various aspects of m-learning scenarios and situations by concentrating on Learner Styles, Contextual Features, Learning Content, Learner Behavior, and Adaptation methods are proposed.**

***Index Terms*—Adaptation, Content, Context, Mobile Learning.**

I. INTRODUCTION

Learning has gone through major changes from its inception, from the basic form of teacher-centric to class room learning to distance learning to e-learning and now, to present m-learning , i.e., mobile learning. Some call m-learning as the form of e-learning with the support of mobile devices and mobile technologies. But mobile learning is more than e-learning through mobile devices, as it is highly influenced by the various elements that come into play when the learner is mobile in nature with his mobile device. Mobile learning can be distinguished "by rapid and continual changes of context, as the learner moves between locations and encounters localized resources, services and co-learners"[10], and these different situations are described by different learning contexts. Nowadays, time is the most valuable, and people tend to be too busy and are spending more time in traveling and the inability to be at one place brings the need for supporting learning activities at any time, place and through different devices; this is the origin of mobile learning [20], whose main purpose is to allow high degree of mobility for learning.

In Human Computer Interaction (HCI), a context feature is any information that can be used to characterize and interpret the situation in which a user interacts with an application at a certain time. The context aware applications are described as "more attentive, responsive and aware of their learner's identity and their learner's environment [40] and hence can derive the learner's needs implicitly in the context which surrounds him/her at any point in time. The task of a context aware mobile learning (CAML) application is to sense the mobile environment and adapt to the changing context during a student's learning process [10].

Characteristics [12] of mobile learning include: a) Urgency of learning need, b) Initiative of knowledge acquisition, c) Mobility of learning setting, d) Interactivity of the learning process, e) Situatedness of instructional activities and f) Integration of instructional content. One of the most straight forward application for the usage of mobile devices as educational supporting tool is messaging where in the learning content is delivered to the learners is implemented in many research experiments [47][48][44][23][16]. Y.S. Chen et. al. [11] used content-based butterfly image learning (BWL) system.

The capabilities that mobile learning possesses made it widespread, and learners are now able to learn at any time and any place with the support of mobile technologies. With context aware mobile learning, many different learning contexts emerge because of the dynamic and continuous change in the learning settings of the learner's mobile learning environment. Mobile learning can be distinguished "by rapid and continual changes of context, as the learner moves between locations and encounters localized resources, services and co-learners" [10]. Context is a key in the design of more adaptive mobile learning systems [35] and context awareness must be integrated within the systems in order to be truly effective [31].

There are many proposed definitions and taxonomies of context. Shilit [51] divided context into three categories: Computing Context, User Context and Physical Context. Chen and Kotz [22] extended it by adding a time context. Dey, Abowd and Salber [2] gave four categories: identity, location, status and time. The importance of obtaining the actual location of the learner helps to identify the contextual features surrounding the location that affect/support the learner's ability to study. Schmidt et al. also found that location is the most often used context parameter and assert that mobile applications could benefit from a broader notion of context. This work investigates the use of multiple sensors to gather a wider range of context information [43]. The systems [9] also includes two location-specific features which their activities adapt to accordingly, namely the concentration level of the learner and the frequency of interruption at a specific location.

From an informational perspective context aims to provide an information space that can be "adapted according to the user's context", and complemented by tools/processes that promote the socially situated construction and sharing of context [39]. Wang's six dimensions of the M-learning context: 1) Identity 2) Learner 3) Activity 4) Collaboration 5) Spatio-temporal and 6) Facility [52]. The first four of these would establish the situational context of M-learning, and the last two would

be associated with the environmental context. It seems very likely the future context aware applications will capture a rich variety of context information and also exhibit a rich variety of context-aware features than the present situation. Providing support for mobile learning application designers in the integration of a wider range of context into the applications will encourage the development of useful and compelling mobile learning applications for mobile devices of the mobile learners and tutors.

Learner's needs are mostly intangible which in most of the cases affected by habit, self-image and even issues of motivation [39] (e.g., a person might be more active in the morning than in the evening). The design of a system must focus on reducing communication barriers by analyzing what can be known about a learner and how to support that information with task, learner and system models. As a rule learner must play an active role in the definition of the context about which the system must be aware of [39]. In addition to being able to obtain context information, applications need to have some "intelligent" component which functions as a predictor of a user's intentions. Developers can intelligently use context information in four primary ways [42]: 1) resolving references, 2) tailoring lists of options 3) triggering automatic behaviors and 4) tagging information for later retrieval.

The fact that different learners have distinct needs, preferences of personal features has been considered with adaptation [38] [17] and recommendation [37] purposes. In the context of mobile learning, the contents also need to be adapted to different devices [3]. A classification of the characteristics that can be used with adaptation purposes in mobile learning environments is presented in [1]. In [34], Yudelson, et al. used techniques for interpreting student behavior data and constructing student models can be classified into three categories: formal, semi-formal (heuristic) and informal (ad-hoc). Formal approaches use methods either from cognitive sciences or from artificial intelligence. Traditional symbolic AI techniques like semantic networks, rule-based reasoning tend to be replaced by non-symbolic techniques like machine learning, neural networks, genetic algorithms, Bayesian models; while symbolic AI techniques try to infer knowledge about the user based on each of his/her actions at click level, non-symbolic techniques have the advantage of extracting information about the user from his/her entire navigation path, viewed as a whole.

For MOBILearn project at the University of Birmingham, an interactional model of context has been developed, having advantages like [4]: it ensures that context is much more than location; it can be used to guide effective choices and propose future actions, rather than simply acting as a filter on information. The University of Tampere for MOBILearn project has developed an adaptive user interface system [4] in relation with the context awareness subsystem. The adaptive user interface subsystem received data from the context awareness subsystem and this contextual, presence and device information was utilized to optimize the user interface for a mobile phone and a PDA.

II. CONTENT-CONTEXT-ADAPTATION CYCLE

For a given or available learning scenario, the basic information to acquire is content design and development, context identification and adaptation mechanisms to place. These three elements and their corresponding requirements are drawn from the learning scenario's objectives and implementation. Among the three, the content design and development is primary as it is the knowledge to be delivered to m-learner through an m-learning application. When the m-learning application becomes context aware, then comes the role of context into play. Next, the adaptation mechanisms or strategies that vary according to the contexts identified and modeled. It is this adaptation which brings completeness to a context aware adaptive m-learning application to fulfill all m-learning activities and achieve m-learning objectives.

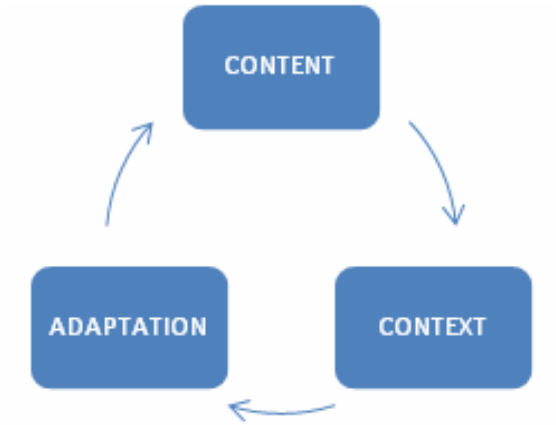


Figure 1. Content-Context-Adaptation Cycle

Given an m-learning scenario, the learning objectives determine the content or knowledge to be delivered to m-learner. Context brings in the ability to impart the content to m-learner so as to make the m-learning activity more appropriate, timely, useful resulting in achieving the learning objective in the most effective manner. Adaptation mechanisms understand and identify the effect of context and content on the m-learner's learning activities and tries to improvise for better learning outcome in the future learning activities. Hence, these three elements are neither static nor fixed. These elements evolve as learning scenario and its constituent learning activities are better understood and achieve higher learning objectives.

Any context aware and adaptive m-learning application development process will be more efficient if it includes this cyclic nature of content-context-adaptation in its process iterations. The cyclic nature is inherent in the relationship between these three elements. Content has to be modeled according the various contextual elements and their features. Adaptation mechanisms primarily depend on the contexts and their values for better adaptation. Depending on the results of adaptation strategies implemented, the content has to be remodeled to achieve better outcome of m-learner's learning activities using context aware m-learning application installed in the mobile device of the m-learner.

III. CONTENT MODELING

The various views of researchers on mobile technologies and its content are worth to consider. Mobile content is any type of media structured for mobile devices, like graphics, tones, films and games [50]; that is delivered through mobile internet [30], using interactivity [27]. In relation to the context of mobile learning, it can be said as "… any service or facility that supplies a learner with general electronic information and educational content that aids in acquisition of knowledge regardless of loca-

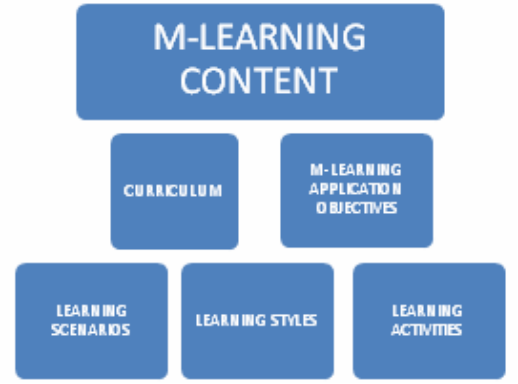


Figure 2. M-learning Content Aspects

tion and time…" [32]. Few of the m-learning projects have addressed the problems of adaptation of learning tasks and personalization of course content based on student's model, learning styles and strategy [8][19]. Norbayah et. al. [36] measures the potential of mobile content in learning to increase learners' tacit knowledge development. At Ultra lab m-learning project, the team produced m-learning materials for people with literacy and numeracy problems [14].

Unlike regular learning content developed for any e-learning application or to any specific requirement, the learning content for mobile learning systems is influenced by a good number of elements, having impact on the content creation and delivery. The very nature of the mobile learning brings these elements into its fold for successful implementation and execution. This motivates the m-learning content creators to consider these aspects in the content development process for modeling the learning content that best suits to a given situation or application. Figure 2 shows these aspects at a glance.

The most influential aspect of m-learning application is said to be the learning styles, for an effective impact of the learning content over the learner in a learning activity. The learning styles designate everything that is characteristic to an individual when he/she is learning, i.e., a specific manner of approaching a learning task, the learning strategies activated in order to fulfill the task [18]. Coffield [13] has identified 71 models of learning styles, among which 13 were categorized as major models according to their theoretical importance, their widespread use and their influence on other learning style models. Whether stable or flexible, genetically determined or experience related, psychological traits or strategies, all categories of learning styles have been proven to exert an influence on learning [18]. In the model [25] by I-Hsueh Tsai et.al., for the development of mobile learning curriculum model, proposed 6-stages; among these, the emphasis was on the design and development of mobile learning content as an integral part for completeness. Personalization of the teaching material has been studied and evaluated in the area of psychology of learning and teaching methods [49][33][7].

The awareness of learning context is important. A learning system that examines the learning context shall adapt learning process with respect to context change [53]. This learning process is enriched by the learning content it presents to the learner making his/her more involved in the learning activities. Anna Trifonova highlights the need for the dependency of the content which could be relative to location context (i.e., the system knows the location where the learner resides and adjusts to it), temporal context (i.e., the system is aware of time dependent data), behavioral context (ie., the system monitors the activities performed by the learner and responds to them adjusting its behavior) and interest specific context (i.e., the system modifies its behavior according to the learner's preferences); and a mix of these is possible and likely. Sharifi et.al.,[45] argued that mobile applications must have context-awareness and personalization as integral parts of the application, and adaptive user interfaces must be generated for the learner, firstly, to maximize learning potential at different locations, and secondly, to decrease the limitations of mobile devices such as the usability of the small screens [5] [41].

In the Electronic Guidebook [24], mobile web content was specifically created for the Exploratorium museum (an interactive science museum) in San Francisco. It was noted that the purpose of context-awareness is to facilitate learning on mobile devices [5]. In the project [28] at Tampere University of Technology, the study-content is presented in the form of a game and the electronic device is used to measure the average students' knowledge level and to adopt the speed of presenting new material to the learners. The Kidsroom project [6] at MIT Media laboratory provided a room that guides children through an interactive storytelling game. Navigation of learning materials is adapted according to the activity context.

The learning content development is a crucial phase and cannot be interpreted as minor task of the entire m-learning application development process. The basic materials that form the low level content has to be transformed into higher forms of content by following a process that treats low level materials against various aspects like syllabus, structure & scope, learning scenarios, learning styles, various contexts. This needs to be carried out in a well defined fashion. A five stage process model for learning content modeling and development in which all the above said aspects are considered is presented here. In the generic process for content modeling presented in the figure 3, every stage will result in intermediate learning content model or design that is specific to that stage-level and can be utilized in an m-learning application considering only those aspects of that stage for its execution. For example, if a preliminary form of m-learning application is used to deliver learning content to the learners' mobiles according to their course specifications, then such an m-learning application can pause at this stage before entering to stage two and use the intermediate learning content model or design produced by the stage one of this process. Similarly, each stage of this process will enhance the design of the learning content by considering various aspects of m-learning needs, and this style gives scope to applications for future scalability options from learning content perspective.

The basic form of learning content is a set of raw materials such as lecture slides, images, clips, animations, selected-passages, FAQs and so on. These materials are created by various tutors and instructors using several authoring tools of their convenience and importance. These materials are very basic to use for any particular application or situation or scenario so as to produce good results. These materials need to be given more appropriate form that enables the tutors to combine or relate or mix various levels of instructions to the students.

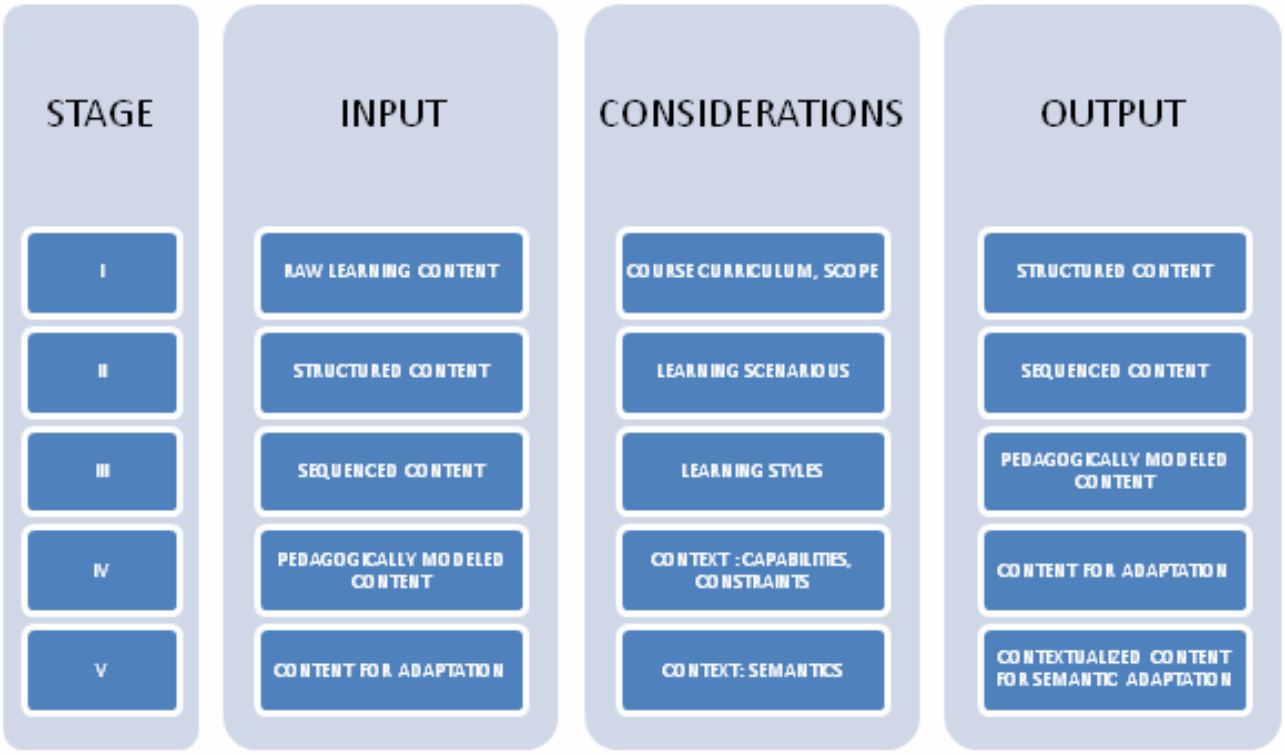


Figure 3. Generic Process Framework for Content Modeling

IV. CONTEXT ELICITATION

Given the diversity of contextual information, it is useful if categorized, to make it easier and understand in a systematic fashion. The context categories identified can be utilized in a number of forms by context aware mobile learning applications. Context can be said to be as comprising of various components that are interdependent in different ways. To understand and identify its relevance for mobile learning one need to scrutinize it in different perspectives and ways in which mobile technologies can usefully support it. One way to do this is to take as many forms of it which we call context exploration and make the stakeholders aware of them when they are involved in the development of context aware mobile learning application.

The following forms of context are explored to atomic levels and serve as a starting point for eliciting contextual requirements in a different manner that can help in focusing the design and development process for CAML applications in more effective fashion.

More clarity to the requirements elicitation is brought by identify and representing the most comprehensible properties of the various contextual elements that are visualized for the context aware mobile learning application. This information makes the application designers more comfortable when designing the contextual elements implementation aspects of the application. The table 1 gives a view of the various properties of the contextual elements.

Contextual element position could be continuous or discrete. In continuous positioning service, a learner's position is known at all times as he/she moves through the space/area covered by the location service. In this kind, application is provided with more information. In a discrete type, the learners must actively provide the system with the information about their position. As the application uses a wider range of context inputs from various sources and sensors; the complexity for the application designers increases. With the higher-level context abstractions (formed by the low level context inputs) the handling of contexts becomes ease to the designers and developers. Dey et al., assert that using higher-level context abstractions that sit on top of individual component abstractions should make it easier for application designers to use context. The higher the level of the context, it is easier to use, at the expense of some information hiding [15].

Given the diversity of context information, it is recommended to categorize and make it comprehensible in a systematic manner. Another contextual element property is shared and individual. Individual context possess information relevant to the learning activity and interaction between the learner and the m-learning application. Shared context possess information relevant to collaborative learning activities or tasks where in a workgroup or a defined set of learners share common goals, interests and experiences.

Given the learning activity that is carried out by the learner with the application comes the contextual element in two variations in terms of their participation in the learning activity. The set of contextual elements that are relevant to the current learning activity are said to be Active and those contextual elements even with value are not relevant to the learning activity currently executed by the learner are said to be Passive. Understanding this variations help the designers to concentrate on the contexts that are required in any given learning activity's design and development.

TABLE I. CONTEXTS

CONTEXT	CHECKLIST TO ELICIT CONTEXT REQUIREMENTS
LEARNER CONTEXT	Preferences, Profile, Calendar, Goals, Contacts, Competences, Practices, Cognitive Abilities, Intentions, Tasks, Results, Needs, e.t.c.
ACTIVITY CONTEXT	Subject, Purpose, Objectives, Expected Outcomes, Pedagogical Theory, Participants, Teams, Achievements & Results, e.t.c.
CONTENT CONTEXT	Content Type, Size, Presentation, Delivery Mode, Storage Options, Content Structure, Content Sequence, e.t.c.
LOCATION/PLACE CONTEXT	. Naming every location such as Home, Library, Lab, Class Room, Hostel, Canteen, e.t.c. . Categorizing such as Private, Public, On Campus, Off Campus, e.t.c.
TIME CONTEXT	. Exact Timing Options . Breaking the day into sessions like Early Morning, Morning, Forenoon, Afternoon, Evening, Night, Late Night, e.t.c. . Time Interval or Time Latencies
ENVIRONMENT CONTEXT	. Weather Context: Sunny, Cloudy, Rainy, Snowfall, e.t.c. . Temperature Context: Very Cold, Cold, Tepid, Warm, Hot, or setting up temperature units. . Noise Context: No Sound, Quiet, Normal, Louder, Hurting or setting up noise levels units.
DAY CONTEXT	. Like Working Days, Holidays . Like Week Days, Weekends . Like On Vacation, Expedition, Festival, Project Period, e.t.c. . Like days of the week, Monday, Tuesday,…,Sunday
MOVEMENT CONTEXT	. Structuring like Slow, Still, Fast, e.t.c. . Structuring like Standing, Walking, Driving, e.t.c.
COMPUTING CONTEXT	CPU power, Display Size, Color Resolution, Input Method, Output Method, Memory Available, Battery Power, Learner Settings.
HISTORY AS CONTEXT	Previous Activities, Outcomes from Database Logs.
USABILITY CONTEXT	Frequency of Access, Usage Statistics, Usage patterns, e.t.c.
CUSTOM CONTEXT	Derived from the Learning Scenarios and Learning Activity Needs.

TABLE II.
PROPERTIES OF CONTEXTUAL ELEMENTS

PROPERTIES OF CONTEXTUAL ELEMENTS	
NATURE	Natural Artificial
STATE	Active Passive
FORM	Individual Shared
SOURCE	Software Hardware
BEHAVIOR	Static Dynamic
COMPUTATION	Computable Non Computable
RELEVANCE	Instantaneous Historical
ADAPTATION	Adaptable Non Adaptable
FLOW	Continuous Discrete
REPRESENTATION	Low Level High Level

The contextual element participation in a given learning activity or task is not sufficient unless their evolution is known. The contextual elements that are of interest to the current learning activity, if undergoes change during the activity's execution are said to possess Dynamic behavior. The contextual elements which participate in the learning activity but remain unchanged are Static in their behavior. The finer details of the contextual elements and their properties make the designers more comfortable in their task execution.

V. ADAPTATION MECHANISM

Mobile Learner is highly mobile in nature and this poses a major challenge in m-learning scenario in which the learning content has to be delivered to the learner based on his/her current context. There are systems or architectures [21] [26] [46] [29] that deliver learning content by adapting to the learner's context. All of them take the context (Physical, Device), the learner style, learner preferences, learner's knowledge, learner's experience or a combination of some of these as a means to adapt and deliver the appropriate content. So, an adaptive delivery of the learning content to the learner based on his place, time, device, physical activity is done. But this doesn't necessarily mean that they are interested in it or in any associated learning activity.

There is a need for identifying the interest of the learner on the delivered learning content by modeling and under-

standing the learner's actions against the learning content. In this work a design methodology called Acceptability Analyzer for identifying learner's interest or acceptance level on the delivered learning content by modeling his/her actions against the learning content with an m-learning application supporting the learning content is devised.

The design methodology is based on the notion that the learning content delivered to the learner has attributes specific to it and its type. The learning content is accessed by the learner with the support of an appropriate application that supports the learning content type and the application has its own specific actions that are used by the learner to interact with the application in the learning activity process.

Figure 4 shows a general schema for a context aware adaptive m-learning system which includes the Acceptability Analyzer module supporting the Adaptation module by sending the information regarding the learner's acceptability levels for the learning content delivered in a context. This is used by the Adaptation module for future decision making or evaluation purposes.

Learning content to be delivered to the learner is modeled and stored in a Learning Content Repository. It is connected to the adaptation module for access in taking decisions to deliver appropriate learning content. The History Log, contains details about learner's experiences and interactions of the past, is also connected to the adaptation module for decision making purpose. The Learner Model consists of details about the learner profile which includes learner preferences, learning style and learner schedule that are accessed, used and updated by the adaptation module. By providing this (learner's) information initially, the system will be able to automatically determine the learning preferences and contextual features of the learner at a given place and time. This saves time and effort for the learner while he/she is on the move. The learner can override a particular learning preference at any time and or location. The learner model is consulted by the adaptation module to draw inferences and take decisions.

M-Learning Application is a mobile software application that is used by the learner in his mobile device to carryout the learning activity with the learning content provided to him/her by the adaptation module taking into all the contextual elements into consideration. The Acceptability Analyzer in figure 5 is the centre of the methodology where in all the concentration regarding the learner's Action analysis is carried out. The source of information for this component are the learner's actions against the m-learning application, learning content presented to the learner and the Action Specific Model which gives information about what to be understood or inferred for the Actions recorded by the Action Recorder module.

The factors that cause interruption in the leaning activity are termed as Acceptability Affecting Factors (AAFs) and play major role in the learning activity's final state. The AAF Categorizer gives information about the factors that cause interruption and their impact on the learning activity flow to the Acceptability Engine. The Action Sequence Log stores all the sequence of actions against the application by the learner in a specific format which ensures the storage of corresponding contextual element values for the recorded actions.

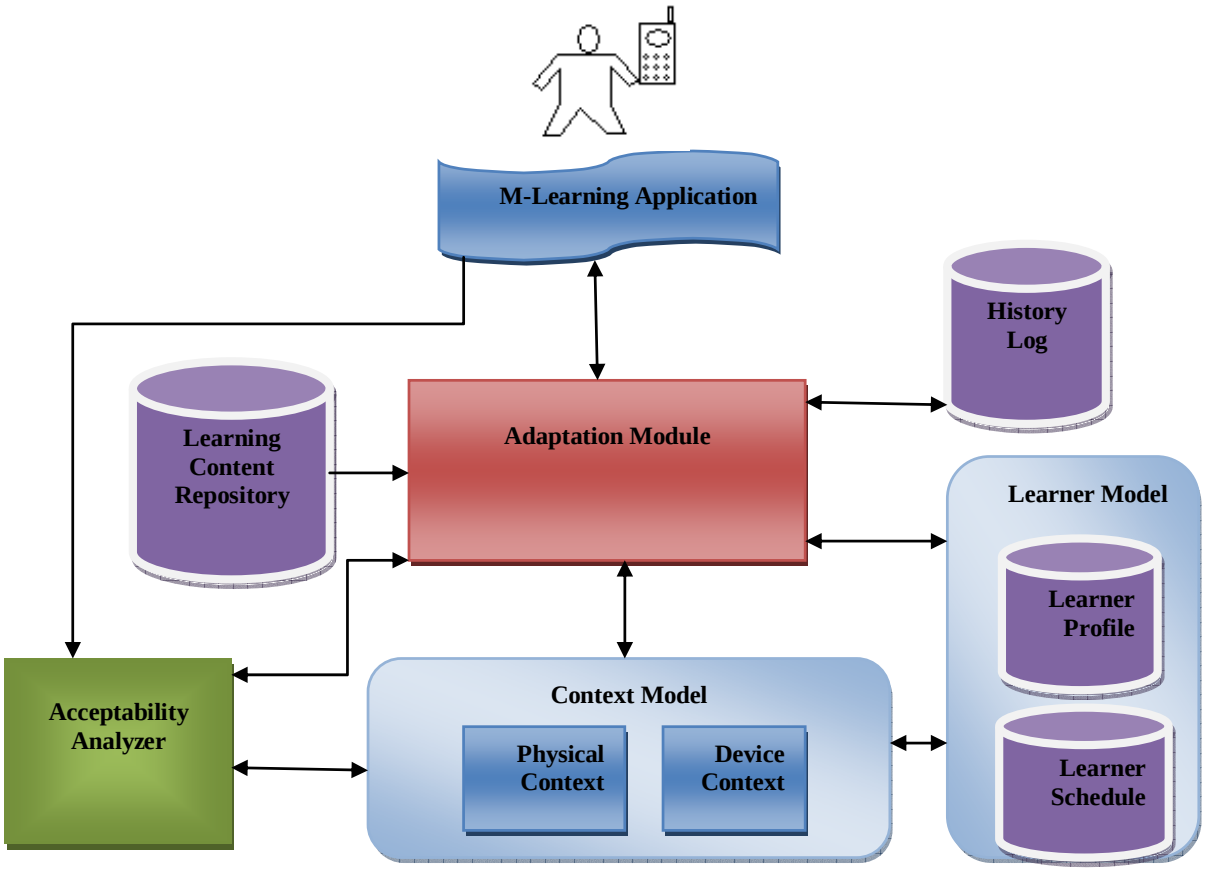
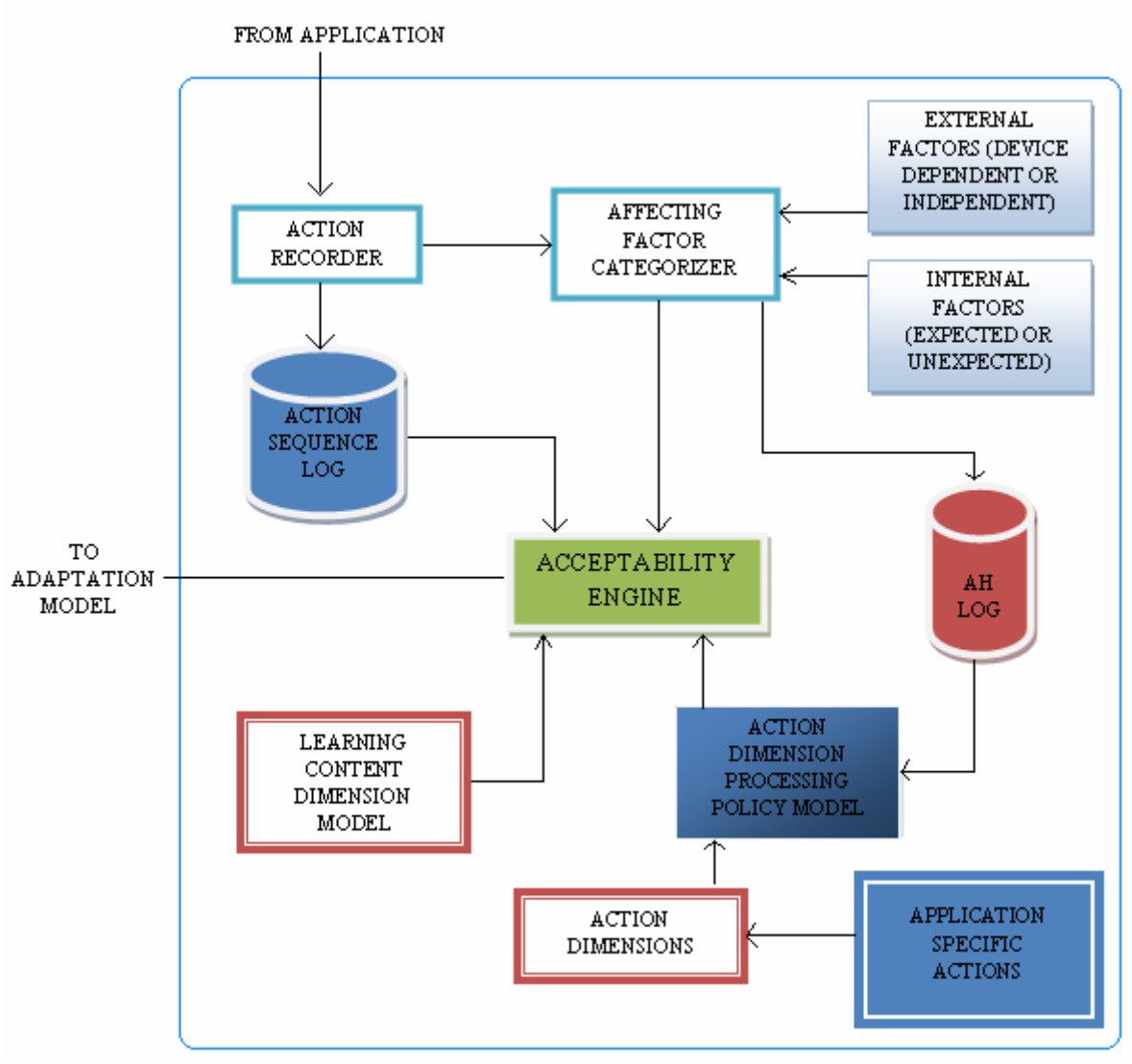


Figure 4. General Schema



Acceptability Analyzer

The Action Dimension Model feeds information to the Acceptability Engine regarding what to infer for each action selected by the learner against the application in terms of Learning Content Dimensions, which are given by the Learning Content Dimension Model. The Learning Content Dimensions are used by the Acceptability Engine to infer how the Content Specific Attributes and Application Specific Actions are related to each other and their effect on the decision making process of acceptability level of the content by the learner. The Acceptability Engine can be implemented by using any intelligent techniques for inference available in the literature.

VI. CONCLUSION

Presented are various context aware and adaptive methods for m-learning and also elicited their functioning for better understanding. These various designs, models and methods concentrate on only either adaptation mechanisms or context awareness or learning styles and are subjected to a particular problem and its solution.

There is a need for better adaptation in context aware m-learning applications' design to integrate various contextual elements and identify their relationships with regard to the m-learning application under development. This also feeds the adaptation process with finer information about contextual features and learners responses to the learning content under these various contextual features, their values by analyzing the learner's actions or interactions that he/she carries out in the learning activity provided by the m-learning application. This requirement sows seed to various models in the coming future.

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Received 2 November 2012. Published as resubmitted by the authors 20 March 2013.