A Design Requirements Framework for Mobile Learning Environments

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***Abstract*—This paper proposes a conceptual framework for mobile learning applications that provides systematic support for mobile learning experience design. It is based on a combination of a game metaphor and several studies of mobile learning contexts. Accounts of four mobile learning projects are used to explore the relationship between the framework and mobile learning design requirements in practice. By applying the framework to previous successful mobile learning implementations, we are better able to understand their key qualities. Similarly, the framework provides forward engineering support for the successful design of future mobile learning systems.**

***Index Terms* - mobile learning, requirements, framework**

I. INTRODUCTION

As mobile technologies have become pervasive, many researchers [e.g. 1,2] have questioned whether they can enhance learning experiences. It could be argued that mobile learning (M-learning) is an approach to electronic learning (E-learning) that simply utilises mobile devices, yet it can also be viewed as a quite different learning experience [3]. Indeed, M-learning can only be delivered with an awareness of the special limitations and benefits of mobile devices, so one cannot simply apply known design requirements from E-learning into the M-learning context.

This paper explores what factors and design requirements are crucial to the M-learning environment, and suggests how M-learning applications can be designed with an understanding of these factors and requirements. In our approach, we develop an M-learning framework for integrating relevant design requirements, grounded in best practices from the literature. This framework is both used as an analysis tool to help understand the critical success factors in previous mobile learning applications, and as a design tool for developing new systems. The following section reviews the literature, identifying several structural factors and contexts for M-learning design. From this we introduce a framework for developing M-learning applications, which is described in section three. Sections four to seven analyse four different M-learning environments with the framework, showing how their different techniques and technologies can all be encompassed within the general structure of the framework. The final section provides some conclusions and proposals for further research.

II. DESIGN REQUIREMENTS FOR M-LEARNING

Portable communication devices are central to M-learning environments, giving access to the learning content. The design concerns of M-learning environments in general are thus combined with those of specific M-learning applications. We review these design concerns from four perspectives: *generic mobile environment issues*, *learning contexts*, *learning experiences*, and *learning objectives*.

A. Generic mobile environment issues

The most important feature in the mobile environment is *mobility* itself. It enables us to be in contact while we are outside the reach of conventional communication spaces. Mobility can be conceptualised in different ways, i.e., mobility of the user, mobility of the device, and mobility of services, and these three aspects should be addressed both technically and contextually.

We should also understand that each user employs their mobile device in a different way. For instance, teenagers frequently use SMS to communicate, while professionals are more likely to be using corporate email. This feature – *different user profiles and their roles* in the use of mobile technologies – becomes even more

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important in an M-learning environment. For instance, the use of SMS in M-learning has been identified as an effective tool to enhance both students' learning experience and tutors' instructing experience, yet the requirements of the two parties were quite different in terms of their previous experience of SMS [4]. A simple way of considering user roles and profiles is Löwgren and Stolterman's classification: core, periphery, and context [5]. Core users are always learning with their mobile devices (e.g., students), and the periphery includes user roles that are not actively incorporated into the learning experience (e.g., tutors). The context is the surrounding user roles and society at large that are not directly involved in the learning experience, but still influence it in indirect and complex ways (e.g., parents or school). In terms of the different roles and profiles in the learning experience, there is a need to manage these relationships in a way that acknowledges the role of stakeholders, honours the integrity of all involved parties, and leads to a viable design.

Awareness of the constraints of the *user interface* is also vital. Mobile devices suffer from small screens, restrictive input methods and limited battery life. Therefore, the interface design for M-learning services must meet users' needs without overloading them with unnecessary complexity, operating too slowly or consuming excessive power.

Successful mobile applications tend to employ many rich *media* objects [6], yet they should not distract from the learner's experience. One of the commonly stated characteristics of M-learning content is that it should be delivered in short 'nuggets' rather than large units of information, which can be supported by appropriate use of different media types. These media types should support content appropriately. For instance, Luchini, Quintana and Soloway [7] stress the importance of the user participating in and learning about underlying concepts and processes, perhaps using simulation tools [8], rather than learning by rote.

One widely noted feature of mobile technologies is that they afford the possibility of perpetual contact. This sense of *communication support* tends to contribute to the other possibilities of M-learning in use. As a simple example, communication support has helped to meet the collective learning objectives of a field trip [9].

B. M-learning contexts

M-learning has been used as a pre and/or post activity to other types of learning [9,10], complementing the classroom experience. This may make us see the M-learning context as part of the traditional learning context [11]. However, some recent M-learning applications, e.g., the Ambient Wood project [9], reveal that the M-learning context is quite different from traditional learning. In this section, we review the contextual features that can be used to understand M-learning design requirements. We base these on Wang's six dimensions of the M-learning context: *identity, learner, activity, collaboration, spatio-temporal, and facility* [12]. The first four of these would establish the situational contexts of M-learning, and the last two would be associated with the environmental context.

Identities of M-learning users (e.g., learners, tutors) are a necessary contextual factor. This would be of value for the development of personalised learning experiences for individual stakeholders.

Several *considerations of the learner* should be made, because each user has different psychological properties that relate to their learning experience. For instance, highly self-motivated learners would probably improve their learning experience by using all the features that the system can provide.

The most promising feature of M-learning contexts is that one can collaboratively perform *activities*. Of course individual learning activities should be addressed in M-learning, but the collective learning experience can be enhanced by mobile systems. Such *collaboration* can take many forms. It may take place in a classroom or be a remote connection to a 'live' tutor [1]. Two-way interactions support the essential characteristics of a shared learning environment, and these virtual learning communities are good for both the organisation and the learner [13].

The *spatio-temporal dimension* means an awareness of time and/or location. Spatial location has been acknowledged as an effective environmental context in many applications, while the temporal context can deal with issues like scheduling collaborative interactions.

The context of *facility* can impact on the design of M-learning interfaces. Most current M-learning environments employ standard mobile devices using public carrier networks, but more innovative technologies (e.g., the Soundhorn in the Ambient Wood project) can enable a richer facility context.

C. Learning experience and objectives

Most of the literature regarding M-learning design has tended to simply map between M-learning contexts and learning objectives, such as individual learning or collective learning. However, as learning activities become a ubiquitous part of our lives, the focus of design and evaluation has turned towards the user's learning experience. Preece *et al.* [14] claim that system designers should concern themselves with setting not only usability goals for their products, but also user experience goals to assess whether the product is, for example, enjoyable, satisfying and motivating.

In considering M-learning design, we noted two useful metaphors, the cinematic metaphor and the game metaphor, that may enable us to both leverage the positive qualities of mobile devices and engage learners by providing a rich experience. In the cinematic metaphor [15], the representation of content embeds narrative or story elements that the learners can easily follow, while the game metaphor helps to engage learners by leveraging the popularity of games, with qualities such as excitement and competition. Schwabe and Göth [16] provide a framework for their game-based M-learning system developed from Prensky's [17] six structural elements of games, namely (i) rules, (ii) goals and objectives, (iii) outcome and feedback, (iv) conflict, competition, challenge and opposition, (v) interaction and (vi) representation or story. In reviewing M-learning experience we owe much to these six aspects but provide some further analysis for M-learning contexts.

We believe that the most basic component of learning experience is that it is an organised delivery of the contents. It may be equivalent to Prensky's "rules"; yet it is concerned more with the contents than the logic behind the contents. Carefully *organised content* should enhance the learning experience by making sense of the material, perhaps using a narrative framework. *Goals and objectives* help the learner to engage. Generally, achieving goals is a big part of what motivates learners, and these goals and objectives could be adapted to match the situations and expertise of the learners. Goals and objectives are measured by *outcomes and feedback*. Prensky [17] claimed this factor has strong emotional and ego-gratification links, which are a big part of the attraction of games. Similarly in learning, feedback comes when something in the learning changes in response to what the learner does. It lets the learner know immediately what they have achieved. The narrative (*representation or story*) in learning experiences can be seen as an important structural factor in developing *new or improved skills*. A big advantage of narrative is that it can be complex and explorative. Following from Csikszentmihalyi [18], a learning environment that places narrative at the centre can help learners to reflect on what they have learned, enabling a sort of meta-learning, illuminating the very processes by which they learn and providing an organising structure for knowledge. *Social interaction* means group experiences or establishing some relevant collective learning. This helps the learner to develop appropriate *social and team skills* and assists team building in reaching joint learning objectives. Finally, *conflict, competition, challenge, and opposition* provide a dynamic for individual or collective problem solving. These factors can engage the learner, facilitating self-motivation and self-regulation.

III. A METAPHOR-BASED FRAMEWORK

From our analysis of the four design perspectives, we have developed a design requirements framework for mobile learning environments that draws on both narrative and game metaphors. Figure 1 shows how the four M-learning design requirements; learning objectives, learning experience, M-learning contexts, and generic mobile environment design issues, interact. As an example of these interactions, consider M-learning for dynamic complex situations, such as rescue services or intensive care. These require the collective learning objectives, particularly developing team skills. This learning objective would be supported by the learning experiences conflict, competition, challenge, and opposition and social interaction. These learning experiences would require the corresponding M-learning contexts; including activity, spatio-temporal, facility and collaboration, which in turn would map in a context specific way to generic mobile design requirements.

To test the framework in detail, we applied it to four successful M-learning environments that had differing characteristics. These were; Ambient Wood [9], Thinking Tags [19], Uniwap mobile teacher training [20] and Mobile Learning Organiser [21]. The Ambient Wood project was based on children exploring a physical environment that included a number of devices that complemented the mobile components. Thinking Tags used infra red communication between 'smart' tags to simulate the spread of disease in the teaching of medical

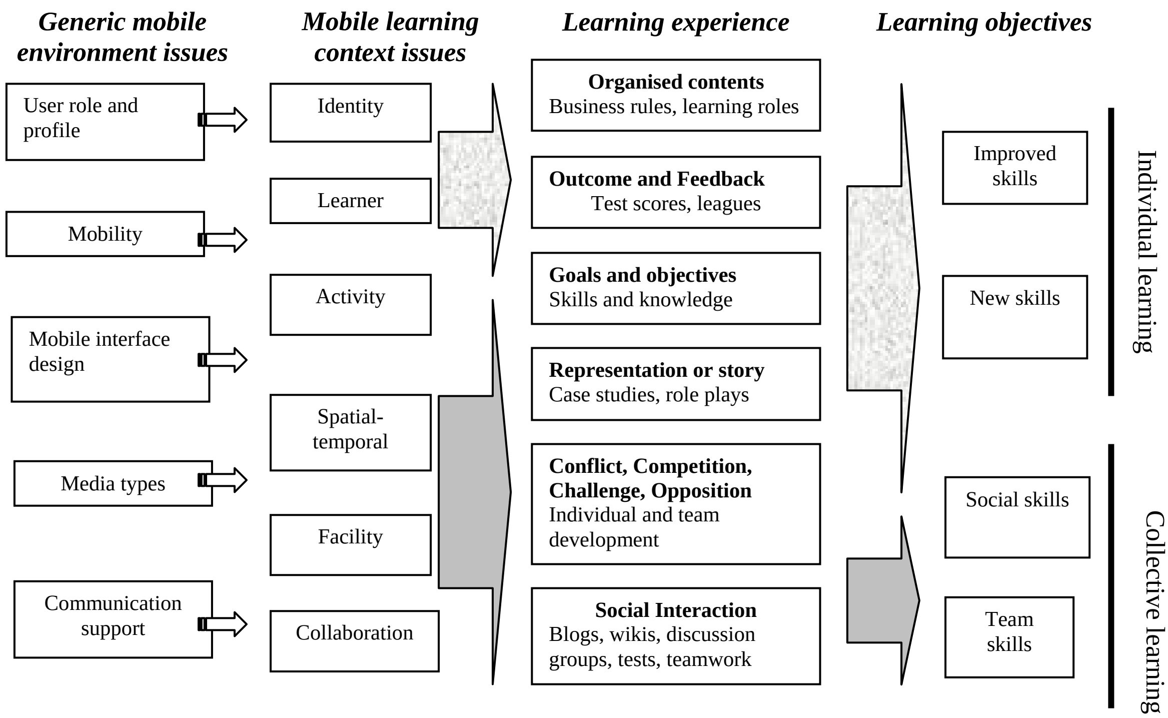

Figure 1. A framework for M-learning design requirements

students. Uniwap used simple text messaging, digital pictures and digital portfolios to assist trainee teachers while on teaching practice, while Mobile Learning Organiser provided a mobile location aware information system for university students. Whereas in the first three examples we use the framework for a post-hoc analysis of mobile learning experiences, for the last example we see how the framework may be used for the analysis of new mobile learning system requirements. Despite the highly diverse nature of these experiments, we show in the following section how they can all be analysed within our framework.

For each example we have provided a table that maps the specific details of the M-learning environment to the components of the framework. Depending on the nature of the M-learning experience, the framework may be applied repeatedly at separate stages of the M-learning process. The Ambient Wood project has three stages; an initial experience in the wood, a group reflection and a return to the wood. In each stage we describe how the framework reflects the experience and environment. In contrast the Thinking Tags example has five stages, as the students are taken though a complex process of discovery learning, hypothesis formation and testing. In the Uniwap project there are two stages, the in-the-field data gathering and the subsequent reflection However we have included a third stage that relates to the experience of the experiment itself, since this also involved reflection by the participants. Finally, the Mobile Learning Organiser project table is limited to a single stage because in this example the framework was used only in the analysis phase.

IV. Applying the Framework for Understanding the Ambient Wood Project

In the Ambient Wood project [9], a playful learning experience was developed where children could explore and reflect upon a physical environment that had been augmented with a medley of digital abstractions. The latter were represented in a number of ambient ways, designed to provoke children to stop, wonder and learn when moving through and interacting with aspects of the physical environment. A variety of devices and multi-modal displays were used to trigger and present the 'added' digital information, sometimes caused by the children's automatic exploratory movements, and at other times determined by their intentional actions. A field trip ‘with a difference’ was created, where children discover, hypothesise about and experiment with biological processes taking place within a physical environment.

Table I. Analysis of the Ambient Wood project

Objectives	Learning experience	Learning contexts	Design issues
Stage1: Reporting and discovering **Individual learning** (improving skills) *Exploring,* *Reflecting,* *Communicating findings* **Collective Learning** *Discussing,* *Collaborating*	**Organised contents:** *Children record environmental observations and report to facilitator* **Outcome & Feedback:** *Various sounds and images in particular parts of the woods. Readings from sensors* **Goals and objectives** *To explore the physical world,* *To discover different aspects of the habitat,* *To discuss and reflect on findings* **Social Interaction:** *Pair working*	**Identity:** *Children, Facilitators* **Learner:** *Children* **Activity :** *To explore the field (touching, looking, smelling, and listening), responding to stimuli and collecting data for further discussion, Reporting to facilitators via mobile devices,* **Spatial-temporal:** *Partner co-located same time, Facilitator remote same time* **Facility:** *PDAs, Soundhorn, Periscope, Probe tool, Wireless speaker, Personal computers, Wireless network* **Collaboration:** *Pair working*	**User roles and profiles** *Exploring the field (children)* *Data collecting (children) and supervising children (facilitators) in the field trip, Children and teachers in the classroom* **Mobility:** *PDA* **Interface design:** *Visualisation software, Mobile software. Avoid information overload* **Media:** *Image, Sound* **Communication:** *WiFi, Sensor-based technologies, Server technologies*
Stage2: Reporting consolidating, hypothesising **Collective learning** (team skills) *Consolidating* *Hypothesising* *Communicating*	**Conflict, competition, challenge, opposition:** *Discussing and challenging the hypotheses* **Social interaction:** *Whole group forum to consolidate learning*	**Activity:** *Reviewing data collected, predicting the outcome of environmental change,* **Spatial-temporal:** *Co-located place, same time* **Collaboration:** *To confirm and refute their hypotheses* **Facility:** *Interactive board*	**User role:** *Participant in group discussion (children)* **Interface:** *Collaboration support, Communication support* **Media:** *Image, , tokens* **Communication:** *Verbal communication support*
Stage 3: Experimenting and reflecting **Individual learning** (new skills) *Testing hypotheses* **Collective learning** **(**team skills) *Collaborative reasoning*	**Organised contents** *Children return to wood, instructed to reason, hypothesize and experiment* **Outcome and Feedback** *Animations, data readings* **Goals and Objectives** *To construct hypotheses* *To predict impact of change* *To experiment*	**Activity** ***Children return to field and introduce environmental changes*** **Spatial-temporal** *Co-located place, same time* **Facility** *As stage 1* **Collaboration** *Pair working*	**User role:** *Experimenter (children)* **Mobility:** *PDA* **Interface:** *Environmental simulation* **Media:** *Visualisation software, sensors, RFID tagged artefacts and readers* **Communication:** *Wi-fi, Sensor based technologies*

From the individual learning perspective, the learning objectives are exploring, consolidating, hypothesising, experimenting, and reflecting the ecological system. Also, for their collective learning, they collaboratively discover a number of things about plants and animals living in the various habitats in the wood. Their experiences are later reflected upon in an area where children share their findings with each other and abstract these to hypotheses of what will happen to the wood in the long term under various conditions. Table I analyses the application in terms of our framework from a learning experience perspective, revealing how learning objectives relate through learning experience and contexts to the generic mobile environment issues.

V. Applying the Framework for Understanding the Thinking Tags Project

Thinking tags were developed at the MIT Media Laboratory and have been used as communication devices in what are described as Participatory Simulations. The Tags are fully programmable mobile devices which communicate using infrared (IR) communication. Between fifteen and seventy five people

TABLE II. ANALYSIS OF PARTICIPATORY SIMULATIONS USING THINKING TAGS

Objectives	Learning experience	Learning contexts	Design issues
Stage1:Initial interaction **Individual learning** *Exploring* *Discovering* **Collective Learning** *Interacting* *Collaborating*	**Organised contents:** *High school students meet in the context of a simulation* **Outcome & Feedback:** *Double digit numeric display, 5 LEDs* **Goals and objectives** *To engage in participatory simulation* *To explore system dynamics* **Social Interaction:** *One to one interaction with any other participants*	**Identity:** *High school students* **Learner:** *High school students* **Activity :** *To engage in participatory simulation of a dynamic system* **Spatial-temporal:** ***C****o-located same time,* **Facility:** ***Thinking tags*** **Collaboration** *Simulation participation*	**User roles and profiles** *Simulation participant (student)* **Mobility:** *Thinking tags* **Interface design: Interface:** *Environmental simulation* *Simple output, "dial-in" input.* *Prevent feedback distracting from participation.* **Media:** *Digital display, LED* **Communication:** *Resistive sensors, IR*
Stage2:Elucidation **Individual learning:** *Elucidating* *Questioning* **Collective Learning:** *Consolidating* *Communicating*	**Organised contents:** *Group session with facilitators* **Goals and objectives** *To elucidate system dynamics* **Social interaction:** *Whole group forum*	**Identity:** *High school students***,** ***facilitators*** **Activity:** *Explaining and discussing participative experience* **Spatial-temporal:** *Co-located place, same time* **Collaboration** *Group working*	**User role:** *Questioner(facilitator)* *Participant in group discussion (student)* **Interface:** *Collaboration support, Communication support* **Communication:** *Verbal communication support*
Stage 3: Collaborative analysis: **Individual learning:** *Analysing data* *Communicating* **Collective Learning** *Collaborative reasoning*	**Goals and objectives** *Analyse individually collected data* *Develop a coherent understanding of whole system* **Conflict, competition, challenge, opposition:** *Discussing and challenging opinions* **Social interaction: A***s above*	**Identity:** ***As above*** **Activity:** *Reviewing individual data and developing a collective understanding of system dynamics,* **Spatial-temporal:** *Co-located place, same time* **Collaboration:** *Group working to synthesise individual findings*	**User role:** *Data retrieval (student)* *Participant in group discussion (student)* **Interface:** *Collaboration support, Communication support, data display* **Media:** ***Tool tags*** **Communication:** *Verbal communication support*
Stage 4: Hypothesis formulation and experimental design **Individual learning** *(new skills)* *Experimental design* *Hypothesis formulation*	**Goals and Objectives** *To construct hypotheses* *To design experiments to test hypotheses* **Social interaction:** *As above*	**Activity** ***Students continue to work together to formulate hypotheses*** **Spatial-temporal** *Co-located place, same time* **Collaboration** *Group working*	**User role:** *Participant in group discussion (student)* **Interface:** *Record hypotheses, experiments* **Communication:** *Verbal communication support*
Stage 5: Hypothesis testing *(new skills)* *Hypothesis testing*	**Organised contents** *Students r***e***start tags and return to the simulation* **Outcome and Feedback** *Double digit numeric display, 5 bicolor LEDs* **Goals and Objectives** *To test hypotheses* *To develop understanding of underlying algorithm* *To predict impact of change*	**Activity** *Students reset tags and return to participatory simulation to test hypotheses***.** **Spatial-temporal** *Co-located place, same time* **Facility** *As stage 1* **Collaboration** *Simulation participation*	**User roles and profiles** *Simulation participant (student)* **Mobility:** *Thinking tags* **Interface design: Interface:** *Environmental simulation* *Simple output, "dial-in" input.* *Prevent feedback distracting from participation.* **Media:** *Digital display, LED* **Communication:** *Resistive sensors, IR*

TABLE III. ANALYSIS OF THE UNIWAP MOBILE TEACHER TRAINING PROJECT

Objectives	Learning experience	Learning contexts	Design issues
Stage1: Reporting and discovering **Individual learning** (improving skills) *Exploring,* *Reflecting,* *Communicating findings* **Collective Learning** *Pooling resources,* *Sharing learning with others*	**Organised contents:** *Trainees record classroom observations and report to facilitator* **Outcome & Feedback:** *Messages and photographs sent to peers, supervisors and central database* **Goals and objectives** *To experience the workplace environment and discuss and reflect on findings* **Social Interaction:** *sharing immediate information with other trainees and supervisors*	**Identity:** *Trainees, Supervisors* **Learner:** *Trainees* **Activity :** *To record and share experiences of teacher training, Creating digital portfolios via mobile devices,* **Spatial-temporal:** *Student and teachers mostly remote but co-located when supervisors visit trainees in school* **Facility:** *Mobile Phones (Nokia Communicator 9210) and digital cameras* **Collaboration:** *Supervisor support via mobile device*	**User roles and profiles** *Working in schools (trainees)* *Data collecting (trainees) and supervising students (supervisors) in schools.* **Mobility:** *Mobile Phones (Nokia Communicator 9210) and digital cameras* **Interface design:** *Simple text messaging and infra-red picture upload* **Media:** *Image, Text* **Communication:** *Cellular phone network*
Stage2: Reporting consolidating, hypothesising **Collective learning** (team skills) *Consolidating* *Hypothesising* *Communicating*	**Conflict, competition, challenge, opposition:** *Challenging assumptions, gaining self insight* **Social interaction:** *Whole group electronic forum to consolidate learning*	**Activity:** *Reviewing data collected, organising information in the digital portfolio,* **Spatial-temporal:** *Co-located place, same time* **Collaboration:** *To jointly reflect on teaching experience* **Facility:** *Central database of digital portfolios*	**User role:** *Building a digital portfolio(trainees)* **Interface:** *Collaboration and Communication support through central database accessed remotely* **Media:** *Image, Text* **Communication:** *Verbal communication support using mobile devices*
Stage 3: **Reflecting** **Individual learning** (new skills) *Understanding* *Reflecting* **Collective learning** **(**team skills) *Understanding the responses of others*	**Organised contents** *Trainees asked to reflect on their mobile learning experience* **Outcome and Feedback** *Transcribed group interview* **Goals and Objectives** *To learn form the mobile learning process*	**Activity** ***Supervisors and trainees discuss the mobile learning experience*** **Spatial-temporal** *Co-located place, same time* **Facility** *No devices used* **Collaboration** *Sharing experiences*	**User role:** *Experimenter (supervisor) trainee* **Mobility:** *n/a* **Interface:** *physical* **Media:** *sound recorder* **Communication:** *face to face*

can participate in a simulation. The aim is for the participants to interact and thus simulate a dynamic system. Each participant has a Tag and as the individuals interact, so do the Tags. Feedback is provided through a two digit digital display and an array of 5 bicolor LEDs. Participation of the individual in the dynamic interactive simulation helps gain a rich understanding of the system under study.

Colella, Borovoy and Resnick [20] describe the Participatory Simulation of a disease epidemic in which the participants are high school students. One Tag starts the disease propagation and the students can observe the virus jumping from Tag to Tag. Factors such as immunity are programmed into the simulation. The students come together as a group after an initial period of interaction where the focus is very much on using and improving individual skills, developing an understanding of the system by exploration and discovery through interaction with other participants and the mobile devices. They are then challenged to elucidate on their experience, considering issues such as whether some people are more susceptible to infection than others or whether the disease has a latency period. The students retrieve information from their Thinking Tags using small sensor tools and work with the whole group to develop an understanding of the dynamics of the whole system. During these stages team and social skills are to the fore. The students then proceed to formulate hypotheses about the disease and design experiments to test them. The final stage sees the students resetting their tags and returning to the simulation to test the outcome of their work. The path from learning objectives through to mobile design issues is shown in Table II.

VI. APPLYING THE FRAMEWORK FOR UNDERSTANDING THE UNIWAP MOBILE TEACHER TRAINING PROJECT

Seppälä and Alamäki [21] describe a mobile learning project designed to assist in teacher training. The project used relatively simple technologies, short message service (SMS) and digital pictures, to enable students to create digital portfolios in a central database built from materials created in the field. Messaging was used to enable the trainees, who were widely distributed when training in different schools, to collaborate with each

TABLE VI. REQUIREMENTS ANALYSIS FOR THE MOBILE HELPER PROJECT

Design issues	Learning contexts	Learning experience	Objectives
User roles and profiles *New students - few ideas of where the classrooms, facilities etc. are located* *Senior students - aware of locality information, but require more depth into personal studies, and assistance in multi-tasking.* **Mobility support** *Students roam the campus to attend all their different learning activities* **Interface design** *Visualisation software (Map)* *Mobile software* *Avoid information overload* **Media** *Images, Sounds, Text*	**Identity** *Junior students* *Senior students* **Learner** *Students* **Activity** *Navigation of the campus* *Obtaining contextual knowledge* *Social communication* **Spatial-temporal** *Location awareness, so the information given on the PDA is really relevant to their current location.* *Morning: the lecture or tutorial information that they must attend;* *Afternoon: more individual study organisation*	**Organised contents** *Lecture, tutorial, and lab information* *Assignments, assessments, library, and recreational information* **Outcome & Feedback** *Locational references* *Various sound alerts* *Images and text in particular parts of the campus* *Web links to the current learning modules* **Goals and objectives** *To discover the locations of lecture, tutorial, and laboratory rooms (Junior students)* *To be aware of the information that is relevant to organising their school life (Senior students)* **Social Interaction** *Discussing the current learning module (Senior students want to discuss directly with lecturers)*	**Improving learning situations**

other and share their experiences. Feedback from the participants showed that the immediacy provided by the mobile devices was an important factor. Messages and pictures could be shared immediately with other students. The supervisors benefited from being able to access the material generated by the students in the shared database while travelling between work placements. Text messaging was used for information, supervision and feedback. Images were used to provide insights into the classroom experience, for example how the teachers actually looked in the classroom. An important aspect of the images was that the database enabled explanatory text to be included for each picture: “These comments about picture messages made them come alive to the people who were not present in actual teaching situations.” [21, p.335]. The analysis in Table III shows three stages, though the final stage was not part of the learning process per se, but the interviews that followed the experiment. However, since it appears that the reflective process of interviewing about the experiment helped the students to gain further insights into their experience, this stage has been included in the analysis.

VII. APPLYING THE FRAMEWORK FOR ANALYSING THE MOBILE HELPER PROJECT

In the three previous examples we took successful mobile learning projects and mapped their characteristics onto the framework. The purpose of this reverse engineering exercise was to attempt to validate the framework against previous work. However the intention of the framework is that it should also be able to provide us with a design guideline for forward engineering new mobile learning solutions. In Ryu et al [22] the framework was used as a guide for requirements gathering in a system intended to provide location aware learning support for university students. Table IV shows the results of this exercise in the context of the framework. Using the framework in requirements gathering helped to identify that junior and senior students had different needs in their mobile learning contexts. This insight enabled a system to be developed that could meet the disparate needs of different learner identities. Note that in this case the table works through from the objectives to the design, whereas in the previous analyses we started with an existing design and worked our way back to the underlying objectives.

VIII. CONCLUSIONS AND FUTURE WORK

This paper discussed what design issues and contexts are important to M-learning. It incorporated best practice in M-learning research into a practical framework of M-learning design requirements based on Schwabe and Göth [16] but providing a broader view to take account of the learning context and objectives beyond a single application domain. This framework was then applied as a post–hoc analytical tool to three successful M-learning systems for the purposes of validation. It was also used as an analysis framework for the requirements phase of a mobile learning project. It is of course recognised that the framework has not yet been thoroughly assessed. Future work will involve the development of a generic design process to enable the application of the framework in a design context and the subsequent design and development of a complete M-Learning application.

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