Context-Aware and Adaptive Learning Schedule for Mobile Learning

Jane Yau, Mike Joy
Department of Computer Science, University of Warwick, UK
{j.y-k.yau, m.s.joy}@warwick.ac.uk

Abstract: Mobile learning has become widespread and students nowadays are able to learn anywhere and at any time, enabled by mobile technologies and wireless internet connections. As a result, context-awareness and adaptation in mobile learning has become increasingly important to support the dynamic and continually changing settings within the learner's mobile learning environment. The challenges associated with the contexts include that they are difficult to identify, acquire and make use of. We examine the relationship between mobile learning and computing contexts and elements from the Dunn and Dunn learning styles model, and establish many similarities, and use this to form a theoretical framework underpinning our proposed architecture *Context-aware and Adaptive Learning Schedule for Mobile Learning.*

Keywords: Context-aware, Adaptive Learning, Learning Schedule, Learning Styles, Mobile Learning

Introduction

The field of *context-aware* computing was proposed around a decade ago and is a "*mobile computing paradigm in which applications can discover and take advantage of contextual information (such as user location, time of day, nearby people and devices, and user activity)*" [1]. An objective of a mobile-aware application is to be adaptive and effective to users' information needs, taking into dynamic environmental characteristics, such as the contextual information mentioned above, without consuming too much of a user's attention.

A broad definition of *context* given by Chen & Kotz [1] is "*the set of environmental states and settings that either determines an application's behaviour or in which an application event occurs and is interesting to the user*". Three categories of context were identified by Schilit *et al*. [2] and a fourth one was added by Chen & Kotz [1], as follows:

1. *Computing context* – this includes network connectivity, communication costs, communication bandwidth and nearby resources (e.g. printers and workstations).
2. *User context* – this includes the user's profile, location, people nearby and current social situation.
3. *Physical context* – this includes lighting, noise levels, traffic conditions and temperature.
4. *Time context* – this includes the time of a day, week, month and season of the year.

The Computing, User and Physical contexts can be recorded across a time span and are used to form a *Context History*, which could be useful for certain applications. For example, if we know the user's calendar, and the current location and time, the application may have an accurate idea of the user's social situation, such as having a meeting or sitting in a class.

The remainder of this paper is organized as follows. First, the context-awareness and adaptation topic specifically for mobile learning is explored. Second, two different learning styles models are examined closely, and the relation between the Dunn and Dunn model and the mobile learning contexts are investigated. Third, the motivation of our proposed research is discussed and the system architecture of our *Context-aware and Adaptive Learning Schedule for Mobile Learning* is illustrated. Finally, our conclusion is given.

1. Context-awareness and Adaptation in Mobile Learning

In mobile learning students are able to learn at any time and at any location they wish with their mobile devices. Chan *et al*. [3] distinguished mobile learning "*by rapid and continual changes of context, as the learner moves between locations and encounters localised resources, services and co-learners*". Different learning contexts are instantiated as a result due to this dynamic and continually changing learning setting in the mobile learning environment. For that reason, context-aware mobile learning has become increasingly important and its task is to sense the mobile environment and react to the changing context during a student's learning process.

Contexts in mobile learning have been categorized by Wang [4] into six dimensions which form a Context Space, as illustrated in Table 1 below.

Table 1 – Wang's Six Dimensions of Contexts in Mobile Learning

Dimension	Explanation
Identity	Unique identifier of each learner, recognized usually via a login system, or through special devices such as smart cards.
Spatio-Temporal	This consists of *Time* and *Location*. The time can be obtained through the clock on the mobile device and the location can be provided through a locating sensor such as Global Positioning System (GPS). Knowing these two elements allows us to indicate an instant or period during which some information will be required by a user. An example is Nottingham Castle museum gallery [5].
Facility	This consists of the type of mobile device, such as PDA, mobile phone, smart phone, tablet PC, laptop; and the capabilities of the devices such as the CPU power, display size, colour resolution and input method. Learning materials can be adapted to the mobile device accordingly.
Activity	To detect and determine an appropriate set of activities for a learning process may be difficult. Ways to obtain this context include using discussion records online, or by viewing live actions occurring in classrooms, or acquired by web actions that are portfolios of the student's access log.
Learner	This consists of the intrinsic and psychological properties of a learner which are important for learning successfully, such as the learner's emotional state, focus of attention and background; however, not easy to detect.
Community	This is the social context and can be complex due to the status and interactions among members of the community. Different learning activities can be connected across time, place, school, home and expertise, and each learner's role can be dynamic among the participants.

1.1 Challenges of Context-awareness for Mobile Learning

Schmidt [6] identified three challenges associated with context-awareness:

1. Context is difficult to identify – there is not a defined set of elicitation methods for obtaining context factors.
2. Context is difficult to acquire – the challenge lies within the question of how to obtain the actual information about the user, once the relevant context features have been identified. Direct methods (such as asking the user) can be applied in only limited cases; Indirect methods (such as observations of the user) have disadvantages associated with them. For example, these methods yield imperfect results, and the observations require a wide range of applications to be attached. Otherwise the data must be obtained from a wide range of data resources.
3. Context is difficult to make use of – "*Empirical results on contextual influence on the learning processes are scarce and mostly scattered among various disciplines.*" If and how learning efficiency can be improved with context-awareness is not known. Context-aware learning support requires pedagogical theories and methodologies as its foundation.

1.2 Related Work

Martín *et al.* [7] designed a system for recommending activities for learners; this recommendation process is dependent on the learner's personal attributes, previous actions and the current context (location, spare time, available devices). The system also has the option to interrupt the user to recommend appropriate activities to them, according to their context. Ogata & Yano's [8] designed a context-aware language learning support system for learning Japanese polite expressions.

2. Learning Styles

Keefe [9] defined learning styles as characteristics which are "*cognitive, affective and psychological behaviours that serve as relatively stable indicators of how learners perceive, interact with, and respond to the learning environment*". Three major learning styles categories are (1) Instructional and Environmental learning preferences, (2) Information and Processing learning preferences, and (3) Personality Related learning preferences (Curry [10]). The Dunn and Dunn learning styles model (Dunn and Dunn [11]) consists of five components which were formed under the three learning styles categories. Table 2 below lists the components along with their factors.

Table 2 - The Dunn and Dunn learning styles model

Environmental	Sound/Noise Level, Temperature, Light, Seating, Layout of Room/Location
Emotional	Motivation, Degree of Responsibility, Persistence and Need for Structure
Physical	Modality Preferences i.e. for visual, auditory, kinaesthetic/tactile learning, Intake (Food and Drink), Time of Day, Mobility
Sociology	Learning Groups, Help/Support from authoring figures, working alone/with peers, motivation from parent/teacher
Personality	Anxious/Depressed, Somatic Complaints, Aggressive Behaviour, Attention Problems, Thought Problems, Delinquent Behaviour (Cheats, Lies, Play Truant), Social Problems

Another model such as the Felder and Silverman model [15] is formed under the Information and Processing learning preferences category and distinguishes the learning preferences of learners based on the following four dimensions - (1) Active/Reflective, (2) Sensing/Intuitive, (3) Visual/Verbal, and (4) Sequential/Global, as shown in Table 3.

Table 3 – The Felder and Silverman learning styles model

1	*Active*	Prefer to actively do something with the information in order to process it e.g. discussing it or testing it
	Reflective	Prefer to read and think about the learned material.
2	*Sensing*	Prefer concrete materials such as facts and data.
	Intuitive	Prefer abstract material such as theories and their underlying meaning.
3	*Visual*	Learns best from what they can see or visualise.
	Verbal	Learns best with communication and discussion.
4	*Sequential*	Prefer to know the details of the sub-topics.
	Global	Prefer to see the 'big picture' of the topic before learning the details.

2.1 Relation between the Dunn and Dunn learning styles model and the contexts of mobile learning

Recall the following contexts of mobile learning (Wang [4]) and the contexts of mobile computing (Schilit *et al*. [2]; Chen & Kotz [1]), summarised in Table 4 below.

Table 4 – Contexts of Mobile Learning and Computing

Contexts of Mobile Learning and Computing	
Dimension/Context	**Elements**
Identity Dimension	Identifier of the learner
Spatio-Temporal Dimension	Time and Location
Facility Dimension	Type of mobile device and its capabilities
Activity Dimension	Learning activities
Learner Dimension	Intrinsic and psychological properties of the learner
Community Dimension	Learning activities in the community
Computing Context	Network connectivity, communication costs, communication bandwidth, nearby resources
User Context	User's profile, location, people nearby, current social situation
Physical Context	Lighting, noise levels, traffic conditions and temperature
Time Context	Time of day, week, month and season of the year

We have established that the underlying elements within these contexts can be mapped directly onto the Dunn and Dunn learning styles model and that these contexts fundamentally have a theoretical learning styles model underpinning it. For example, the Environmental category of the Dunn and Dunn model maps onto the Physical context; the Emotional and Personality categories map onto the Learner Dimension. Table 5 below shows the details of our contribution of this relationship.

Table 5 – Relationship between the Dunn & Dunn model and the Contexts of Mobile Learning and Computing

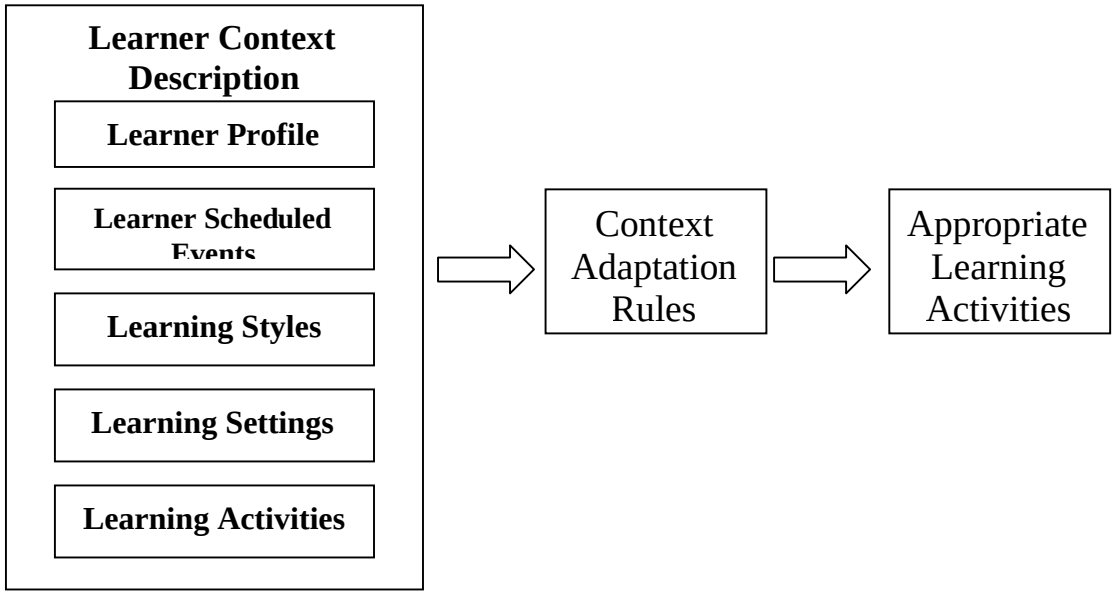
Dunn & Dunn Learning Styles Model		**Contexts of Mobile Learning and Computing**
Environmental	Sound/Noise Level	Physical Context
	Temperature	Physical Context
	Light	Physical Context
	Seating	N/A
	Layout of Room/Location	User Context & Spatio-Temporal Dimension
Emotional	Motivation	Learner Dimension
	Degree of Responsibility	Learner Dimension
	Persistence	Learner Dimension
	Need for Structure	Learner Dimension
Physical	Modality Preferences	Learner Dimension
	Intake (Food & Drink)	N/A
	Time of Day	Time Context & Spatio-Temporal Dimension
	Mobility	N/A
Sociology	Learning Groups	Community Dimension
	Help/Support from authoring figures	Community Dimension
	Working alone/with peers	Community Dimension
	Motivation from parent/teacher	Community Dimension
Personality	Anxious/Depressed	Learner Dimension
	Somatic Complaints	Learner Dimension
	Aggressive Behaviour	Learner Dimension
	Attention Problems	Learner Dimension
	Delinquent Behaviour	Learner Dimension
	Social Problems	Learner Dimension

3. Context-aware and Adaptive Learning Schedule Framework

Our proposed system draws upon three fundamental underlying frameworks – the Dunn and Dunn learning style model, the contexts of mobile learning and computing, and the Felder and Silverman learning style model. Given the identified challenges within context-awareness, we propose a novel system which employs a Learning Schedule which will store the learner's scheduled events (both learning-related and unrelated). A schedule is defined as "*a program of events or appointments expected in a given time*" or "*a student's program of classes*" [12]. The learner can also input diary entries accompanying each scheduled event, before, during and/or after it had occurred. Pedagogical advantages for the use of learner diaries include that experiences can be recorded and that learning can be facilitated from these experiences [13]. Context adaptation rules will be used to select appropriate learning activities for the learners, according to their learning styles and the mobile learning settings. An alternative approach to using learning styles is to use learning strategies [14]. Note that our system would rely on the learner to provide accurate and up-to-date information about his/her learning schedule. Learners' privacy may be affected and also work is required by the learner to input their schedule. We aim to provide the learner with an effective as well as an efficient learning service.

Figure 1 below shows the pedagogical architecture of our framework, which is divided into three parts (1) Learner Context Description, (2) Context Adaptation Rules, and (3) Adapted Learning Activities.

Figure 1 – Pedagogical architecture of our Context-aware Learning Schedule



3.1 Aims and Motivation

We are aiming to construct a system which will have some of the typical functions as illustrated by the following examples:

1. If a learner is commuting on the bus/train for 30 minutes before a lecture, some review material for the lecture will be selected for him/her. (We assume that this environment would be too distracting to undertake assessments). Note that we would need to take into account of overhead time when the learner is getting on and off the transport and time should also be allowed for settling down.
2. If a learner is in a café/restaurant for 30 minutes, some short exercises will be selected for him/her.
3. If a learner is in the library for an hour, some assessments will be selected for him/her.
4. If a learner is at home for two hours, a large review activity will be assigned for him/her.

The motivation for using a Learning Schedule for our system is as follows,

- Wang [4] noted that the "*effectiveness of the combination of context adaptation with pedagogical approaches needs more research efforts*". We have chosen the Learning Schedule pedagogical approach, which is a research topic which has not yet been explored within the Context-Aware for Mobile Learning paradigm.
- A learning schedule can help a learner manage their time for learning more effectively and can help make use of time (such as commuting) which would otherwise be wasted.
- We can retrieve information about the user's learning schedule such as coursework deadlines and course workload. We can also distinguish how much spare time the

learner has and when it would be appropriate to assign which type and length of learning activities for him/her.

3.2 Learner Context Description

The Learner Context Description is further divided into five components – Learner Profile, Learner Scheduled Events, Learning Styles, Learning Settings and Learning Activities.

a) The Learner Profile contains personal information about the learner such as a unique identifier for the learner, surname, forename, address, email address, gender and date of birth.
b) The Learner Scheduled Events component contains all the scheduled events that the learner will be participating in at a specific time; these can either be learning related or unrelated. A unique identifier for the event will be recorded, as well as a name for quick reference, the event start and finish time, the category (whether learning related or unrelated), the event location, subject and type (whether seminar, lecture, tutorial and so on).
c) The Learning Styles section will record the learning preferences of the learner. We have identified the Felder and Silverman Learning Style theory [15] as one which will be appropriate for use within our system. Therefore each of learner's preferences under the following categories will be recorded - (1) Active/Reflective, (2) Sensing/Intuitive, (3) Visual/Verbal, and (4) Sequential/Global.
d) The Learning Settings component contains contextual-related information affecting the learner's learning process. For example the current location of the learner, the type of location (such as computer lab, library, café, home etc), the category of the location (public, private, transport), coordinate, and the time.
e) The Learning Activities component records all the activities that the learner will be undertaking (can either be pending or completed). A unique identifier is recorded, as well as a title, the status of the activity (e.g. not started, in progress or accomplished), the type of the activity (such as Review, Exercise or Assessment), Priority of the activity to be undertaken (high, medium, low), Duration of time needed for completion of the activity, time that the activity starts and finishes (if applicable), the subject, description and objective of the activity.

3.3 Context Adaptation specification

We are currently working on the *Context Adaptation specification* for our system. These specification will take into account the five Learner components – *Learner Profile*, *Learner Scheduled Events*, *Learning Styles*, *Learning Settings* and *Learning Activities* – and appropriate learning activities will be assigned for the learner accordingly. The following shows an example of what the specification might look like.

Learner-Context-Description = {Learner-Profile, Learner-Scheduled-Events, Learning-Styles, Learning-Settings, Learning Activities}
Learner-Scheduled-Events = {Time-Available}
Time Available (minutes) = {<10 | > 10 & < 20 | > 20 & < 30 | > 30}
Learning-Styles = {Active/Reflective, Sensing/Intuitive, Visual/Verbal, Sequential/Globall}
Learning-Settings = {Time, Location}
Location = {private | public | transport}

3.4 System Design and Development

A prototype will be developed from this model and we have chosen the Windows Mobile 5.0 platform on which to build our system because of the following main benefits:

- It uses the .NET Compact Framework 1.0 SP2 – allows .NET programs to be used.
- It has a new generation of platform application programming interfaces (APIs) which allows rich multimedia support.
- Global Positioning System is built-in.

3.5 System Evaluation

The effectiveness of our system will be evaluated using a series of simulations to provide us with quantitative results. A small number of human users will be employed to work with the system and to provide us with qualitative results.

4. Conclusion

We have described our proposed Context-aware and Adaptive Learning Schedule for Mobile Learning and we are currently designing the system prototype which will be implemented and evaluated.

References

[1] Chen, G. and Kotz, D. (2000) A Survey of Context-Aware Mobile Computing Research. *Dartmouth Computer Science Technical Report TR2000-381.*

[2] Schilit, B., Adams, N. and Want, R. (1994) Context-aware computing applications. IEEE Workshop on Mobile Computing Systems and Applications, 85-90.

[3] Chan, T., Sharples, M., Vavoula, G. and Lonsdale, P. (2004) Educational Metadata for Mobile Learning. International Workshop on Wireless and Mobile Technologies in Education.

[4] Wang, Y-K. (2004) Context Awareness and Adaptation in Mobile Learning. IEEE Workshop on Wireless and Mobile Technologies in Education, 154-158.

[5] Lonsdale, P., Beale, R. and Bryne, W. (2005) Using context awareness to enhance visitor engagement in a gallery space. International Conference on Human-Computer Interaction.

[6] Schmidt, A. (2005) Potentials and Challenges of Context-Awareness for Learning Solutions, Workshop of the SIG Adaptivity and User Modelling in Interactive Systems.

[7] Martín, E., Andueza, N., Carro, R. & Podríguez, P. (2006) Recommending Activities in Collaborative M-Learning. International Conference on Adaptive Hypermedia and Adaptive Web-Based Systems.

[8] Ogata, H. and Yano, Y. (2004) Context-aware Support for Computer-Supported Ubiquitous Learning. IEEE Workshop on Wireless and Mobile Technologies in Education, 27-34.

[9] Keefe, J. W. (1979) Learning Style: An Overview, in J. W. Keefe (ed.), Student learning styles: Diagnosing and prescribing programs. NASSP.

[10] Curry, L. (1987) Integrating concepts of cognitive or learning styles: A review with attention to psychometric standards. *Ottawa: Canadian College of Health Service Executives.*

[11] Dunn, R. and Dunn, K. (1978) Teaching Students through their individual learning styles: *A practical approach. Reston, VA: Prentice-Hall.*

[12] Dictionary definition - available at http://dictionary.reference.com/browse/schedule [Accessed 10/08/06]

[13] Lancaster University (2006) Diaries as Learning Support for the Year Abroad – available at http://www.lancs.ac.uk/users/interculture/docs/diaryrep.rtf [Accessed 12/10/06]

[14] McKeachie, W. J (1995) Learning Styles can become Learning Strategies. National Teaching and Learning Forum Vol. 4, No. 6.

[15] Felder , R. and Silverman, L. (1998) Learning Styles and Teaching Styles in Engineering Education. Engineering Education, Vol. 78, No. 7, 674-681.