



MOBIlearn

WP 4 – PEDAGOGICAL METHODOLOGIES AND PARADIGMS

[UON, UOB, OU]

Guidelines for learning/teaching/tutoring in a mobile environment

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Summary

Mobile learning is an emergent paradigm in a state of intense development fuelled by the confluence of three technological streams, ambient computing power, ambient communication and development of intelligent user interfaces (Sharples et al., 2002). A consequence of this rapid development is that the pedagogy of mobile learning has yet to become clearly established. The purpose of this report is:

1. To attempt to define mobile learning in terms of a flexible model that will enable developers, tutors and learners to identify learning practices and effective pedagogies incorporated in a particular 'learning space'.
2. To identify key elements that are unique to mobile learning, and provide initial check list indicating pedagogically useful learning activities that can be supported by the technologies.
3. To look at the current literature on the pedagogy of mobile learning and thereby assist designers in developing a user-centred approach that is driven by 'learner pull' rather than 'technological push' and to provide sign posts for tutoring, teaching and learning with mobile devices. In addition literature from other paradigms, such as e-learning and online communities, is included where the results are thought likely to contribute to the mobile pedagogical paradigm.
4. To begin compiling a database of guidelines which capture this expertise.

Document History

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Summary of Changes

Version	Section(s)	Synopsis of Change
0.1	All	Document writing
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1.0	All	Document writing
1.1	2.3, 3.2, 4, 6	Section 3.2 moved to 2.3 because it seems to introduce the following sections on theories of learning and case studies of mobile learning. New section 3.2 reviews some recent case studies of mobile learning. New guidelines on usability for learning technologies added – NB this needs further development and checking for overlap with WP2 outputs. Reference section needs updating to reflect new material. Table of contents needs updating to reflect changes.
1.1	2.1, 2.2, 2.3, 3.1.7, 3.1.8, 3.1.9, 3.3	<p>Revised section 2.1.</p> <p>Revised section 2.2 to reflect WMTE paper.</p> <p>Removed heading 2.3 – was not really a separate section.</p> <p>Renamed section 3.1.8 to 'informal learning'.</p> <p>Renamed section 3.1.9 to 'lifelong learning'.</p> <p>Revised sections 3.1.7 and 3.1.8 (adult learning, informal learning). Removed paragraphs that were not helping; rephrased other paragraphs.</p> <p>Started section 3.3 as a conclusive paragraph to section 3. Purpose: relate discussion in 3.1 to mobile learning</p>
1.2	All	Revisions to section 3 to include task model. New section 4 including case studies of mobile learning applications. Section 5 now contains guidelines.

Note

Reviews after final document delivery (Version 1.0) to the project may or may not result in modifications to the document. If modifications post review are necessary, then the first version of the resultant document is 1.1.

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1. Object of this Document

Mobile learning is an emergent paradigm in a state of intense development fuelled by the confluence of three technological streams, ambient computing power, ambient communication and development of intelligent user interfaces (Sharples, M. et al., 2002). A consequence of this rapid development is that the pedagogy of mobile learning has yet to become clearly established. The purpose of this report is:

1. To attempt to define mobile learning in terms of a flexible model that will enable developers, tutors and learners to identify learning practices and effective pedagogies incorporated in a particular 'learning space'.
2. To identify key elements that are unique to mobile learning, and provide initial check list indicating pedagogically useful learning activities that can be supported by the technologies.
3. To look at the current literature on the pedagogy of mobile learning and thereby assist designers in developing a user-centred approach that is driven by 'learner pull' rather than 'technological push' and to provide sign posts for tutoring, teaching and learning with mobile devices. In addition literature from other paradigms, such as e-learning and online communities, is included where the results are thought likely to contribute to the mobile pedagogical paradigm.
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2. Introduction

2.1 What is Mobile Learning?

Advances in computer technology, intelligent user interfaces, context modelling applications and recent developments in the field of wireless communications, including Wi-Fi, Bluetooth, multi-hop wireless LAN and the global wireless technologies such as GPS, GSM, GPRS, 3G and satellite systems have created a wide array of new possibilities for technology users. When these technologies started to be used in conjunction with mobile computers in learning contexts, a new learning paradigm, mobile learning, emerged.

Mobile learning, or m-learning, has been defined as learning that takes place via such wireless devices as mobile phones, personal digital assistants (PDAs), or laptop computers. Some example definitions encountered in the literature include:

"It's elearning through mobile computational devices: Palms, Windows CE machines, even your digital cell phone." (Quinn, 2000)

"The term mobile learning (m-learning) refers to the use of mobile and handheld IT devices, such as PDAs, mobile phones, laptops and tablet PCs, in teaching and learning." (Wood, C., 2003)

"According to software vendors, it's 'the point at which mobile computing and e-learning intersect to produce an anytime, anywhere learning experience.' Translation: It's the ability to enjoy an educational moment from a cell phone or personal digital assistant (PDA)" (Harris, 2001)

As is evident in the above definitions, it is the employment of mobile technologies that differentiates mobile learning from other forms of learning. So if learning happens through or with a mobile device away from a person's usual learning environment, then it is mobile learning.

However, when considering mobility from the learner's point of view rather than the technology's, it can be argued that mobile learning goes on everywhere – for example, pupils revising for exams on the bus to school, doctors updating their medical knowledge while on hospital rounds, language students improving their language skills while travelling abroad. All these instances of formal or informal learning do not necessarily involve the use of mobile technologies, but have been taking place while people are on the move and should therefore be classified as instances of mobile learning. Moreover, mobile technologies can be used at a person's usual learning environment. In fact, there has been a substantial amount of research in recent years looking at the employment of PDAs in classrooms. By virtue of the technology's mobility, such PDA-based classroom learning has also been considered as mobile learning.

A definition of mobile learning should therefore be widened (see also table 1 below):

Any sort of learning that happens when the learner is not at a fixed, predetermined location, or learning that happens when the learner takes advantage of the learning opportunities offered by mobile technologies.

Location \ Technology	Fixed	Mobile
At usual environment (home, office, classroom)	Non-mobile learning	Mobile learning
Away from usual environment	Mobile learning	Mobile learning

Table 1: When learning is mobile

2.2 What are guidelines?

We define guidelines to be:

Rules or principles for action, encapsulating some combination of practitioner-determined best practices in a domain and research-based insights into factors relevant in that domain.

On this definition, the relatively recent domain of mobile learning has little best practice to draw upon, in contrast to other domains involving media-based learning, most obviously text-based learning. Many sets of guidelines have been published on learning from text, as well as reviews of guidelines and critiques of articles about guidelines. Wright (Wright, 1985) is an example from that mature field, and is particularly critical of pragmatically-based, low-level (i.e. detailed) guidelines which, if applied without sensitivity to their inevitably numerous exceptions, can do more harm than good. Pragmatically-based guidelines tend to be quite brittle, in the sense that their range of applicability is narrow. Well-grounded (research-based) guidelines are more desirable, since their theoretical basis is explicit, and it is clearer how to extrapolate from them, to handle cases not covered by the original evidence-base. Wright (op. cit.) notes that if only pragmatically-based guidelines are available, then a

large number of guidelines will be needed to cover the range of real-life problems encountered in a given domain (in her case, text design).

Guidelines should never become detached from supporting evidence. The field of text design has many examples of breaking this rule, and mobile learning must avoid this trap. Thus, a typical guideline might be 'Use simple language (<author, date reference>)', without detailing those circumstances under which simple language might be misleading, or what constitutes simple language. More seriously, on following up the reference given one can find that the cited author has simply remarked 'Use simple language' in a general context with no supporting evidence. Well-grounded (research-based) guidelines are qualitatively different from guidelines that cite research for persuasive purposes.

Mobile learning is characterised by being delivered through technology and interfaces that are fast-changing. This is a further reason to avoid over-dependence on pragmatically-based guidelines, which tend to be very contextual: if the context keeps changing, the guidelines will soon lose their value. Another weakness of such guidelines is that they are often neither detailed enough for exact application or generalisable enough through reference to a theory. As a consequence, they can appear to offer contradictory advice. Furthermore, it is also often difficult to bear in mind the number of guidelines that can apply to a design task. For example, in the context of designing interactive interfaces, Alm (Alm, 2003) observes:

"It is expected of a designer to consider at least a dozen, usually considerably more, different principles or guidelines in designing an interface. Such principles are associated with, for example, elegance and simplicity; scale, contrast and proportions; perceptual organisation; module and program; semiotics in image and representation; interaction style; task, user and context characteristics, etc. There is simply no possibility for a human being to consciously keep track of the interconnections between so many variables or to calculate all the consequences and constraints which may emerge from putting all of the principles and guidelines together." (p. 110)

From a review of how guidelines are presented in other fields, we anticipate that mobile learning will evolve to a point where there are many checklists, and much borrowing between checklists, but few instances of systematic comparison between one checklist and another. Often, it is unclear what empirical evidence exists on the effect of adhering to the guideline on usability and learnability. Likewise, it is unclear why a particular guideline has been included or excluded. It is important that guidelines can be located within contexts, that they are verifiable and that the original sources for the guidelines are specified.

We are in the early stages of this work, and our aim is to have a database of guidelines that is being added to, and updated on a regular basis. But to avoid some of the problems already noted, we adopt the following principles:

Guidelines will be theory-informed "do and don'ts"

This in itself is somewhat problematic, given the current lack of evidence on effective teaching and learning with mobile technologies. We shall have to be careful that the guidelines are based either on a) theory and practice of learning with conventional tools that are relevant to MOBlearn b) evidence from desktop e-learning which we have good reason to believe will transfer to m-learning, or c) findings from those studies of m-learning that are available.

Guidelines will be validated

Each guideline is grounded in either theory or relevant empirical studies. Thus, our guidelines will provide references to the relevant sources, and a justification for their inclusion in our database. Other information, for example, known limitations a particular guideline, will also be included.

Guidelines will be segmented into audiences

A primary audience is direct users of mobile learning technologies, but there are other stakeholders, such as policy makers. This is a wide audience - ranging from teachers and students in higher education through health workers and other professionals, to families and tourists, as well as system designers and usability engineers etc.

Initially, guidelines will be produced from the literature on theories of learning, from mobile learning projects, and any existing guidelines we are able to identify (e.g. <http://www.w3.org/TR/NOTE-html40-mobile/>).

To keep all these issues in mind, we shall use a template as follows:

Description	What the guideline says
Audience	Who the intended audience is
Basis	Where the guideline derives from
Notes	Considerations that need to be borne in mind about this guideline
Justification / elaboration	Justification or validation of the guideline, and elaboration of contexts in which it could be used.

(courtesy G. Vavoula)

Through the use of the template, we hope that our guidelines will not simply reduce to context-free slogans.

We shall now turn our attention to the implementation of mobile learning. The remainder of this document is dedicated to the development of guidelines for (a) organisations and institutions who want to enable their employees or students to learn on the move, (b) teachers who want to support their students in their mobile learning efforts, and (c) learners who want to take advantage of mobile technologies to enhance their learning experiences and expand them beyond their usual fixed locations. We concentrate on two sources to devise the guidelines: first, we will review theories of learning in an attempt to identify the closeness of mobile learning to traditional notions of learning and to decide how practices of learning can be translated for mobile environments; and second, we will review cases of implementation of mobile learning to date in an attempt to identify elements of success and to abstract them into more general success criteria.

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3. Theories of Learning

3.1 A Brief History of Learning Theories and Their Influence on Learning Technologies

Although the current interest in 'e-learning' and 'm-learning' is a relatively recent phenomenon, especially fuelled by developments in the Internet since the WWW was created in 1992, in fact the history of learning with technology goes back much further. In his book on the emergence of computer-supported collaborative learning (CSCL), Tim Koschmann (Koschmann, T., 1996) suggests that a reasonable starting point is the development in 1960 of IBM's first courseware authoring system for CAL, Coursewriter I (Suppes & Macken, 1978). In the 40 years since there have obviously been huge changes in terms of technology and several just as significant changes in theories of effective learning and teaching. Koschmann suggests that there have been several 'paradigm shifts' occurring in roughly 10-year cycles. The Kuhnian term which Koschmann borrows implies radical shifts in ways of thinking about learning. However, this may be, on the one hand, an idealised view – much of the world of ICT in education still operates on primitive CAL models of the 1960s, even if the technology is new (e.g., the world wide web) – and some examples are, for all that, quite effective, in limited circumstances. It may also be a wrong way to think about science in this field – for example, the information processing approaches of the 1970s proved inadequate in capturing some features of learning, particularly issues of motivation and context/meaning. However, some of those theories have proved the most successful in developing tutoring systems, with a huge amount of empirical evidence for their effectiveness – this is particularly so of John Anderson's work with the ACT family of tutoring systems (see (Anderson & Schunn, 2000), for example). However, they are, arguably, suited to a particular type of learning – that involving the acquisition of procedural rules and skill in well-structured domains. The systems are less suitable for learning involving conceptual change or more 'informal learning'. Similarly, whilst the predominant paradigm in CSCL is based on socio-cultural theory of one form or another (situated learning, activity theory, distributed cognition, and so on), few would want to deny that learning also involves changes occurring at the level of the individual – there is still very much a place for talking about representational change in individual learners. In fact, activity theory was developed as a means of analysing how individual representations could be changed and mediated by social and cultural artefacts, tools and signs.

In the light of these remarks, what follows is a brief review of the major paradigms in terms of learning theory, not just as historiography, but as a synopsis of the strengths and weaknesses of particular approaches, how they have in the past been applied to learning technology, and how their may still be useful in thinking about mobile learning contexts, both in formal and informal settings.

3.1.1 Associationism & CAL

The early developments in learning technology during the 1960s were framed by the possibilities offered by the then technology and influenced by the predominant theories of learning of the time – associationism and behaviourism.

The technology of the time involved initially the use of teleprinters or lineprinters, and then the development of CRT monitors capable of displaying alphanumeric characters of 24 lines and 80 characters per line. The software technologies of the time involved the development and use of high level programming languages such as Fortran and Pascal. Later developments, particularly in high-level courseware tools (e.g., Coursewriter I), enabled non-programmers to develop courseware.

The learning theories of the time involved the application of Skinner's brand of behaviourism, which held that learning involved the simple association between a stimulus and a response, enabled by reinforcement. The method of operant conditioning was used to shape responses to particular stimuli. In terms of application to learning technology, the approach has been characterised as "drill-and-practice", and "present-test-feedback". Typically, the learner is given some information or problem, they are then asked to respond to some question or questions, and then they are given feedback on their response. It was very much a transmission model of teaching, with the tutor seen as driving the learning process.

In terms of its legacy today, CAL remains as a widely used approach, even if the technology is now the World Wide Web and more recently the PDA in some applications of mobile learning (e.g., http://www.advancework.com/Products/courseware/professional_english.htm)

Examples of commercially successful CAL products abound – one of the most successful is the suite of packages known as integrated learning systems (ILS). An example in the USA is NCS Learn's SuccessMaker (<http://www.ncslearn.com/successmaker/courseware.html>) and in the UK, RM Maths (<http://www.rm.com/primary/Products/Product.asp?cref=PD2381>). The success of such systems in terms of their appeal to teachers lies in their extensive and comprehensive coverage of the curriculum, the fact that the pace of learning is individualised and based on the learner's ability level, and, most importantly, the detailed information provided for teachers on the progress of individual students. However, despite this appeal, the ILS approach has not fared well in terms of empirical evaluation studies that assess learning gains (see for example, (Wood, D., Underwood, & Avis, 1999)) – largely because of variability due to context of use (i.e., variation in teachers, schools, classrooms). Some of these issues may well have been concerning the context in which the technology was introduced, rather than having to do with the technology or curriculum per se.

Applicability to MOBIlearn:

Even if the learning approach adopted within MOBIlearn is not based on the simplistic model of learning at the heart of CAL approaches, recent developments in learner content management and the profiling of individual progress against curriculum goals may prove useful as a starting point for at least the MBA content (see D2.1, section 4.2). Experiences from previous research in this field may therefore be of use to WP7.

3.1.2 Information Processing Theory & ITS

The 1970s saw the birth of the cognitive revolution and a focus on mental representations and the content of learning and problem solving, absent in the behaviourist paradigm. However, it is important to note that associationism never entirely disappeared from the scene. For example, John Anderson is for many an archetypal information processing theorist, but his ACT models are most certainly derived from associationist principles (see below).

With respect to general theories of learning under the information processing paradigm, two strands of research have been, arguably, foremost. The first derives from the work on the General Problem Solver (GPS) by Alan Newell and Herb Simon (Ernst & Newell, 1969; Newell & Simon, 1972). In this approach, learning is seen as a matter of problem solving and proceeds as a function of memory operations, control processes and rules. The methodology for testing the theory involved developing a computational model (GPS) and then comparing the results of the simulation with human behaviour in a given task.

GPS was intended to provide a core set of processes that could be used to solve a variety of different types of problems. The critical step in solving a problem with GPS is the definition of the problem space in terms of the goal to be achieved and the transformation rules. Using a means-end-analysis approach, GPS would divide the overall goal into sub-goals and attempt to solve each of those. Some of the basic solution rules include: (1) transform one object into another, (2) reduce the difference between two objects, and (3) apply an operator to an object. One of the key elements used by GPS to solve problems was an operator-difference table that specified what transformations were possible.

While GPS was intended to be a general problem-solver, it could only be applied to well-defined problems such as proving theorems in logic or geometry, word puzzles and chess. However, GPS was the basis for other theoretical work by Newell et al. such as SOAR. Newell (Newell, 1990) provides a summary of how this work evolved.

SOAR is an architecture for human cognition expressed in the form of a production system (Laird, Newell, & Rosenbloom, 1987). The principal element in SOAR is the idea of a problem space: all cognitive acts are some form of search task. Memory is unitary and procedural; there is no distinction between procedural and declarative memory. Chunking is the primary mechanism for learning and represents the conversion of problem-solving acts into long-term memory. The occasion for chunking is an impasse and its resolution in the problem solving process (i.e., satisfying production rules).

Newell (Newell, 1990) proposed SOAR as the basis for a unified theory of cognition and attempted to show how it explains a wide range of past results and phenomena. For example, he provided interpretations for response time data, verbal learning tasks, reasoning tasks, mental models and skill acquisition. In addition, versions of SOAR have been developed that perform as intelligent systems for configuring computer systems and formulating algorithms.

As a theory of learning, SOAR specifies (or confirms) a number of principles:

1. All learning arises from goal-directed activities; specific knowledge is acquired in order to satisfy goals (needs)
2. Learning occurs at a constant rate - the rate at which impasses occur while problem solving
3. Transfer occurs by identical elements and is highly specific. Transfer can be general if the productions are abstract.
4. Rehearsal helps learning provided it involves active processing (i.e., creation of chunks).

5. Chunking is the basis for the organization of memory.

The second major body of work on learning within the human information processing paradigm has been that of John Anderson and his ACT suite of theories/models, the latest of which is ACT-R (Anderson, 1993; Anderson & Lebiere, 1998). ACT theory has undergone three major revisions, from ACT, to ACT* to ACT-R. In what follows, the generic term ACT will be used.

ACT is a general theory of cognition developed by John Anderson and colleagues at Carnegie Mellon University that focuses on memory processes. It is an elaboration of the original ACT theory (Anderson, 1976) and builds upon HAM, a model of semantic memory proposed by (Anderson & Bower, 1973).

ACT distinguishes among three types of memory structures: declarative, procedural and working memory. Declarative memory takes the form of a semantic net linking propositions, images, and sequences by associations. Procedural memory (also long-term) represents information in the form of productions; each production has a set of conditions and actions based in declarative memory. The nodes of long-term memory all have some degree of activation and working memory is that part of long-term memory that is most highly activated.

According to ACT, all knowledge begins as declarative information; procedural knowledge is learned by making inferences from already existing factual knowledge. ACT supports three fundamental types of learning: generalization, in which productions become broader in their range of application, discrimination, in which productions become narrow in their range of application, and strengthening, in which some productions are applied more often. New productions are formed by the conjunction or disjunction of existing productions.

ACT can explain a wide variety of memory effects as well as account for higher order skills such as geometry proofs, programming and language learning (see (Anderson, 1983, 1990). ACT has been the basis for intelligent tutoring systems (Anderson, Boyle, Farrell, & Reiser, 1987).

One of the strengths of ACT is that it includes both propositional and procedural representation of knowledge as well as accounting for the use of goals and plans.

The main elements of ACT theory are:

- A distinction between procedural and declarative knowledge
- Goal-independent declarative knowledge is encoded directly from observation and/or instruction
- Learners use interpretative procedures (e.g., analogy, instruction-following) to solve problems by relating declarative knowledge to task goals
- Knowledge compilation converts this into production rules
- Therefore production rules can only be learned in the context of a problem solving activity
- Strengthening of associations and finally automaticity takes place with extensive practice

The implications for tutoring under the ACT framework are:

- Begin by presenting declarative instructions
- Then provide extensive guided practice to develop production rules
- NB: declarative knowledge is not necessarily lost

-
- It is a simple conception of skill acquisition:
 - Learning each production rule is simple
 - Complexity lies in the complexity of the domain (rule set)

The key elements in ACT tutors are:

- A production model of the underlying skill
- Correct solution paths are recognised by the tutor
- If students produce off-path actions instruction is tailored to get them back on path
- 'Buggy productions' are recognised by the tutor in order to provide feedback and help
- The student model uses a model-tracing approach based on AI models of plan-recognition
- Observed behaviour is related to the sequence of productions in the model

This approach is computationally difficult (combinatorial problem) so later ACT tutors relaxed the constraint that the student is always on-path and used disambiguation menus to select between alternative interpretations of bugs.

The general principles for tutoring with ACT are:

- Represent student competence as a production set
- Tutoring is driven by an accurate model of the domain (target skill)
- Communicate the goal structure underlying problem solving
- Solving a problem involves decomposition into goals & sub-goals
- Need to make this explicit to students
- Provide instruction in the problem solving context
- Learning is context-specific (cf. situated learning approach)
- Promote an abstract understanding of problem-solving knowledge
- Achieved through language of help and error messages
- Minimise working memory load
- Learning a new production requires all relevant information to be kept in working memory
- Implies only teaching a few new things at any time (contrast with cognitive apprenticeship or anchored instruction)
- Provide immediate feedback on errors (necessary for ACT* tutors which assumed that productions were built from all problem solving traces, but not necessary for ACT-R based tutors since they assume that productions are built from problem solving products - i.e., it doesn't matter whether all the steps occur in time or not)
- Adjust granularity of instruction with learning (NB: this was not a successful strategy even though predicted by the model)
- Facilitate successive approximations to the target skill
- Scaffolding and fading

There are many other theories of learning and teaching which were implicit and explicit in the burgeoning work on intelligent tutoring systems during its heyday in the 1970s and 1980s. To date the best review of these can be found in (Wenger, 1987).

In terms of today's learning technology, Anderson's ACT-based tutors remain the most successful of all intelligent tutoring systems, especially the algebra tutors, which have had widespread take-up in US schools.

Although the general approach here is a teacher-driven one, there are recent attempts to develop more learner-centred approaches similar in spirit to Anderson's, but where the learner drives the learning. In particular, the approach of 'scaffolding and fading', mentioned above, has been developed over a number of years by David and Heather Wood. The concept of scaffolding derives from the work of Jerome Bruner and is, in turn, derived from Vygotskian theory. Vygotsky proposed a very simple but powerful theory of learning and development (for him the terms were intertwined, though separate). It is best stated in his famous statement of the "zone of proximal development": the distance between a child's actual developmental level as determined by independent problem solving and the higher level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers.

This is not just a theory of assessment of development but also a theory of teaching. Bruner developed this into the notion of scaffolding and fading, and David Wood developed this further into his theory of contingent instruction (Wood, D., Bruner, & Ross, 1976; Wood, D. & Wood, 1996). Very simply, this states that effective tutoring involves giving a little more help when the learner needs it and withdrawing help as long as the learner is succeeding. The simplicity of this approach is traded-off however by the effort needed to analyse the domain into the right level of granularity to determine the appropriate "steps" for learning, and thereafter, the right level of instruction to determine appropriate levels of help – the twin aspects of domain and instructional contingency, respectively (a third aspect is that of temporal contingency – recognising when to intervene in terms of timing). The theory was developed and tested over a number of years with adults, children and teachers and the evidence for its effectiveness as a tutoring strategy is impressive (Wood, D. & Wood, 1996; Wood, D. J., Wood, & Middleton, 1978).

More recently David Wood has developed this theory further as a model of effective help-seeking in learners using computer systems to learn algebra (Wood, D. et al., 1999). Analysis of help-seeking behaviour is used to assess prior knowledge and to profile their learning strategies.

Applicability to MOBIlearn:

It is not the goal of the MOBIlearn project to develop mobile intelligent tutoring systems, but there are aspects of the approaches of SOAR, ACT and Wood's theory of contingent instruction / help-seeking which may well be useful in some contexts, particularly the MBA and health contexts. However, they are useful only once the learning goals and the knowledge domains have been well-articulated, in particular, for example, where a learner needs to learn a certain, well-specified procedure.

3.1.3 Constructivism – interactive learning environments

The 1980s saw the launch of the era of the personal computer, with the capability for presenting not just text, but graphics, video and sound, and input via many different devices such as mice, joysticks and so on, rather than just keyboards. These direct manipulation interfaces presented many more possibilities for interactive learning activities. This period also saw a sea-change in philosophies of teaching and learning, moving away from a teacher-centred to a learner-centred approach. The two paradigm shifts – to human-centred computing and learner-centred education –

were ripe for exploitation. The chief architect of this was Seymour Papert. Papert's approach, summed up famously in his seminal book *Mindstorms* (Papert, 1980), was inspired by, if not derived from, Piagetian theory. Aspects of Piaget's developmental theory which Papert took up included a view of the learner as actively constructing knowledge, rather than more passively responding to a tutorial action, and a serious attempt to take up Piaget's arguments about the importance of the physical activity of the learner, particularly his theory of sensori-motor intelligence and the internalisation of physical actions. Although Piaget's notion of sensori-motor intelligence was developed to account for early infant development and the construction of mental representations through action, Papert broadened this and applied it to the activities of much older children. Put very simply, his argument was that a child's knowledge of the relationship between its own physical actions (e.g., moving its own body through space) and the subsequent effects on perceptions of the world (e.g., change in visual perspective), provided a powerful occasion for reflecting upon the control of representation by action, and vice versa. With the right tools, Papert argued, the child could learn to gradually abstract principles from reflecting upon the relation between action and perception. The tool he developed for this progressive construction of rules was LOGO.

Although LOGO was developed as a tool for children, the principles (or 'powerful ideas') upon which Papert based his theory were held to be more generally applicable and spawned an industry of research and development in 'tools for thinking' for all ages of learners. This approach has led to a more general pedagogical theory of 'learning by doing'.

Papert's 'powerful ideas' were:

- Making thinking explicit
- Making reasoning and its consequences 'visible'
- Fostering effective problem solving & planning skills
- Learning to learn from errors (debugging skills)
- Developing reflective metacognitive skills

The general notion of constructionism (Papert's re-phrasing of constructivism) was that by actively trying to create something concrete (either physical or computational) to solve a problem the learner naturally had to make their thinking – that which was implicit – explicit. Furthermore, having to make something concrete enabled the learner to 'see' the results of their thinking, whether it worked, and whether it needed revision (debugging). Papert argued that such a process fostered the development of metacognitive skills in the domain.

The importance attached to articulation (explicitation) and reflection is common to most constructivist approaches. In addition, both Papert and others attached importance to the concept of the learner 'owning' the problem – in other words, the personal meaningful activity of constructing some artifact (again, either physical or computational) gave learning a much more powerful motivation than the teacher's owning and framing of problems.

Another aspect of Papert's theory, at least implicitly, was the importance of representation. Although the term 'external representation' was coined much later than Papert's *Mindstorms* (e.g. (Scaife & Rogers, 1996)) the fact that LOGO provided particular kinds of representational constraints (e.g., control structures) had, for Papert, important implications for learning higher level abstractions or concepts in the domain.

The significance of representations and representational change was key to the theory of Jerome Bruner, who in many ways served to synthesise elements of Piagetian and Vygotskian theory concerning conceptual change, for the former and mediation of conceptual change (by tools and symbol systems) for the latter, and apply them to education.

A major theme in the theoretical framework of Bruner is that learning is an active process in which learners construct new ideas or concepts based upon their current/past knowledge. The learner selects and transforms information, constructs hypotheses, and makes decisions, relying on a cognitive structure to do so. Cognitive structure (i.e., schema, mental models) provides meaning and organization to experiences and allows the individual to "go beyond the information given".

As far as instruction is concerned, the instructor should try and encourage students to discover principles by themselves. The instructor and student should engage in an active dialogue (i.e. Socratic learning). The task of the instructor is to translate information to be learned into a format appropriate to the learner's current state of understanding. The curriculum should be organized in a spiral manner so that the student continually builds upon what they have already learned.

(Bruner, 1966) stated that a theory of instruction should address four major aspects: (1) predisposition towards learning, (2) the ways in which a body of knowledge can be structured so that it can be most readily grasped by the learner, (3) the most effective sequences in which to present material, and (4) the nature and pacing of feedback. Effective methods for structuring knowledge should result in simplifying, generating new propositions, and increasing the manipulation of information.

In his more recent work, (Bruner, 1986, 1990, 1996) expanded his theoretical framework to encompass the social and cultural aspects of learning.

There are three major principles in his instructional approach:

1. Instruction must be concerned with the experiences and contexts that make the student willing and able to learn (readiness).
2. Instruction must be structured so that it can be easily grasped by the student (spiral organization).
3. Instruction should be designed to facilitate extrapolation and or fill in the gaps (going beyond the information given).

In addition, Bruner also described three major phases through which learner's representations develop:

Enactive – at first the learner's representations involve active manipulation of physical objects

Iconic – internal representations now come to stand for objects but in a one-to-one correspondence rather than at a higher level of abstraction (e.g., a variable name)

Symbolic – internal abstract representations which no longer have a one-to-one correspondence (e.g., the concept of a variable)

It is important to note that Bruner was not talking about stages of development in the sense of age-related changes, but of phases of change which representations

undergo in learning. It is also not a theory that is restricted to child development. In many respects it has similarities to Anderson's stages of skill acquisition, although for Bruner, representational change is a process of making the implicit explicit, whereas in Anderson's model the explicit (declarative) gradually becomes implicit (procedural) and compiled. Bruner's theory of representational change also bears similarities to Annette Karmiloff-Smith's theory of representational re-description (e.g. see (Karmiloff-Smith, 1992)).

Another influential theory of learning which emphasises representational change is cognitive flexibility theory (Spiro, Coulson, Feltovich, & Anderson, 1988). Cognitive flexibility theory focuses on the nature of learning in complex and ill-structured domains. (Spiro & Jehng, 1990) (p. 165) state: "By cognitive flexibility, we mean the ability to spontaneously restructure one's knowledge, in many ways, in adaptive response to radically changing situational demands...This is a function of both the way knowledge is represented (e.g., along multiple rather single conceptual dimensions) and the processes that operate on those mental representations (e.g., processes of schema assembly rather than intact schema retrieval)."

The theory is largely concerned with transfer of knowledge and skills beyond their initial learning situation. For this reason, emphasis is placed upon the presentation of information from multiple perspectives and use of many case studies that present diverse examples. The theory also asserts that effective learning is context-dependent, so instruction needs to be very specific. In addition, the theory stresses the importance of constructed knowledge; learners must be given an opportunity to develop their own representations of information in order to properly learn.

Cognitive flexibility theory is especially formulated to support the use of interactive technology. Its primary applications have been literary comprehension, history, biology and medicine. For example, (Jonassen, Ambruso, & Olesen, 1992) describe an application of cognitive flexibility theory to the design of a system for teaching transfusion medicine. The system provides a number of different clinical cases which students must diagnose and treat using various sources of information available (including advice from experts). The learning environment presents multiple perspectives on the content, is complex and ill-defined, and emphasizes the construction of knowledge by the learner.

The tutoring principles derivable from cognitive flexibility theory are:

1. Learning activities must provide multiple representations of content.
2. Instructional materials should avoid oversimplifying the content domain and support context-dependent knowledge.
3. Instruction should be case-based and emphasize knowledge construction, not transmission of information.
4. Knowledge sources should be highly interconnected rather than compartmentalized.

More recent work which emphasises the importance of multiple representations is that of Ainsworth (e.g. (Ainsworth, 1999; Ainsworth, Bibby, & Wood, 2002)). Ainsworth has developed a number of principles for designing multiple representations that describe how two or more representations can serve to constrain interpretation, elaborate knowledge, provide abstractions and so on. Similar relevant work has been done in research on learning by analogy (see (Gentner & Clement, 1988) on bridging analogies).

Although developed independently, this emphasis on the relationship between different external representations and their role in learning is also seen in Chandler and Sweller's cognitive load theory (Chandler & Sweller, 1991). Cognitive load theory is derived from an analysis of the nature of attention and working memory (and thus shares its roots with the theories of Anderson, Newell and Simon described earlier). A number of implications for the design and use of external representations in learning and teaching can be derived. These include, amongst others:

- The use of multiple representations (e.g., a diagram and some text or algebraic expression) can produce what (Cooper, 1998) refers to as a 'split-attention effect'. In other words attention has to be split between the two representations, leaving fewer resources available for integrating the material (until at least the information from multiple sources has been well learned). Learners can be supported in the process of integration if the external representations clearly indicate how the mappings are to be made between diagram and text (e.g., by containing integrating material within the diagram).
- The use of multi-modal representations can in many respects overcome the memory and attentional load resulting from multiple representations by, for example, capitalising on the fact that visuo-spatial (e.g., diagrams) and phonological (e.g., sound) information can be processed in parallel.

Whilst cognitive load theory and its implications for instructional design appear to have some basis in empirical evidence and are generally in line with what is known about working memory and attention, some care has to be taken in interpreting the instructional principles derived from this theory. For example, (Cooper, 1998) states that redundancy between representations should be avoided. However others (e.g., (Ainsworth et al., 2002) have shown that redundancy can be important in facilitating mappings between and abstractions from representations.

3.1.4 Case-based Learning

Case-based learning (Kolodner & Guzdiak, 2000) is one of a number of pedagogical approaches that use concrete situations, examples, problems or scenarios as a starting point for learning by analogy and abstraction via reflection. A similar approach can be seen in anchored instruction (see below). In many ways these approaches could come under the section on socio-cultural theory, since they represent some of the characteristics of the situated learning approach. However, they differ from situated learning in that the cases, examples or problems are not necessarily selected by learners; neither do they necessarily involve learners' own problems or situations. (The same is true of anchored instruction.) The main reason for including them under the section on constructivism is that they emphasise the active construction of knowledge and meaning through reflection on specific concrete situations – the same principles underlying Papert's approach, for example.

3.1.5 Problem-based Learning

Problem-based learning (Koschmann, T., 1996) is a similar approach. It is fairly widely used in medical education (Albanese & Mitchell, 1993), business administration (Merchant, 1995; Stinson & Milter, 1995) and nursing (Higgins, 1994), amongst others. As (Koschmann, T., Kelson, Feltovich, & Barrows, 1996) explain it, PBL starts from the observation that "existing educational systems are producing individuals who fail to develop a valid, robust knowledge base; who have difficulty reasoning and applying knowledge; and who lack the ability to reflect upon their performance and continue the process of learning" (Koschmann, T. et al., 1996).

They argue that some of the reasons for this are the complexity and interconnectedness of much of the conceptual material to be learned in both formal and informal (professional) learning settings. A reason for difficulties in applying knowledge, they argue, may stem both from the ill-structured nature of many domains and/or the ill-structured nature of problems in those domains. Finally, they argue that learners' inability to reflect effectively upon their own learning is a product of an educational system that fails to hand responsibility for learning and problem solving over to learners.

(Koschmann, T. et al., 1996) set out six principles of learning and effective instruction in domains and problems that are complex and ill-structured:

- Multiplicity – knowledge is complex, dynamic, context-sensitive and interactively related; instructions should promote multiple perspectives, representations and strategies.
- Activeness – learning is an active process, requiring mental construction on the part of the learner; instruction should foster cognitive initiative and effort after meaning.
- Accommodation and adaptation – learning is a process of accommodation and adaptation; instruction should stimulate ongoing appraisal, incorporation and/or modification of the learner's understanding.
- Authenticity – learning is sensitive to perspective, goals and context, that is, the learner's orientation, goals and experiences in the learning process determine the nature and usability of what is learned; instruction, therefore, should provide for engagement in the types of activities that are required and valued in the real world.
- Articulation – learning is enhanced by articulation, abstraction and commitment on the part of the learner; instruction should provide opportunities for learners to articulate their newly acquired knowledge.
- Termlessness – learning of rich material is termless; instruction should instil a sense of tentativeness with regard to knowing, a realisation that understanding of complex material is never 'completed', only enriched, and a life-long commitment to advancing one's knowledge.

Generally, PBL is an example of a collaborative, case-centred and learner-directed method of instruction. In its ideal implementation, a small group of students (five or six), together with a PBL tutor or coach, learn in the process of working through a collection of clinical teaching cases (in the case of medicine). The case involves an ill-structured problem, requiring students to develop the case from minimal presenting information. Throughout the process of building a case students generate learning issues – areas of knowledge in which members of the group feel they are not sufficiently prepared for understanding the problem they are studying. These, together with data, hypotheses and plans for future inquiry are collected together by the group in a structured manner, facilitated by shared information resources (e.g., physical or electronic whiteboard), to form the basis for problem formulation, problem solution, reflection and abstraction.

Applicability to MOBIlearn

There is considerable potential in adapting some of the PBL approach in MOBIlearn. It has been developed and refined especially for contexts involving life-long learning and professional development. It has had some proven success as a pedagogical strategy in domains of relevance to MOBIlearn, especially medicine/health and business administration.

3.1.6 Socio-cultural theory – CSCL

The early 1990s saw the emergence of an increasing dissatisfaction with the limits of classical information processing theory, particularly its emphasis on individual learning and cognition 'in-the-head' and a move towards emphasising the collaborative and social aspects of learning and the physical context in which learning occurs. There are many factors which led to the rise of socio-cultural approaches to learning, but certainly one was the consistent failure of teaching and learning approaches under this framework to show evidence of transfer of learning beyond the specific learning context. (For example, Papert's claims about the value of LOGO to foster general problem solving skills were shown over countless studies to lack validity – LOGO was good for teaching specific mathematical procedures but did not transfer to other contexts).

A number of new approaches to thinking about learning arose during the 1990s, most of which have their intellectual roots in Vygotsky's socio-cultural psychology. These include, amongst others, situated learning and distributed cognition. More specific instructional theories emerging from these approaches include anchored instruction, problem-based learning, case-based learning (although the latter two originally developed independently, and, ironically, case-based learning can be clearly derived from work on case-based reasoning developed during the heyday of intelligent tutoring systems and what were then called expert systems).

Situated learning theory is attributed mainly to the work of Jean Lave and Etienne Wenger (Lave & Wenger, 1991). Lave argues that learning as it normally occurs is a function of the activity, context and culture in which it occurs (i.e., it is situated). This contrasts with most classroom learning activities which involve knowledge which is abstract and out of context. Social interaction is a critical component of situated learning – learners become involved in or apprenticed to a "community of practice" which embodies certain beliefs and behaviours to be acquired. As the novice moves from the periphery of this community to its centre, they become more active and engaged within the culture and hence assume the role of expert. Furthermore, situated learning is usually unintentional rather than deliberate. These ideas are what Lave & Wenger (1991) call the process of "legitimate peripheral participation."

Other researchers have further developed the theory of situated learning. Brown, Collins & Duguid (1989) emphasize the idea of cognitive apprenticeship: "Cognitive apprenticeship supports learning in a domain by enabling students to acquire, develop and use cognitive tools in authentic domain activity. Learning, both outside and inside school, advances through collaborative social interaction and the social construction of knowledge." Brown et al. also emphasize the need for a new epistemology for learning -- one that emphasizes active perception over concepts and representation.

Two of the main principles of situated learning are that (1) knowledge needs to be presented in an authentic context, i.e., settings and applications that would normally involve that knowledge; (2) Learning requires social interaction and collaboration.

Anchored instruction is a major paradigm for technology-based learning that has been developed by the Cognition & Technology Group at Vanderbilt (CTGV) under the leadership of John Bransford. While many people have contributed to the theory and research of anchored instruction, Bransford is the principal spokesperson and hence the theory is attributed to him.

The initial focus of the work was on the development of interactive videodisc tools that encouraged students and teachers to pose and solve complex, realistic problems. The video materials serve as "anchors" (macro-contexts) for all subsequent learning and instruction. As explained by CTGV (1993, p52):

"...our goal was to create interesting, realistic contexts that encouraged the active construction of knowledge by learners. Our anchors were stories rather than lectures and were designed to be explored by students and teachers."

The main principles of anchored instruction are that (1) learning and teaching activities should be designed around an "anchor" which should be some sort of case-study or problem situation; (2) curriculum materials should allow active exploration by the learner.

Distributed cognition is an approach that has been developed mainly by Ed Hutchins and Jim Hollan (Hollan, Hutchins & Kirsh, 2000). It has also recently been applied by Scaife and Rogers (1996) to considering the design of external representations and their role in cognition and learning.

Distributed cognition is the study of:

- the representation of knowledge both inside the heads of individuals and in the world;
- the propagation of knowledge between different individuals and artifacts;
- the transformations which external structures undergo when operated on by individuals and artifacts.

"By studying cognitive phenomena in this fashion it is hoped that an understanding of how intelligence is manifested at the systems level, as opposed to the individual cognitive level, will be obtained." (Flor & Hutchins, 1991)

Distributed cognition is a challenge to existing ways of thinking about human tasks and activities. It is a way of bringing social and cultural issues into the realm of cognitive science, and a means of understanding how apparently complex activities can be achieved via relatively simple systems. The theory is concerned with structure, in terms of representations inside and 'outside' the head, and the transformations which these structures undergo. It is in many respects in line with traditional Cognitive Science (Newell & Simon, 1972), but the main difference is that access to external resources (other people and artifacts) is taken to be a crucial aspect of cognition. Thus the focus is on representations but both internal to an individual and those created and displayed in artifacts.

Hutchins talks about knowledge being distributed between individuals and artifacts, but an artifact can't know anything: it serves as a medium of knowledge for a human being. Thus a potential problem with distributed cognition is the notion that artifacts are somehow cognising entities. However, the notion of "mediation" is crucial to distributed cognition:

"A tool mediates activity that connects a person not only with the world of objects, but also with other people. This means that a person's activity assimilates the experience of humanity" (Leontiev, 1974)

In other words, it is the *interaction* of person and artifact that transforms representations. We take advantage of artifacts designed by others for various purposes, which distributes ideas/representations across time and space. Hutchins' famous example is that of a navigator using a map — the cartographer who created the map contributes, every time the navigator uses the map, to a remote collaboration in the navigator's task.

In his book "Cognition in the Wild" (Hutchins, 1995), Hutchins gives a detailed ethnography of the process of navigating a large naval vessel through a narrow harbour, as an illustration of a system of distributed cognition. Each of the roles that the ship's team plays, the tools and other artifacts they use, their means of communication, is analysed in terms of their contribution to and coordination of the goal of the overall system.

Hutchins argues that it's not just that (cultural) artifacts amplify cognition (i.e., people can do things with artifacts which they couldn't do without them, but that:

"each tool presents the task to the user as a different set of cognitive abilities or a different organisation of the same set of abilities" (Hutchins, 1990).

Thus the expertise or cognition is not in the artifacts, but in the interaction of the person with the artifact:

"These tools permit the people using them to do the tasks that need to be done while doing the things that people are good at: recognising patterns, modelling simple dynamics of the world, and manipulating objects in the environment." (Hutchins, 1990)

"...the computational power of the system composed of person and technology is not determined primarily by the information-processing capacity internal to the technological device, but by the way the technology exploits the cognitive resources of the task performer." (Hutchins, 1990).

Therefore, in this theory, the stress is on the "system goal" rather than just individual goals (e.g., the goal of the bridge of a ship is to negotiate the harbour exit successfully). Because the system is not relative to an individual but to a distributed collection of people and artifacts, we cannot understand how a system achieves its goal by understanding the properties of individual agents alone, no matter how detailed the knowledge of those properties might be

Hutchins describes the process of 'fixing' a bearing and notes that the fix cycle is a task that can be performed by an individual (and is done when the ship is not in restricted waters). He contrasts the individual performance of the task with that of the team. The problems with the individual performance are to do with controlling the sequence of actions required. This is done by means of a standard procedure. When the team performs the task, it isn't done by a procedure, but instead emerges from the interactions among the members of the team. Coordination among the team members arises because some of the conditions for each team member's actions are produced by the activities of the other members of the team (e.g., the bearing timer recorder can only listen to one bearing report at a time, so the two bearing takers must coordinate their reports). Thus, a central executive isn't needed to coordinate things — instead the arrangement of the functional units achieves this

Also, the sequence of actions to be performed is not represented explicitly anywhere in the system. If the participants know how to coordinate their activities with the technologies and people with whom they interact, the global structure of the task performance will emerge from local interactions of the members

The distribution of access to information is an important property of systems of distributed cognition. The properties of the larger system emerge from the interactions among the interpretations formed by the members of the team and the content of those interpretations are determined in part by the access to information. Hutchins talks about how the boundaries of individual tasks create interpsychological (shareability) constraints and how these constraints have important consequences both for error correction and learning. The process of making some parts of a joint task more visible to other participants permits group members to educate each other.

Hutchins also talks about how knowledge is distributed through practices. For example, in a study of cooperative error correction on navigation in ships (Seifert & Hutchins, 1992), virtually all navigational errors were collaboratively detected and corrected within the navigation team. He also talks about how functions are reproduced through learning or training practices which produce an overlap in the distribution of knowledge.

Recent research on mobile learning, particularly by Roschelle and Pea (CSCL2002) and Rogers et al (Ambient Wood project) can be seen as applications of the ideas of distributed cognition, even if they were not presented as such explicitly. For example, in their analysis of the potential of wireless networked mobile applications, Roschelle and Pea talk about how these technological artefacts (e.g., digital probes) augment or amplify existing physical spaces with information exchanges. Interestingly, they recall Papert's original ideas of microworlds:

“This potential power of augmentation may be understood by analogy to microworlds. Piaget, the intellectual spirit behind Papert's concepts of microworlds, theorized that facility with abstract representations, which are more advanced than concrete representations, arrives later developmentally. Developers of microworlds invert this theory with the design principle that transforming abstract ideas into a manipulable, exploratory concrete form makes the abstract more learnable. But microworlds only took the abstractions as far back as concretely realized sign systems. Participatory Simulations and Probeware reconnect abstractions with embodied, physical, spatial explorations that precede concrete sign systems. This may make the learners' experience of abstract concepts yet more visceral and meaningful”. (Roschelle & Pea, 2002).

Roschelle and Pea (op cit) also talk about how mobile learning applications can serve to integrate typological (categorical, abstract) and topological (physical, spatial) representations. They argue that the affordance of these devices to do so also applies to the input/interaction techniques of, for example, PDAs with stylus and touchscreen input, as well as physical probes: “The stylus used with handheld computers as a pointing and inscription device makes it especially easy to correlate user control with spatial representations”.

3.1.7 Adult learning

A number of theories for adult learning have been developed. Notions of the autonomous, self-directed learner who learns from experience of real world situations have been discussed largely in different theoretical frameworks, such as experiential learning. Experiential learning has been defined as

“...the process of creating and transforming experience into knowledge, skills, attitudes, values, emotions, beliefs and senses. It is the process through which individuals become themselves.” (Jarvis, Holford, & Griffin, 1998), pg. 46).

The process of experiential learning was described by Kolb and Fry (1975; cited in (Jarvis et al., 1998), pg. 48) as a circular one:

- the person encounters a concrete experience;
- next, the person reflects on that experience by analysing what just happened;
- this reflection then leads to the formulation of abstract concepts and generalisations - in other words, understanding;
- finally the person tests the implications of the newly formulated concepts on new situations and thus new opportunities for concrete experience arise, enabling the process to be re-initiated.

Jarvis worked further on the experiential learning cycle and illuminated further the processes involved, by identifying more activities in the cycle and depicting the different possible routes a person might take and the different effects a learning experience might have on the person: reflective (or critical) learning, non-reflective (or reproducing) learning, or non-learning at all ((Jarvis et al., 1998), pg. 45-55).

Experiential learning gives only a description of the processes of learning from experience. What is the mechanism, though, of construing our experiences? Transformation theory, developed by Mezirow, provides an explanation of such a mechanism. In this theory:

“...learning is understood as the process of using a prior interpretation to construe a new or revised interpretation of the meaning of one’s experience in order to guide future action” (Mezirow, 1996).

Mezirow describes learning as the construction of meaning in a two-step process: first, perceptions are filtered through our personal frame of reference which is shaped by both our predispositions (defined as meaning perspectives) and our existing knowledge (defined as meaning schemes); meaning schemes are then projected on to the filtered perceptions to produce personal meaning. Learning happens both when we reflect on our filtering mechanisms and transform our meaning perspectives, and when we create, elaborate and transform our meaning schemes (Mezirow, 1996).

(Schon, 1983) has explored the role of reflection in experiential learning further. His account of the “Reflective Practitioner” explains how professionals like doctors, lawyers, and engineers not only apply but also augment and extend their knowledge through reflection relevant to their action and practice. The most commonly encountered and discussed kind of reflection is the one that occurs once an action is completed. Schon calls this “reflection-on-action” and distinguishes it from “reflection-in-action”, which occurs while an action is still ongoing and is presenting the actor

with some surprising, unexpected results (Schon, 1983). By reflecting-in-action, the surprising results of a current situation will be added to his/her repertoire of unsurprising results in the future, which constitutes the process of augmenting the person's professional knowledge.

3.1.8 Informal learning

Formal education is extended into adulthood in the form of continuing/professional education when people enrol to some formal course in order to gain specific knowledge, skills, or formal qualifications. Mobile technologies are being tested as learning devices in such settings, offering a host of new opportunities to learners. However, learning goes beyond formal education. People continue to learn outside school and university when they are called to undertake a new role, or to adapt to other changing circumstances. For example, a career promotion, parenthood, or the starting of a new hobby or sport, all constitute circumstances that call for learning.

In fact, studies of informal learning show (Livingstone, 2001; Tough, 1971) that most of adults' learning happens outside formal education. (Tough, 1971) found that the average person in Canada carried out eight informal learning projects per year in the late 1960s, and spent an average of 500 hours per year on each project. In the late 1990s, similar figures apply: almost all Canadians (95%) are involved in informal learning, spending an average of 15 hours per week on informal learning (Livingstone, 2001). Similar studies in other parts of the world (US, UK, Finland) revealed similar results (see (Livingstone, 2001)). Given these figures, support for informal learning becomes at least equally important as support for formal learning.

Informal learning is a reality in people's lives – a reality they do not always recognise. In studies of informal learning, researchers often report that respondents' first reaction when asked about their informal learning projects is negative. It takes considerable prompting on the interviewer's side to help respondents recognise their informal learning as learning. The reason for this is the way learning is blended with everyday life. People do not usually think 'I need to learn about electric circuits', they think 'I want to have a dimmer on that lamp' and then learn about electric circuits in order to do the task. As (Tough, 1971) notes:

"...when the person's central concern is a task or decision, he will not be very interested in learning a complete body of subject matter. Instead, he will want just the knowledge and skill that will be useful to him in dealing with the particular responsibility of the moment" (p 51).

Thus, people learn in order to be able to carry out a specific task, or even to be able to carry it out in a better, more efficient or elegant way. Technology that is used to support learning should be blended with everyday life seamlessly, unobtrusively, and feel natural rather than disrupting to use. Mobile technologies with their reduced size and proclaimed unobtrusiveness and ease of use, bear the potential of supporting such on-the-job learning.

A distinction has been made between intentional and unintentional learning. Both (Tough, 1971) and (Livingstone, 2001) examined intentional informal learning. For (Tough, 1971), the focus was on 'highly intensive, significant and deliberate learning efforts'. For (Livingstone, 2001) the focus was on 'intentional rather than more diffuse forms of learning'. (Vavoula, G. N., 2004) asked participants to report all their learning experiences on a 4-day-long diary, irrespective of whether they were intentional or not. People reported experiences that related to one of their on-going learning projects in 56% of the cases, and general learning that often happened

accidentally, in 44% of the cases. Accidental or incidental learning is also acknowledged in other studies. (Tough, 1971) lists a number of forces and activities that are not deliberate and yet change the individual in the same way as deliberate learning: acquiring information through conversations, TV and newspapers; observing the world; unexpected experiences such as accidents and embarrassing situations; etc. These cases of learning might be hard to plan for, and therefore hard to provide for in terms of technological support. Again, the flexibility of mobile technologies makes them very strong candidates for supporting unexpected learning.

(Tough, 1971) found that people's informal learning relates to preparing for and keeping up with occupational demands, to self-improvement, to personal interests and leisure, or to adequately dealing with personal responsibilities. (Vavoula, G. N., 2004) likewise found that people's learning relates to work, leisure, self-improvement, or dealing with everyday life demands. The study described by (Livingstone, 2001) examined learning that relates to employment, household work, community volunteer work, and general interests.

(Vavoula, G. N., 2004) further examined the location and time of learning. She identifies four types of learning locations: home, the workplace, a place of leisure (like theatres, museums, sports clubs), and other public locations (on the bus, at a travel centre); and found that learning happens at any time of the day, on working days or weekends. No correlation between time, location and topic of learning is reported. The learning practice is thus mobile with regard to location, time, and also topic area. It makes sense to assume that technologies in support of learning should also be mobile in the same ways.

Learning is organised into a three-level hierarchical structure of learning activities, episodes, and projects (Tough, 1971; Vavoula, G. N., 2004). (Tough, 1971) defines a learning episode as a well-defined period of time that is held together by the similarity in intent, activity or place of the thoughts and actions that occur during it, and that is not interrupted much by other activities; it has a definite beginning and ending in time. A learning project is then defined as a series of clearly related episodes, usually spread over a period of time, adding up to at least seven hours. Learning activities include all of the person's experiences during an episode: what they do, think, feel, hear or see. (Vavoula, G. N., 2004) similarly defines learning activities as the distinct acts that the person carries out during learning: reading, discussing, listening, and making notes. Episodes are then defined as groups of learning activities, which are formed by virtue of their spatial, temporal, and thematic proximity. Learning projects are formed by grouping episodes together on the basis of their contingency in terms of purposes and outcomes: learning episodes that contribute to the achievement of a particular aim are likely to be grouped together under a single project. Learning activities and episodes may happen while the learner is on the move, away from their fixed learning environments. Learning projects can involve episodes that happen at different locations. Learning technologies should be supporting the learner in carrying out learning activities, experiencing learning episodes, and integrating them into learning projects. Similarly, mobile learning technologies should be supporting the carrying out of learning activities and episodes on the move. Research into mobile learning should have a focus on the identification of learning activities that are appropriate for mobile learners and on supporting those activities.

We should stress here that we do not suggest that exclusively mobile technologies be used for assisting the learning process. The argument is that, should the learner wish or need, they should be enabled to use either fixed or mobile technologies to aid their learning. Along this line, the importance of providing integrated, continuous service between fixed and mobile technologies should be highlighted, in a way that

allows the learner to transfer between environments and settings with minimum effort.

3.1.9 Lifelong learning

Many authors have been concerned with the different aspects of an educational system for lifelong learning. Some of them are writing about the pre-eminent goals that should be adapted by the educational system so that it can shape attitudes that favour lifelong learning (Bentley, 1998; Cropley, 1980; Fischer, 1998; Fischer & Scharff, 1998). Others are concerned with the more practical issues of how lifelong learning should be accredited and evaluated (Jones, 1999; Wilson, 1999). Some are discussing the methods and models of teaching that would be most appropriate for lifelong learning (Davies, 1998a; Fischer, 1998; Fischer & Scharff, 1998; Jarvis et al., 1998; Sharples, M., 1999). Others, finally, are concerned with the qualities and fundamental skills people should possess in order to become successful lifelong learners (Bentley, 1998; Cunliffe, 1999; Davies, 1998b). An assembling of their concerns and recommendations results in the following list of precepts for an educational reality oriented towards lifelong learning:

Educating to shape attitudes

- Education should be creating mindsets and habits that help people become empowered and willing to actively contribute to the design of their lives and communities.
- People should be motivated to engage in self-directed learning activities; the perception should be promoted that learning can be pleasant, personally meaningful, empowering and fun.
- Learning should be advertised as the way to respond to the constantly changing conditions of modern life and to promote the self-fulfilment of each individual.
- The idea should be supported that learning should last the whole life of each individual.

Accrediting learning

- The contribution to the individual's qualifications and abilities of all possible educational influences including formal, non-formal and informal, should be recognised.
- An effective and flexible lifelong learning qualification assessment system should be devised.

Teaching methods/models

- Education should move from the traditional face-to-face model on which most higher education institutions rely today to a model that relies more heavily on resource-based learning.
- The locality as well as the historically changing nature of knowledge should be acknowledged and the perception of learning as knowledge re-construction should be adapted.
- The teacher should act as a facilitator to the process of knowledge re-construction, as a coach or mentor who offers guidance to the self-directed learner, and should step out of the centre of the learning process and allow for a student-centred approach, where students have more control over the structuring, pace and content of their learning.

Skills and competencies that people need to develop

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- It should be recognised that the 'basic skills' are changing continuously and, thus, have lesser lifetimes than before; the main basic skill taught should now be that of adaptability and flexibility in the course of dealing with uncertainty, change and distribution of knowledge.
 - To the end of being flexible, lifelong learners should possess the following competencies:
 - Problem solving: ability to define and frame problems; use of analytical and conceptual thinking; search for information and application of techniques; making decisions.
 - Team work/collaborative skills: use of logical and rational argumentation to persuade others; sharing information to achieve goals; understanding the needs of others and building positive relationships.
 - Creativity and imagination skills: ability to provide new solutions and choices; ability to seek alternative solutions.
 - Communication skills: oral and written skills; ability to express oneself verbally; listening/counselling skills.
 - Self-awareness: taking responsibility for one's own learning; dealing with pressures and emotions; knowing one's own mental models; ability to adapt mental models to changed circumstances; setting realistic targets for oneself and others; being aware of changes, being inquisitive.
 - Managing skills: focusing on achieving key objectives; retrieving, analysing and synthesising data and information; using information technology; understanding the whole picture of the meaning of how things are related; ability to apply knowledge to practical tasks.
 - Learning skills: learning to learn; understanding one's own learning style; understanding learning processes.
 - Personal mastery: personal vision and values; strong sense of reality; understanding the value of competency; ability to move from competence to capability.

Educational institutions, organisations and teachers alike should take the responsibility for offering people the opportunities, and equipping them with the means as well as the skills and capabilities necessary for an effective involvement in lifelong learning. With regard to the 'means', they need to be flexible enough to adapt to the learner's needs and lifestyles – this is where mobile technologies can play an important role.

3.2 A theory of use for mobile learning

Most theories of pedagogy (as distinct from theories of learning) fail to capture the distinctiveness of mobile learning. This is because they are theories of teaching, predicated on the assumption that learning occurs in a classroom environment, mediated by a trained teacher. Thus (Watkins & Mortimore, 1999) reviewed three phases of research literature on pedagogy, with a focus on:

- different types of teachers,
- the contexts of teaching, and
- teaching and learning.

It is only the last that is of direct relevance to mobile learning. The second focus is important, but only with a shift in emphasis to the contexts of *learning*, rather than of teaching. Changing the focus from teaching to learning reveals a much broader horizon of activity.

Livingstone (2002) makes a useful distinction between internal and external initiation and structure of learning, shown in Figure 1.

	<i>External structure</i>	<i>Internal structure</i>
<i>External initiation</i>	Formal teaching	Resource-based learning
<i>Internal initiation</i>	Voluntary learning	Informal learning

Figure 1. Initiation and structure of learning

Traditional teaching is initiated by demands external to the learner, including the curriculum and examination system, and structured by a classroom teacher. Learning may be externally initiated, but structured by the learner, as in resource-based learning where learners are encouraged to manage their own study, but within the constraints of a curriculum. It may also be initiated by the learner, but externally structured, for example in professional or personal development, where the learner opts to study in an evening class or coaching session. Lastly, learning may be both initiated and structured by the learner. (Vavoula, G., 2004) has extended this categorisation to include the process and object of learning, and who has control over it. Her typology covers learning where the process is not prescribed and the object is unspecified, as in unintentional informal learning

Such informal learning activity has been described as the “hidden iceberg” of learning (Livingstone, 1999). Livingstone and colleagues questioned 1562 Canadian adults about their informal learning activities. The study revealed the breadth of informal learning. On average an adult spends 15 hours per week in informal learning, and this was generally consistent across age and social class (apart from the 18-24 age group, which spent on average 23 hours per week in informal learning). It contrasted with an average of about four hours per week of study in organised education courses.

Any theory of mobile learning must embrace the considerable learning that occurs outside the classroom and is personally initiated and structured. It must also account for the dynamics of learning. Increasingly, we work away from our normal working environment, at home, on trains, in airport lounges. Such work includes both formal and informal learning (Waycott, 2004). Physical mobility is one aspect of the dynamics of learning. Others include a continually changing social environment and access to resources, as we move in and out of communication with the Internet or other knowledge spaces, and as colleagues become available physically and online. We shall use the term ‘context’ to refer to the combined physical, information and social setting of learning, which for mobile learning in particular is in continual change.

Lastly, a relevant theory of learning must embrace contemporary accounts of the practices and ontogeny of learning. Learning is a constructive process, involving the active construction of knowledge. It is a both a social and a cognitive activity,

occurring within a rich milieu of physical and cultural tools, settings and social interactions. And it comprises not only a process of continual personal development and enrichment, but also the possibility of rapid and radical conceptual change.

Thus, theories of learning must be tested against the following criteria:

- Do they account for both formal and informal learning?
- Do they analyse the dynamic context of learning?
- Do they theorise learning as a constructive and social activity?

We argue that no single current theory of learning satisfies these criteria entirely, but that two are particularly appropriate and complementary: these are post-Vygotskian theories of mind, culture and activity as applied to learning; and theories of learning as conversation, developed by Pask and Laurillard. There is not the space here to discuss these theories in depth, but fortunately both are thoroughly and elegantly expounded, by Daniels (Daniels, 2001) on Vygotsky and pedagogy, and Laurillard (Laurillard, 2002) on learning as conversation. We discuss how these can contribute towards a task model for mobile learning.

3.2.1 Activity Theory and learning

Sociocultural theory, and its near relation, activity theory, derive from the work of Vygotsky (Vygotsky, 1978), who attempted to describe learning and development as a process mediated by tools. The tools include both physical artefacts and semiotic constructs including language and society. In activity theory, the focus is on the activity itself, including the processes by which social, cultural and historical factors shape human functioning (Daniels, 2001). Vygotsky's original writings have been examined and developed, initially by Russian academics including Leont'ev and in recent years by Western theorists including Cole, Wertsch and Engeström. Activity theory has been applied to the study of pedagogy, notably by Daniels (2001), and to the analysis and design of technology-mediated activity by Kuutti and others (Iacucci & Kuutti, 2002; Koschmann, K., Kuutti, & Hickman, 1998; Tuikka & Kuutti, 2000; Virkkunen & Kuutti, 2000).

Engeström proposes five principles of activity theory, that "stand as a manifesto of the current state of activity theory" (Daniels, 2001). In summary, they are as follows:

- Activity is the focus of analysis. Individual and group actions can only be understood in relation to an interwoven system of activity.
- Activity systems are multi-voiced. They include many perspectives, traditions and interests which are in continual interaction and change, giving rise to inevitable conflict that demands analysis and resolution.
- Activity systems are shaped over time. Current activity can only be fully understood by taking a historical perspective, to understand how it has been shaped and transformed by previous ideas and practices.
- Contradictions are sources of change and development. Activities are open systems, such that the introduction of new ideas and practices can cause conflict with existing ways of acting and describing. The process of resolving such tensions may lead to new understanding and thus to opportunities for change.
- Activity systems contain the possibility for expansive transformation. They go through extended periods of qualitative change, as the contradictions are internalised and resolved, leading to the emergence of new structure, tools and activity.

Sociocultural and activity theory provides a very different perspective on learning and development to previous theories of behaviour and mind. As a systems theory, it is suited to the analysis of collective behaviour, such as a classroom or workplace, but it has also been applied to the analysis of the individual learner. Vygotsky proposed the Zone of Proximal Development (ZPD) as a way to understand the contradictions between a learner's personal understanding and the external opportunities afforded by teachers and peers. By working within the region between what a learner can currently achieve unaided, and what is possible with outside support, a teacher can continually help the child to strive and develop.

Activity theory provides a framework to analyse the mediating role of new technology in activity of learning, and the inevitable contradictions that arise from introducing new technology into an environment such as a classroom or workplace.

In recent years, the original formulation by Vygotsky of the relations between a *subject*, such as a learner, an *object* ("objective" is a more accurate translation of the Russian), such as a course of study, and *tool*, such as a teacher or a text, has been expanded by Engeström (Engeström, 1987) into a generalised activity system that also includes *rules*, *community*, and *division of labour* (see Figure 2). This expansive activity model is a powerful analytic tool that has been applied to the understanding of practice in classrooms and workplaces.

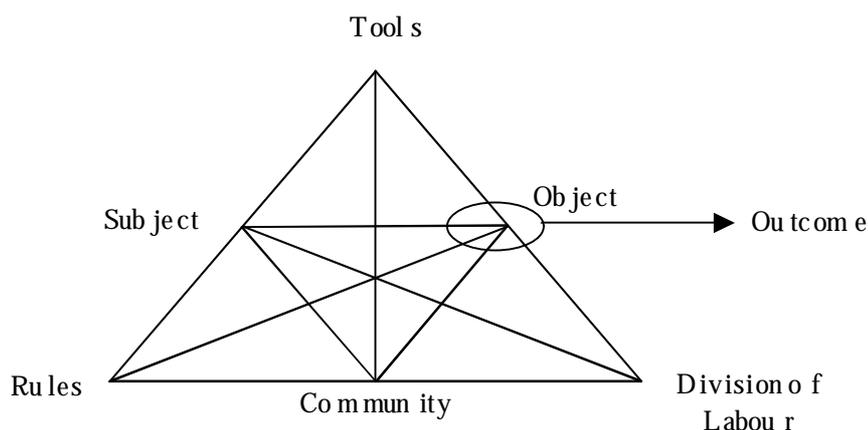


Figure 2. Engeström's (1987) extended activity system

The introduction and appropriation of technology is itself an activity system, and so can be analysed with the tools of activity theory. Waycott (2004) has applied Engeström's expansive model to the process of appropriating wireless technology for learning and knowledge working. Waycott derives a model of the Tool Integration Procedure which illustrates how new tools can resolve contradictions in the tool user's activity, but also how such tools can also introduce contradictions of their own.

However, the very benefits of the expanded activity model are also its limitations. By focusing on particular elements of the activity system, and on activity itself, the model inevitably de-emphasises other aspects that may be important to a full understanding of the processes of learning and of technology appropriation. Returning to Engeström's five principles, we would suggest that they fail to give sufficient emphasis to the following:

Learning is conversation. All learning is a process of internal conversation with oneself, to understand new phenomena and resolve internal contradictions, and external conversation with peers, with teachers, and nowadays with interactive artefacts such as computers. The role of conversation has been extensively analysed by Sociocultural theorists such as Bakhtin (Bakhtin, 1990) and more recently by Heath and Luff (Heath & Luff, 1992), but, as Daniels (2001) points out, although Engeström's work addresses the production of the outcome, he does not discuss the production and structure of the tool itself. There is, therefore, a resulting "...lack of theory of structure of discourse as a cultural artefact" (Daniels, 2001, p. 135).

Activities are contextual. All activity is performed in contexts, and these are historic constructs. Cole (Cole, 1996) makes an important distinction between context as "that which surrounds us" and context as "that which weaves together". Activity is not only occurring *in* a context, but it also creates context through continual interaction and change. Engeström certainly describes the characteristics of activity theory as 'contextual and oriented at understanding historically specific local practices, their objects, mediating artifacts, and social organization' (Engeström, 1996). The expansive activity theory sets activity within a social and cultural context, but does not sufficiently theorise about the nature of context – for example contexts as historic constructs. Engeström (Engeström, 1993) points out the danger of the relative under-theorising of context: 'Individual experience is described and analysed as if consisting of relatively discrete and situated actions while the system or objectively given context of which those actions are a part is either treated as an immutable given or barely described at all.'

An activity system can understand itself. Human activity systems are reflexive; they have the possibility to analyse themselves, and through self-examination to reveal contradiction and to deliberately explore future paths without actually following them. This ability to hypothesise and predict is an essential aspect of any system that learns through introspection and self-awareness. We haven't space for a detailed discussion of this issue, but note Giddens' (Giddens, 1984) comment:

'Human social activities, like some self-reproducing items in nature, are recursive. .. they are not brought into being by social actors but continually recreated by them via the means whereby they express themselves as actors. In and through their activities agents reproduce the conditions that make these activities possible.'

Thus, we suggest that sociocultural and activity theory, while providing a powerful analytic tool has its limitations. For the purposes of developing the Task Model, we have also explored an alternative theory of learning, Conversation Theory. It is a similarly extensive framework for analysing and designing the practices of learning and, like activity theory, it takes a systems perspective. It differs in that its prime focus is conversation, not activity.

3.2.2 A Theory of Learning as Conversation

An encompassing theory of learning based on conversation is Pask's Conversation Theory (Pask, 1976). It derives from cybernetics, the study of communication and control in natural and artificial systems, and its more recent extension to second order cybernetics, the study of the mechanisms by which a system can understand itself. The relevance to our Task Model is in its view of learning as a process of "coming to know", by which learners in cooperation with peers and teachers, construct an interpretation of their world. This 'radical constructivism' (von Glaserfeld,

1984) extends the notion of learning as a constructive process beyond the individual to describe how organisations, communities and cultures learn and develop. The general approach makes no distinction between people and interactive systems such as computers, with the great advantage that the theory can be applied equally to human teachers and learners, or to technology-based teaching or learning support systems.

Conversation Theory describes learning in terms of conversations between different systems of knowledge. In order to constitute a 'conversation', the learner must be able to formulate a description of himself and his actions, explore and extend that description and carry forward the understanding to a future activity. In order to learn, a person or system must be able to converse with itself about what it knows.

Learning can be even more effective when learners can converse with each other, by interrogating and sharing their descriptions of the world. We can say that the two people share an understanding if Person A can make sense of B's explanations of what B knows, and person B can make sense of A's explanation of what A knows. Thus, it is through mutual conversation that we come to a shared understanding of the world. Learning is a continual conversation: with the external world and its artefacts, with oneself, and also with other learners and teachers. The most successful learning comes when the learner is in control of the activity, able to test ideas by performing experiments, ask questions, collaborate with other people, seek out new knowledge, and plan new actions.

Laurillard (2002) relates Pask's theory to the realm of academic knowledge. Though primarily concerned with the application of educational technology to university-level teaching, the 'conversational framework' she puts forward can be applied to the full range of subject areas and topic types. The learning process includes the following aspects: apprehending structure, integrating parts, acting on descriptions, using feedback and reflecting on goal-action-feedback. As illustrated in Figure 3, technology may play multiple roles within the conversation space.



Figure 3. Role of technology in supporting conversational learning (adapted from Laurillard, 2002)

Technology may take the place of the teacher, as in drill and feedback. The difficulty here is that the computer can hold a limited dialogue at the level of actions: “look here”; “what’s this?”; “do that”, but is not able to reflect on its *own* activities or its *own* knowledge. Although some systems have been developed which attempt to model the student, and to tailor feedback to the perceived student needs, the computer is not engaging in developing a shared understanding. And because it cannot hold a conversation at the level of descriptions, it has no way of exploring students’ misconceptions or helping them to reach a shared understanding.

Technology can also demonstrate ideas or offer advice at the level of descriptions, as with the worldwide web or online help systems, but their practical advice, at the level of actions, is limited.

Alternatively, the technology may provide the environment in which conversational learning takes place. It can extend the range of activities and the reach of a discussion, into other worlds through games, and to other parts of this world by mobile phone or email. The technology provides a shared conversational learning space, which can be used not only for single learners but also for groups of learners.

Activity theory and conversation theory complement each other in their analytic power and focus. Whereas activity theory can provide an analysis of activity systems such as classrooms, workplaces and learning communities, conversation theory illuminates the process of coming to know, as a continual conversation with oneself, with other people and with interactive technology.

The theory of use, then, supports the general principle that communication and collaboration lies at the heart of an effective pedagogy for mobile learning environments.

3.3 A task model for mobile learning

Our discussion so far has led us now to the introduction of a task model for mobile learning. There are two spaces within which learners move – the mental space which consists of required, or preferred, functionalities, and the space of possible actual embodiments of those functionalities in the form of devices. There is a dialectic between these two spaces – as the learner sees a device that has a good match to their requirements, she may choose to appropriate that technology and in so doing, integrate it into her activities, which will be shaped by that device.

So we can see that there must be a dialectical relationship between the technological space, and the more abstract semiotic 'learn-space'. A learner enters the task of learning with an objective – to augment knowledge and skills they may or may not already possess, and the output from this activity is a new set of knowledge and skills. But several other important factors impinge on this rather simplified process, and in our view, these other factors share the same dialectical relationship between a technological (or physical) domain, and a more abstract human, social — or as we describe it semiotic — domain. Adapting Engeström's Expanded Activity System, this can be represented as an activity system as depicted in Figure 4.

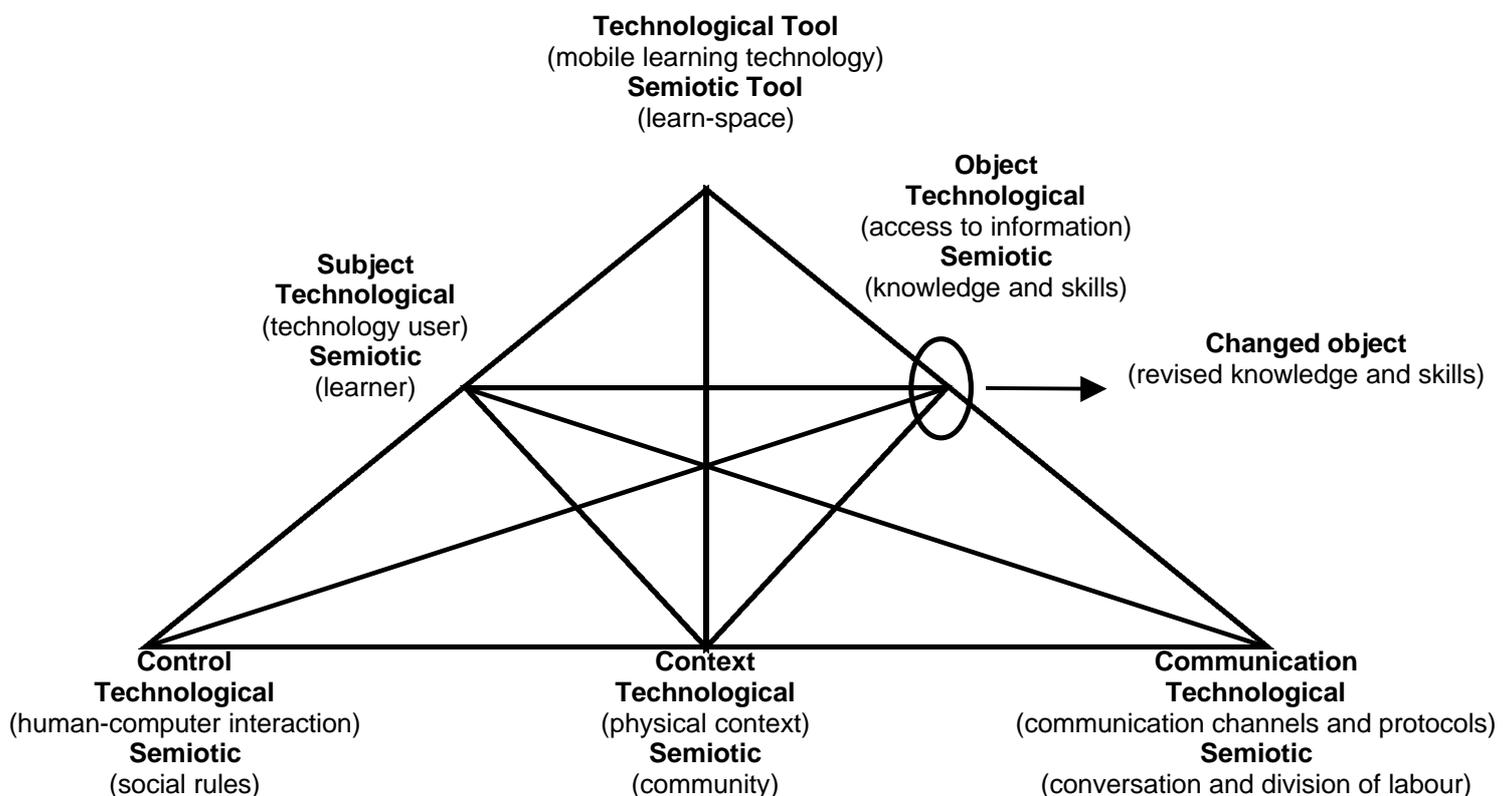


Figure 4. A task model for mobile learners

The influencing factors are identified as Control, Context and Communication, which are adaptations of Engeström's original 'Rules, Community and Division of Labour'. This adaptation enables the diagram to capture the two spaces (technological and semiotic) and illustrates points at which the dialectic works. We believe that this relationship has not been fully explored in studies of learners to date, but that it must be accounted for by any theory of technology augmented learning to understand how people adopt, adapt and use technology.

3.3.1 Control

We know that putting learners in control of their learning is one of the much vaunted benefits of technology enhanced learning (e.g. see Laurillard 2002). To a certain extent this is a technological benefit which derives from the way in which learning is delivered – if the learners can access materials as and when convenient, they can work through the materials at their own speed, revising and re-checking as they wish. This benefit can be lost, however, if the application is not useable – i.e. the user interfaces must be effective and fit for purpose, and expectations of the system's performance must be met.

However, technology use occurs within a social system of other users, and people can be easily influenced not only by what other users are actually doing, but also how they feel about it. Social rules govern what is acceptable (e.g. how to use e-mail, who is allowed to email whom, what kinds of document format should be used etc). The user's attitudes to technology can be influenced by what people around them think about it – i.e. are people resentful at having to use the technology, or are they keen and eager to try it out? And individuals can also express informal rules which capture the way they like to do things (e.g. never leaving documents on the desktop, but always filing them).

3.3.2 Context

The context in which learning takes place is clearly a significant factor, but the term has many connotations for different theorists. In the Task Model, we aim to pin down two important aspects of context – the physically embodied technological context, and the human, semiotic context (i.e. the community) within which learning takes place. We mention above the kinds of social rules that serve to control what users are likely to do. This node refers to how it is done. The community may consist of many related co-workers or co-learners who may or may not share the same current 'object' or objective, but may play a large part in what an individual may like to do.

3.3.3 Communication

The dialectical relationship between the technological and semiotic worlds is perhaps the easiest to see in the Communication node – if the system enables certain forms of communication, learners can adapt their communication behaviours accordingly, and sometimes find ways to subvert the technology (e.g. finding novel ways of connecting across networks). There have been many studies of the use of text-based communication as a substitute for live conversation (e.g. email, computer conferencing) – such communication is not the same as face to face discussion. But as has been demonstrated in the use of SMS text messaging with mobile phones, particularly by younger generations of users, if people see an opportunity offered by a device that they can exploit, then they will take it, regardless of the usability

aspects involved. The perhaps surprising popularity of texting, in turn, has encouraged mobile phone designers to develop tools to support it (e.g. predictive text), so the dialectic rolls on.

3.3.4 Summary

As pointed out earlier, the aim of the task model is to provide a coherent account of how the activities are performed, the people involved, their contexts, the tools and technologies they employ, the structure of the tasks and an account of their cognitive processes, management of knowledge, and social interactions. This is necessarily a complex exercise, which relies on drawing together the three strands of information from theory, field studies and requirements. These are all mutually supporting, and the task model aims to hold all these elements in tension so that attention does not focus on one area to the exclusion of the others. Nevertheless, our current articulation is not considered to be complete. We have yet to consider more fully how to take into account the temporal element, and for that we still need something like Conversation Theory as a systems account of the process of coming to know. For the time being, Figure 3 appropriately captures this aspect.

The task model is not itself prescriptive (e.g. what contexts are important for what types of learning) nor do the elements need to be explicitly modelled in the technology (e.g. whether the technology should contain a computational model of the learner, or of the context). But these lower level considerations can be explored through case studies, and further empirical work, to illuminate the model further. This is achieved in Deliverables 4.4 and 11.2.

3.3.5 Dialectical relations between Task Model and System Designs

The main purpose of the task model is not to create a hierarchical analysis of the task structure or to model of the mental states and operations of the principal actors (though it might include both of these), but to describe the interactions between the people and their tools and resources, and to analyse how people externalise their work, through representations such as notes and diagrams, the rules and conventions that influence the activity, and the terminology and patterns of discourse.

The task model provides the bridge to a cycle of iterative design that includes: specifying a design concept; generating a space of possible system designs; specifying the functional and non-functional aspects of the system; implementing and deploying the system. Testing is an integral part of the design process, with the results of the evaluation being fed forwards to provide an understanding of how to deploy and implement the system, and backwards to assist in fixing bugs and improving the design choices. Although this stage is based on a conventional process of interactive systems design (see (Newman & Lamming, 1995), it gives equal emphasis to cognitive and organisational factors as well as task and software specifications.

The result of the process is a new socio-technical system consisting of new technology and its associated documentation and proposed methods of use. When this is deployed, in the workplace, home, or other location it will not only produce bugs and limitations that need to be addressed, but also engender new patterns of work and social and organisational structures. These become contexts for further analysis and design.

In terms of the MOBIlearn project, the use of the model enables us to capture the myriad possible interactions that learners may engage in as they roam around their

respective environments, picking up and using devices as they go. Each of the three test scenarios can now be mapped onto the model, instantiating each of the nodes, and encapsulating the learners, their objectives, their context and their tasks.

The great advantage of this development is that the various scenarios can be instantiated according to the requirements, and this provides both a common structure, but also an individualised representation of each. From a design point of view, the MOBlearn system can be considered successful if it enables all of these activities using a multiplicity of devices in different contexts.

Thus, we are able to provide structure to an enormously complex learning situation, which, from a design point of view, would otherwise be very difficult to engage with. This view also helps emphasise to the design team that designing strictly to one set of requirements from one scenario is likely to exclude the needs of other learners at other times. The use of the task model, however, keeps the overall needs to the fore. The pedagogic experts can also maintain a view of the components of the system which bear upon the space of possible activities – i.e. it is of little use specifying that learners must have access to wireless networks if there are none in the environment.

We set out to describe our approach to understanding the domain of mobile learning with a theoretical position that was rich enough to capture the complexity of the learners' activities and the contexts in which they occur. We believe that the proposed task model is a first step in this direction. Refinements will occur as field studies are conducted, and as new user requirements emerge. However, this model provides us with a research agenda for our developing work – we need to explore each of the dialectic relationships identified, clarifying and elaborating the activities people engage in, and how those can be optimised to support mobile learners of the future.

4. Types of learning technology applications

There are many ways of categorising applications of learning technology. In this section we offer major categories that have been used in past overviews (e.g., (Alessi & Trollip, 2001)). These are orthogonal to the theories of learning that have been reviewed in previous sections, but it is in many cases possible to map particular pedagogical approaches onto particular types of application. For example, both behaviourist and information processing theories can be seen to underlie many traditional CAL or drill-and-practice tutorial programs. Likewise, constructivist approaches are well-suited to educational simulations. However, this mapping is not straightforward, hence the reason for considering types of application separately, particularly with respect to deriving more specific guidelines for adapting these approaches to a mobile learning context.

4.1 Tutorials

Tutorials are applications that are generally tutor-led rather than learner-led, and which follow an overall cycle of 'present-test-feedback'. These applications have a long history, stretching back to the behaviourist-inspired early CAL programs of the 1960s and 1970s (so-called "programmed learning"). However, they remain prevalent today in the form of interactive CD-ROMs and web-based learning applications. Despite the relative lack of learner control in such applications, they have proven utility in certain domains of skill acquisition, particularly in acquiring factual or procedural knowledge (rather than concept formation and conceptual change). For example, John Anderson's suite of ACT-based tutors has been

impressively successful in teaching algebra, programming and geometry at high-school and university level.

(Alessi & Trollip, 2001) recommend starting tutorials with explicit statements of behavioural objectives. (Arguably perhaps, this is advisable for other types of learning software as well, e.g., simulations and games.) Apart from providing 'advance organisers' (Ausubel, 1970) these may also serve to enhance motivation. A well known finding in the psychology of learning is that people learn best when new information is linked with prior knowledge. Therefore tutorials should also begin by setting a context which will elicit learners' prior knowledge or understanding. This need not be given in detail. One common form of setting context in terms of prior knowledge, particularly where the domain is novel to the learner, is to use analogy. Such an approach can be seen in the work of Bransford et al. and the CGTV group in their use of 'anchored instruction', mentioned earlier (see also Bransford et al., 2000, pp. 68-73).

Another technique for making tutorial information relevant to learners is to use pre-tests as diagnostics – either for the system to use (in the sense of creating a learner profile) or for the learner to use in deciding which sections to attend to and which to skip. (Alessi & Trollip, 2001) advise against making such pre-tests required – they should only be provided as options to the learner and should be kept short and relevant, including only those items that test either the necessary prerequisites or the final learning objectives of a tutorial (and exactly which purpose is being served should be made clear to the learner prior to taking the pre-test).

Tutorials typically involve testing learners about knowledge they have acquired at various points in the tutorial, either through asking questions or setting problems to solve. Such testing not only keeps the learner's attention focussed, they also provide practice for skills being acquired, they encourage deeper processing, they provide feedback to learners about how well the material is remembered and understood, and they provide information for the system to adapt subsequent instruction to learners' needs. Opinion is divided in the literature in general about how frequently to provide such testing. Anderson's theory and that of scaffolding or contingent tutoring (e.g., Wood) would seem to advocate a fairly frequent regime of questioning, so as to provide feedback closely coupled to the units of teaching and learning. On the other hand, frequent testing may be off-putting and disrupt the tutorial 'flow'. Clearly, some careful judgement is required in trading off the benefits for adaptation of learning material against the potential disjointedness of the interaction for the learner. (Alessi & Trollip, 2001) are advocates of a frequent cycle of 'present-test-feedback', and argue that otherwise tutorials become little more than multimedia books with final quizzes, and that the latter are less effective at facilitating learning and retention of information. In a classical Socratic dialogue, this cycle is reversed: learners are asked a question, then given feedback, followed by the presentation of tutorial material (Reigeluth, 1996).

The design of questions is an important consideration in effective tutorials. Several guidelines exist (and there is a large literature in psychology and education concerning questioning and question design). Some key recommendations derived from the review by (Alessi & Trollip, 2001) are provided in the later guidelines section of this report. Another key issue for tutorial design is how to handle responses – obviously also an important consideration in question design. Indeed, one of the key problems for CAL programs and intelligent tutoring systems in the past has been what is termed the 'credit assignment problem' – i.e., how to diagnose the source of a learner's misunderstanding from their response to a question. There are several possible judgements for a learner's response to a question. The response may be

correct, or the response may contain an expected error. Difficulties arise where the learner's response contains an unexpected error or is partially correct.

The provision of feedback is also a crucial consideration in the design of effective tutorial interactions. Feedback should normally be given immediately after a response, with positive reinforcement for correct responses and correction with a view to improving future responses in the case where the response is incorrect. (However, some researchers differ on whether feedback should be immediate or not – Anderson recommends it for procedural learning.) The nature of feedback is also an important consideration. Contingent feedback is tailored to the nature of the learner's error, as discussed previously (Wood & Wood, 1999), where gradually more specific feedback is given as the learner continues to make errors and gradually less specific feedback as the learner manages to succeed.

The sequencing or organization of material for tutorial presentation is a huge topic and one which covers many years of research in CAL and ITS. It is beyond the scope of this document to go into very much detail. Any recommendations about forms of sequencing (e.g., from specific to general or from concrete to abstract) will depend to some extent on the nature of the learning under consideration (e.g., concept acquisition or procedural skills), as well as the prior knowledge of learners.

4.2 Case studies of mobile learning

In his review of mobile learning, (Keegan, 2002), writing in November 2002, argued that the then WAP technology made it best suited to the following particular aspects of e-learning:

- Quick reminders and alerts
- Communication with peers and managers
- Multiple-choice quizzes with immediate feedback
- Daily tips
- Glossary information
- Browsing e-learning course material
- Searching for specific information within a topic
- Links to WAP sites
- Course registration

Keegan reports on the early experiences of Stanford Learning Lab on mobile learning ((Keegan, 2002), pp. 67-69). Guidelines emerging from these experiences include:

- Mobile learning is a highly fragmented experience – the degree of concentration and reflection normally required in intentional learning can be difficult because mobile users are usually in “situations that place intermittent, unpredictable, yet critically important demands on their attention.” Mobile learning applications therefore have to be designed with such attentional demands in mind.
- Poor network connections and environmental noise can cause imperfect voice recognition and therefore any menu navigation relying on voice input, or responses to questions in a learning context needs to be designed with this in mind. Keegan notes that repeated voice recognition misunderstandings impact on users in interesting ways: “on the surface, frustration and a reluctance to continue the lesson; on a perhaps less conscious level, a perception of the system as stupid or uncaring and therefore not an effective,

trustful way to learn.” Interestingly also, users seemed to be more forgiving when the system made an incorrect response to their attempts at answering a question (in the case in question, an attempt at speaking in Spanish) then when it made an incorrect response to a simple navigation command like ‘back’.

Generally the conclusion of the Stanford Learning Lab’s experience with using audio for mobile language learning is to keep it simple, focus on those parts of the learning process most suited to audio, most suited to small chunks of time, and most suited to a highly distractible learner. They recommend allowing learners to personalise their experience to match their own preferred interaction styles and situational needs.

Wireless mobile technologies such as handhelds and RFID tags have been used to:

- deliver/access web content whilst on the move (Hsi, 2003)
- support collaborative learning through e.g., participatory simulations (Colella, Borovoy, & Resnick, 1998; Danesh, Inkpen, Lau, Shu, & Booth, 2001)
- support scientific enquiry and data collection through probeware (Tinker, 1999; Tinker & Krajcik, 2001)
- support aggregation of data from individuals or small groups for large-group or whole class displays (Tatar, Roschelle, Vahey, & Penuel, 2003)
- multimedia tour guides for galleries and museums (Grinter et al., 2002; Proctor & Burton, 2003)
- augmented field trips (Chen, Y., Kao, Sheu, & Chiang, 2003; Grant, 1993; Reiger & Gay, 2001)

Handheld, pervasive and wireless technologies have also begun to be experimented with in the classroom to augment learning in a number of other innovative ways. Paper, walls and various manmade artefacts (e.g. bricks, cubes, mats) have been embedded with RF tags and other sensor technologies to create novel forms of collaborative learning experiences (e.g. (Colella et al., 1998; Danesh et al., 2001; Fraser et al., 2003)). Another benefit of embedding and coupling physical artefacts with digital information is the promotion of reasoning about the world through discovery and participation (e.g. (Soloway, Guzdial, & Hay, 1994; Tapscott, 1998; Underkoffler & Ishii, 1998)). When engaged with physical objects, students have been found to build up highly complex models of physical behaviour (Piper, Ratti, & Ishii, 2002).

(Roschelle & Pea, 2002) describes several affordances of wireless interactive devices for collaborative learning:

- augmenting physical space with digital information – e.g., probeware and participatory simulations connect abstract representations with embodied, physical, spatial explorations
- enabling mappings between topological and typological representations of two kinds, geospatial (e.g., mapping physical events onto abstract graphical representations as in data probes for motion mapping onto velocity graphs) and semiospatial (i.e., mapping between multiple abstract representations)
- aggregating information across individuals and groups, orchestrating or conducting group learning activities from individual contributions, and instrumenting the learning space by collecting and summarising contents of individual and group activities over time and space

In a more recent analysis Roschelle (Roschelle, 2003) points out how distributed wireless learning environments create affordances for participation in and mappings between three kinds of learning space: physical, informational and social. For example, even very simple wireless devices such as classroom response systems can change the learning environment by enabling individual students to post anonymous answers, speeding up response collation and representation of patterns of responses in a shared visualisation. Although most of the teaching is achieved through standard classroom social processes, research with these systems shows that the social dynamic of the learning environment is considerably different in many positive ways (Davis, 2003). In terms of more advanced technologies, physical interactions with networked handhelds and multimedia data capture facilities (probes, video, images, sound) can be linked to virtual collaboration spaces to change the topologies of social interaction in interesting ways. (Okada, Yamada, Tarumi, Yoshida, & Moriya, 2003) describe a mobile CVE where learners in a physical 'experimental forest' (a wired outdoor space similar to the wired wood described in this paper) use handhelds with GPS, video cameras and audio to collaborate with their virtual peers connected from classroom based laptops. The shared collaborative environment maps the augmented reality space onto the 'augmented virtuality' space. Similar approaches have been used to integrate online game players or museum visitors with 'on-the-street' participants (Brown et al., 2003; Flintham et al., 2003). Finally, simple everyday technology such as paper can be digitally enhanced with tags in order to assemble a coherent collaborative learning experience across a range of different technologies (Fraser et al., 2003).

All of these examples, from the simplest, in technology terms, to the most sophisticated, create their own particular learning spaces, interweaving physical, digital and social topologies. As (Roschelle, 2003) points out, there is a danger of over-complicating the technology aspects and over-simplifying the social aspects of such learning environments. From a research perspective it is important to understand how the intersections of these spaces mediate learning. For example, the small screens of PDAs limit the shareability of graphical information to at most probably two learners, but this may actually have benefits in providing a private shared space within which pairs of learners can come up with a joint decision, un-overlooked by a teacher or facilitator, before reporting some result. Audio representations, how and where they are employed and deployed, also have their own sets of tradeoffs (Hsi, 2003).

A recent review by Naismith et al. (Naismith, Lonsdale, Vavoula, & Sharples, 2005) classifies mobile technologies as follows:

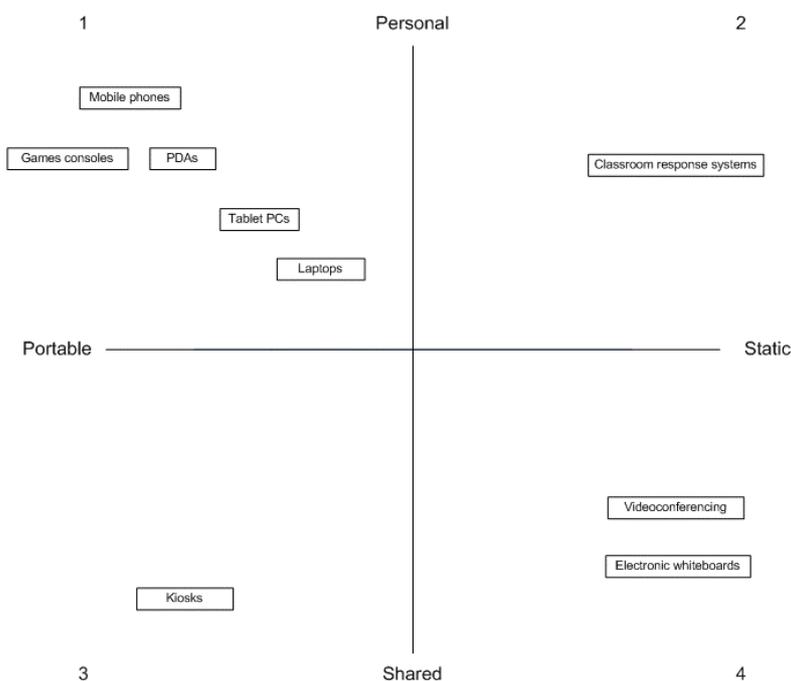


Figure 5. Classification of mobile technologies (Naismith et al., 2005)

Quadrant 1 shows devices that can be classified as both portable and personal. These kinds of devices are what people most commonly think of in relation to mobile technologies: mobile phones, PDAs, tablet PCs and laptops. It also includes handheld video game consoles, with (Rosas et al., 2003) and (Lee, Luchini, Michael, Norris, & Soloway, 2004) reporting on early evaluations of their educational use. Since these devices normally support a single user, they are generally perceived as being very personal. The networked nature of such devices affords communication and information sharing, meaning that while the devices themselves are personal, the information within them can be shared easily. These devices are portable because they are taken from place to place and hence they can be available in many different locations. These are personal portable technologies.

Some other technologies, less portable than mobile phones and PDAs, can still offer personal interactions with learning experiences. Classroom response systems, shown in quadrant 2, consist of individual student devices that are used to respond anonymously to multiple choice questions administered by a teacher on a central server. This technology is static in the sense that it can only be used in one location, but remains personal because of its small size and allocation to (typically) one single user. These are personal static technologies.

Being physically moved from one place to another is not the only way in which mobile technologies can be 'portable'. In quadrant 3, there are examples of technologies that can provide learning experiences to users on the move, but the devices themselves are not physically movable. Street kiosks, interactive museum displays and other kinds of installations offer pervasive access to information and learning experiences, but it is the learner who is portable, not the delivery technology. Such devices are typically seen as being less personal, and are likely to be shared between multiple users. Their larger size means they are also better suited to multiple user interactions. These are shared portable technologies.

For more shareable interactions, the devices themselves must become larger and hence less portable. Examples include interactive classroom whiteboards and

videoconferencing facilities, as shown in quadrant 4. These technologies have been included to show the complete space of possibilities engendered by our classification, but would generally not be classed as mobile technologies.

In their review, Naismith et al. present several examples of mobile learning applications which they organise according to which approaches to learning they seem to embody. These are reproduced in the following sections.

4.3 Behaviourist learning

The following case studies demonstrate the unique capabilities for anytime, anywhere learning that mobile devices can offer, even for the most straightforward 'drill and feedback' activities.

4.3.1 Skills Arena

Skills Arena (Lee et al., 2004) is a mathematics video game, implemented using the Nintendo Game Boy Advance system, that supplements traditional curricula and teaching methods. Drills in addition and subtraction are presented as a game with advanced scoring and record keeping, character creation and variable difficulty level. Students can select the name and physical traits of their character, which they use to compete in 'matches' against computer-generated opponents, ranked by difficulty. Difficulty is increased by increasing the speed at which the problems display on the screen.

Compared to traditional worksheets, Skills Arena was designed to offer faster feedback, the ability for each student to select the appropriate difficulty level and provide increased motivation.

An initial pilot study of Skills Arena was tested with two classes of second grade students (39 students in total) over 19 days. Students completed an average of 1296 problems each during this period, three times what would be expected with traditional worksheets. Skills Arena also had a significant impact on the classroom culture. Both teachers found the activity was easy to administer and control and one teacher even used Skills Arena as a reward for good behaviour. Students' active engagement with Skills Arena extended beyond the time allotted in the classroom, as they were inspired to create stories about both their experience and their characters.

Based on the results of the pilot study, additional classroom studies are planned to quantify whether using Skills Arena improves student's performance in addition and subtraction and to compare the impact with traditional drill activities such as worksheets.

4.3.2 BBC Bitesize

BBC Bitesize (2003; 2004) is an initiative to provide revision materials via mobile phones, using a downloadable Java game and SMS text messages. Given the limited amount of information that can be displayed on-screen and sent via text, the revision materials really are 'bite-sized'. This initiative has been running since 2003, and has proved to be very popular, especially with the growing number of phones with Java capabilities. The main impact of the BBC Bitesize programme comes from the size of its audience: over 650 000 GCSE students (as well as a number of curious adult learners).

Some implementation problems highlighted include:

- **Problem of localised content:** Some questions were not relevant to what a particular student had studied at school.
- **Lack of detailed feedback for learners:** The small screen size and memory capacity of the mobile phones meant that no detailed feedback about question responses could be given. This was highlighted as a key issue that learners wanted to see addressed.
- **Compatibility across devices:** Despite Java being promoted as a cross-platform environment, it was difficult to get the Java game running on all phones.
- **Costs:** The SMS service was originally free, but excessive demand forced BBC to charge for messages, leading to a significant decline in popularity.

4.3.3 Mobile phones for language learning

Two mobile language learning systems for mobile phones were implemented and tested in 2003 (Thornton & Houser, 2004). SMS was used as part of an English language course, where students were sent frequent vocabulary messages, also acting as reminders to revise. The lessons proved effective and were well received by the students. The system takes advantage of 'push' technologies and promotes regular study. Researchers did note, however, that students were postponing study until they would have the time to concentrate on the task.

Video delivered on mobile platforms (both mobile phone and PDA) was used to demonstrate the literal meaning and the special use of English idioms. Students found the video quality low, but the experience of using the videos was engaging.

A related commercial application is Pocket Eijiro¹, started in December 2002 as a English-Japanese, Japanese-English dictionary. The site now receives more than 100,000 hits per day and subscribers number in the hundred thousands.

4.3.4 Classroom response systems

Classroom response systems can be implemented as either specialist systems, comprising both the hardware and software such as Educue² or as software only systems that can be installed on mobile devices, such as Discourse³.

Dufresne et al (Dufresne, Gerace, Leonard, Mestre, & Wenk, 1996) report on the use of a classroom response system called 'Classtalk' with first year physics students at the University of Massachusetts, USA. Classtalk helped to clarify the students' conceptual understanding of the material by allowing them to articulate and elaborate

¹ <http://ojr.org/japan/wireless/1080854640.php>

² <http://www.educue.com>

³ <http://www.ets.org/discourse/about.html>

their ideas, reflect on both their own ideas and the ideas of others and evaluate the usefulness of having a number of different perspectives. The key benefit of a technology-supported system was that it afforded all the students the opportunity to present a viewpoint, whether or not they were comfortable presenting their ideas to the entire class. In addition to engaging students in active learning during the lectures, Classtalk also enhanced the overall communication within the classroom.

A more recent examples of a classroom response system implementation is the Northern Ireland eLearning 'Assessment for Learning' Project, which evaluated the Qwizdom Classroom Response System (*Qwizdom: Assessment for Learning in the Classroom*, 2003) with 114 students and 4 teachers at 3 schools.

4.4 Constructivist learning

Participatory simulations are games where learners play an active role in the simulation of a dynamic system or process. The key challenge is to make sure the technology is unobtrusive, so that it facilitates rather than hinders interactions between the learners.

4.4.1 The Virus Game

Collella (2000) describes a study where learners took part in a participatory simulation about the spread of a virus. Students were asked to simulate and observe the spread of a virus in a population by moving around the classroom meeting each other face to face. Each student wore a custom-built 'Thinking Tag' that showed whether or not they were infected by means of coloured lights. These tags were worn like badges, and would communicate with other tags whenever they were in range – in this way, meetings between learners were tracked by the tags, and the virus, which started in just one person, could spread to other people as they met and their tags communicated. The students were able to take part in a simulation without worrying about underlying rules of that simulation – their tags did all the thinking about rules for them, and the students could concentrate on the important questions: "Where did the disease start?" "How does it get spread?" "Who can catch it?"

Key findings include:

- Students readily engaged with the simulation, and found it to be a rewarding and stimulating experience.
- Students successfully collaborated to answer the relevant questions about the simulation.
- The technology facilitated, rather than hindered, normal interactions between the students – the devices augmented rather than replaced normal channels of communication, and hence provide unobtrusive technology support.
- Students were able to test out experimental hypotheses within the simulation after observing specific behaviours.

This simulation has been re-created for the PalmOS PDA, and is freely available from <http://education.mit.edu/pda/games.htm>.

4.4.2 Savannah

Savannah (Facer et al., in preparation) was a pilot study exploring the use of mobile devices to enable a rich, interactive learning experience where students got to play the role of, and hence learn about, lions.

The Savannah study builds on Colella's work by taking the simulation out of the classroom and situating it in an appropriate environment for the topic. Students in Savannah got to play the role of lions roaming in the wild in an area 100m x 50m. Each student carried a PDA that gave them a window into the game-world, displaying content and actions that were appropriate to their current location and what was going on in the rest of the game. Each PDA could be tracked using GPS, and allowed the students to 'see', 'hear', and 'smell' the virtual Savannah they were exploring. The PDA screen displayed visual content and indications of scents, and the children wore headphones for an auditory experience. The PDAs also displayed informative and instructional messages such as "You're hungry", "You're too hot", "Return to the den". They also had a den area, to which they could retreat for more reflective learning after being out in the field.

As in Colella's Virus game, the children were more than willing to suspend their disbelief, and reported that they felt they had really experienced what it was like to be a lion on the savannah. During the game, they often talked as if they were directly experiencing the simulation (i.e. "I'm hungry", "I'm too hot"). They had the opportunity to explore multiple aspects of lion behaviour, and reported that the game had increased their understanding.

Several findings are important to note:

- This study highlights the changing role of teachers and facilitators in the mobile learning experience. While in the den, children were encouraged to reflect on the success of their activities, but this was mainly teacher-led. When this reflection was led by the children themselves, they were highly engaged and motivated. When the teacher took control, the students became more passive and resistant to engagement. To be successful as a learning experience, the game needs to allow the students to control their own learning.
- Students occupied multiple roles, including the role of the lion itself, the role of the child action as a lion and the role of a child reflecting on his or her actions on the rules of the game in order to play better, and needed support in transitioning between these roles.
- Despite suspending their disbelief, children had high expectations of the system, and were disappointed that they didn't have access to more lion-like powers and expected a more rich and interactive experience than current technology can provide.

4.4.3 Environmental Detectives

The MIT Games-to-Teach project seeks to further explore the development of 'augmented reality educational gaming' (Klopfer and Squire in preparation). Augmented reality educational gaming builds on recent developments in handheld gaming, where context sensitive data and social interactions are used to supplement real world interactions.

The goal of the Environmental Detectives game was to teach secondary school and first year undergraduate students the skills of environmental inquiry, using a simulated environmental problem. Through collaborations with environmental engineers, a scenario was built around a spill of a toxin called Tri-Chloro-Ethelene, which is a ground water contaminant with moderate long-term health effects. The game included functionality to support the collection of both primary data (raw data on contamination levels acquired by sampling) and secondary data (interviews with 'virtual' experts).

The game was location-based, with the 'virtual' activities only being available in certain 'physical' locations, as detected by a GPS module attached to the Pocket PC. The interface was primarily map-based and students worked in pairs to navigate through the physical space to get to the virtual information. The goal of the game was to discover the source of the contamination and prepare a suitable remediation plan. The students were required to make trade-offs between soliciting interviews and drilling a well to sample ground water, mimicking the real challenges encountered in environmental investigations.

Five trials were conducted with game play lasting for between 90 minutes and 2 hours. Most groups were able to either locate the general area of the toxin or some basic remediation strategies, but few groups had fully coherent solutions. The secondary school students had particular difficulties with the subtlety of the investigation, indicating the need for additional scaffolding. Students responded very favourably to both the investigative experience and the experience of interacting with the technology.

The researchers have designed a toolkit for implementing customised scenarios, available through the Games-to-Teach website at:
<http://www.educationarcade.org/gtt/Handheld/Intro.htm>.

As Environmental Detectives is easy to learn, but difficult to fully master, it can support an iterative approach to teaching investigative skills, with students having the ability to try new strategies on new maps with different contaminants.

4.5 Situated learning

The portability of mobile technology allows the learning environment to be extended beyond the classroom into authentic and appropriate contexts of use. This is cited in (Juniu, 2002) as the most important benefit of the PDA for educators and students.

4.5.1 Ambient Wood

The Ambient Wood (Rogers et al., 2002) was part of the six-year, EPSRC-supported Equator project focusing on the integration of physical and digital interaction. The project built upon the benefits of incorporating physicality and tangibility into learning. Digital information was coupled with novel arrangements of electronically embedded physical objects, providing alternative forms of interactions that were more intuitive; but also allowing the juxtaposition of familiar actions with unfamiliar effects, thus encouraging children to reflect and think beyond the present of their actions to higher levels of abstraction.

The experience was designed for 10-12 year-olds. A series of activities were designed around the topic of habitats, focusing on the plants and animals in the different habitats of woodland and the relationships between them. An open clearing

and a wooded area were chosen as they have different distributions of organisms and interdependencies among them.

The learning experience had 3 stages:

Stage 1: Exploring and Discovering. Pairs of children equipped with a PDA explored the two habitats. In addition to what was observable around them, they could find out additional information about growing processes, feeding behaviours and organism dependencies. The PDA provided information either in response to probe readings on moisture and light at a specific location; or was triggered by the children's physical presence in a certain location in the habitat, using a combination of pinging and GPS location tracking. In the second case, the children first heard a relevant sound transmitted through wireless speakers hidden in the habitat, followed by a voice-over and the display of relevant images and information on the PDA. A special-purpose periscope was located in the wood, where children could go for additional information on 'hidden' processes, such as the behaviour of tiny insects.

Stage 2: Reflecting, Consolidating, and Hypothesising. After exploration, the children gathered in a den with a classroom-like setup, where they could use an interactive display to share their readings from the exploration and collaboratively reflect on their findings and experiences. An area was also available where the children could reconstruct the habitat they just encountered, using paper 'tokens' to represent different entities and a computer to provide appropriate feedback to their testing of their hypotheses on different combinations of the organisms.

Stage 3: Hypothesising and Experimenting. The children were sent back into the wood to observe experiments where either new organisms were introduced into the habitat, or changing moisture and light levels. The children tried to predict the outcomes, and they could use the periscope to get feedback and answers to their hypothesis in the form of animations.

The Ambient Wood was trialled with 16 11-year-olds, who worked in pairs. They would spend 30 minutes in stage 1, 15-20 minutes in stage 2, and 30 minutes in stage 3. During stage 1 the children made successful use of the probe and PDA, which proved an engaging, collaborative activity. It was easy for the children to understand the connection between the digital readings and the activity. The coupling of the exploration with the periscope provided an intuitive and explicit way of integrating different kinds of knowledge, where the periscope was providing information about hidden aspects of the environment. The triggering of information display on the PDA based on the children's bodily presence was less successful, as often the kids were too engrossed with their activities to notice sounds, voice-over and PDA display. Stage 2 enabled children to consolidate knowledge from their activity in the wood. The reconstruction activity based on information delivered on the PDA during exploration was not as successful, possibly because the coupling between the physical activity and the digital feedback was not close enough. Stage 3 was engaging and fun, and verified that children were able to make accurate hypothesis.

There are currently no reports on how the Ambient Wood experience compared with more traditional field trips.

4.5.2 Natural science learning in Taiwan

A butterfly-watching system was implemented and tested at an elementary school in Taiwan (Chen, Y.-S., Kao, Yu, & Sheu, 2004). The objective was for the students to

learn about natural sciences, and more specifically about the different kinds of butterflies in the region.

The project was based on the premises of independent learning with the assumption being that providing appropriate mobile tools would help students to become capable, self-reliant, self-motivated and independent. The system was implemented using a wireless ad-hoc networking environment, comprising of a (teacher's) notebook with a WiFi wireless LAN card that acted as the local server; and student PDAs with 802.11 LAN cards and small-sized CCD cameras.

A database of different butterfly species in Taiwan was used with a content-based image retrieval system, and an online nature journal system. The students visited a butterfly farm, where the networking environment was set up and they could use their PDA cameras to take photographs of the butterflies they observed. Using the photos, they could then query the database, which would send back possible matches. The students could then decide which match was best, and the database would verify based on image content similarity. The students then made the final decision, which they recorded on their journal together with their notes of the whole experience and post it to the teacher. The teacher in turn sent feedback to the students on their PDAs.

In the evaluations, a control group used a text-based butterfly guidebook and the experimental group used the system described above. Multiple choice tests on the key features of the butterfly species were administered before and after the trial. Six field trips were conducted in total with students encountering three new species and three old species at each trip. In four out of the six field trips, the experimental group was able to more correctly identify the key features than the control group.

4.5.3 HP Mobility project supports problem-based learning

Through the HP Mobility project at San Jose State University in California, USA, engineering and business students are using a problem-based learning approach to "collaborate in cross-functional, entrepreneurial teams to develop mobile computing applications for clients from business or non-profit organizations in our local community" (SJSU, 2004) The portability and connectivity of the mobile devices allows the students to move freely around the classroom and on and off campus, and allows them to rapidly change settings and configurations for team collaboration and coursework.

4.5.4 Multimedia tours at the Tate Modern

The Tate Modern museum in London (Proctor & Burton, 2003) launched an interactive audio-visual tour in July 2002. A wireless network implementation allowed visitors using iPAQ 3850 Pocket PCs to view video and still images, listen to expert commentary and reflect on their experience by answering questions or mixing a collection of sound clips to create their own soundtrack for an artwork. The wireless network was location-sensitive, which meant that they did not have to search out the information.

The pilot tour was taken by 852 visitors. Through evaluations and focus groups, visitors reported their enthusiasm for the tour and the services it provided. The average visitor spent about 55 minutes on the tour and over 70% reported that they had spent longer that they would have without the multimedia tour. Interestingly,

45% of the visitors found the system difficult to use, with older visitors reporting more technological difficulties than younger visitors.

Regarding the content itself, the most effective design approaches were those that incorporated audio particularly audio-visual coherence and interactive messages. Visitors did not respond well to long messages, particularly those that were primarily text-based. A second phase of trials ran until May 2004, with comprehensive results expected later in the year.

4.6 Collaborative learning

The most compelling examples of conversational learning occur when mobile technology is used to provide a shared conversation space. Effective learning occurs when people can converse with each other, by interrogating and sharing their descriptions of the world.

4.6.1 Chile embraces mobile computer supported collaborative learning (MCSCCL)

Researchers from the Universidad Católica de Chile are using handheld computers to encourage face-to-face collaborative learning for both primary and secondary education (Cortez et al., 2004; Zurita & Nussbaum, 2004; Zurita, Nussbaum, & Sharples, 2003).

A general architecture for MCSCCL that uses a mobile ad hoc network (MANET) has also been developed, that works over a wireless 802.11b network. The devices are set up to communicate only between each other (Peer-to-Peer or P2P) and have no access to either the Internet or local networks. The system can thus be used independent of any other hardware infrastructure.

The MCSCCL activities are distributed through the teacher's handheld (Pocket PCs in this case). The teacher first downloads the activity from the project website and then transmits the activity to the students using the MANET. After the teacher launches the activity, the students are automatically assigned to collaborative groups (typically 3-5 students per group). Upon completion of the activity, the teacher's Pocket PC collects the students work, which can then be downloaded to the school's PC for analysis.

During the MCSCCL activities, students are not allowed to progress to the next question until they answer the current question correctly. If the students submit different answers, the system prompts them to come to agreement before the answer can be submitted for marking. Students have various resources available to them during the activity, including textbooks, their own notes and the guidance of their teacher. It should be noted that rather than seeking to replace the teacher, the MCSCCL system attempts to support teachers by providing additional tools to support them in performing their duties.

A wide range of curriculum-based activities can be supported. Trials of the MCSCCL architecture have been conducted with both primary and secondary school students. At the secondary school level, MCSCCL was tested with 90 students for five weeks to teach physics (Cortez et al., 2004). At the primary level, 48 children performed a trial of MCSCCL for an activity on ordering numbers (Zurita et al., 2003). In each case, statistically significant results showed that the MCSCCL system assisted learning. Qualitative responses from students also indicated their enthusiasm to participate in

such activities. The secondary school physics experiment also had a broad social impact, as it was covered extensively by the Chilean media. The experiment was expanded to cover 1000 students during 2003.

4.7 Informal and lifelong learning

The personal nature of mobile devices makes them well-suited for learning applications outside of formal education.

4.7.1 m-Learning: reaching out to disengaged youth

m-Learning is a three year pan-European research and development programme, initiated in 2001, that uses mobile technology to teach basic literacy and numeracy skills (Attewell & Savill-Smith, 2003; Colley & Stead, 2003; Mitchell & Doherty, 2003; Traxler, 2003). It is targeted at young adults, aged 16 to 24, who are deemed to be 'at-risk' because they are either outside of formal education, in low-skilled employment or unemployed in the effort to give them better future prospects.

Initial research revealed widespread use of mobile phones across the partner countries (UK, Italy and Sweden), with even 80% of young, homeless people in the UK have access to a mobile phone. Mobile phones are used to send and receive text messages, communicate with friends and play simple computer games. The facts that mobile phones are very personal in nature, have a constant presence on the user and are highly important to teenage identity and friendships indicate that this technology holds high potential for individual and collaborative learning.

The infrastructure supporting this project includes a Learning Management System and a custom designed microportal interface, m-Portal, contributed by project partner Ultralab. This facilitates access to m-learning materials and services from a variety of mobile devices plus web and TV access. Technologies such as SMS, VoiceXML and picture messaging are implemented in a device-independent way via mobile phones, smart phones, handheld computers and networked PCs.

To ensure learning activities were relevant, custom content was created to reflect the new adult literacy standards for England and Wales. Some examples of content include an urban soap opera about two characters moving into a flat for the first time to help with language and provide advice about how to set up a home and a referee quiz, coinciding with the World Cup, to help with literacy.

VoiceXML is used extensively with mobile phones to deliver interactive stories or quizzes, while a simple database system receives registrations and sends instructions and reminders via SMS. Compaq iPAQ Pocket PCs are used to deliver both browser-based materials and Pocket PC-specific applications, including soap opera storylines, animations, quizzes and other interactive information.

Rather than measuring specific learning gains, m-Learning evaluations seek to measure changes in attitudes towards learning. In the Phase 1 trial, thirty four individuals took part in one week trials in four locations. Initial response from the participants was highly enthusiastic and believed to have helped the participants to develop a heightened interest in improving their education. Planning for Phase 2 trials is currently underway, which will concentrate on engaging a larger number of learners by with mobile phones. Twelve schemes are planned, encompassing a total of 200 learners.

4.7.2 Mobile devices for breast cancer care

The International Centre for Digital Content at Liverpool John Moores University, UK, designed a PDA application for personalised education of breast cancer patients (Wood, J., Keen, Basu, & Robertshaw, 2003). The project started in 2002 and involved the delivery of text, images and audio-visual material to the patients' PDAs via the Internet and the hospital's Intranet for the duration of their course of treatment. The information delivered is selected based on the individual patient's needs.

The user can query specific subject knowledge bases through a content specialist, to gain the information they need. This feature provides an answer to the problem of gathering information that is valid, reliable, specific, and personal. The user can also make personal notes linked to a diary application. This provides them with key points for discussion at hospital meetings, allowing the patient to annotate content and receive timely reminders from the diary.

Patient communication is enabled via SMS, allowing a patient community to share valuable insights and experiences.

No evaluation is currently available.

4.8 Learning and teaching support

The following examples demonstrate how mobile devices can be used to support learning-related activities for students, teachers and administrators.

4.8.1 Helping university students organise their own learning

Researchers at The University of Birmingham, UK developed and trialed a mobile learning organiser, based on a wirelessly-enabled Pocket PC, with Master's level students in 2002-2003 to determine the key tools necessary for such a learning device (Corlett, Sharples, Chan, & Bull, 2004; Holme & Sharples, 2002; Sharples, Mike, Chan, Rudman, & Bull, 2003).

The Student Learning Organiser is an integrated suite of software tools developed at the University of Birmingham. The 'Time Manager' tool included the ability to create, delete and view timetable events and deadlines, while the 'Course Manager' tool allowed students to wirelessly download course material packages, created by a complementary desktop tool, in Microsoft Reader format.

A one year trial was conducted with 17 MSc students in the Department of Electronic, Electrical and Computer Engineering. Each student was given a Compaq iPAQ 3760 Pocket PC 2002 handheld with 64MB of memory. As devices with integrated wireless capabilities were not available at the time, it was necessary to provide each student with an expansion sleeve and an 802.11b wireless network card. In addition to the Student Learning Organiser tools, the students had access to cut-down versions of Microsoft Word, Excel, Outlook, Internet Explorer and Media Player, email, instant messaging and two concept mapping tools. The students were encouraged to use the handhelds for their personal activities and to install additional software as they wished.

Results were collected via questionnaires, focus groups, video recordings and log books. No single tool stood out as a 'killer app' that significantly changed students' learning or personal organisation. Communication tools and timetabling features were consistently rated by the students to be the most useful, while the course content and concept mapping tools showed a trend of decreasing usefulness over time. Little additional software was installed, with the main reasons being that students saw the value of the handhelds being in the time management of email/messaging applications provided and that students were reluctant to invest time and money in personalising a device they had to return at the end of the year.

Significant usability issues were encountered. The students found that the handheld, expansion sleeve and wireless card too large and heavy for comfortable use, the 64MB memory size was not sufficient for their data storage requirements and that not recharging the handheld regularly could cause the entire memory of the device to be cleared (including any stored data). Apart from issues with the device itself, the main reported limitation was the loss of wireless connectivity outside the department.

Institutional support issues were also considerable. In addition to not having standardised provision of content and course dates by all lecturers, timetable information was not provided consistently. The handheld became another mode of communicating information between students and departments, making it more difficult to find relevant information quickly. The students also felt that further training sessions and integration with other departmental systems would be beneficial.

While this study was not designed to gather quantitative results into specific learning gains, it did show that the students thought the technology to be useful, even though it did not revolutionise or improve their learning significantly.

4.8.2 Support for teachers and administrators

A DfES sponsored handheld computing pilot was conducted in 2002-2003 with 150 teachers at 30 schools (Perry, 2003). The foci of the project were managing teachers' workloads and supporting teaching and learning. A number of features of mobile technologies met with universal approval. These included pragmatic features such as the small size and longer battery life than laptops. The storage capacity of PDAs was generally rated as highly favourable, along with ease of synchronising data with other devices. The relatively low price of PDAs was also cited.

As Headteachers and senior managers most closely match the mobile professional profile for which handhelds were designed, they were thus in the best position to experience immediate benefits. This group of users found the handhelds amazingly efficient at ensuring contact lists, diaries and meeting arrangements were up to date and were able to employ the facilities for rapid accrual and reporting of data to address truancy control problems. Classroom teachers were also able to benefit from the handhelds' data administration capabilities to help record attendance and marks and also help organise their lesson plans.

Though most users were able to benefit from the handhelds, some were reluctant to adopt the new ways of working afforded by the handhelds. In addition to dissatisfaction with the small screens, volatile storage (some types of PDA lose their stored data when their batteries run out of charge), and a concern about the ruggedness of the design, training issues were frequently cited as an inhibitor to progress.

4.8.3 SMS supports computing students at risk

Blended learning technologies were used to support HND computing students at the University of Wolverhampton during the 2002-2003 academic year (Riordan & Traxler, 2003; Traxler & Riordan, 2003).

The objectives of this project were to develop, deliver and evaluate blending learning opportunities that exploited SMS, WAP and VLE technologies. Initial research indicated that students used SMS text messaging promptly and effectively and that they would prefer to receive notice-board information such as room changes, appointments, feedback and exam tips via SMS rather than via email or notice boards. The target group was HND computing students, whose attendance and performance were considered to be at-risk due to poor literacy skills exhibited in their coursework.

SMS-based interventions took place over the second semester of the 2002-2003 academic year. Initial test messages gauged the effectiveness and the level of timeliness of student responses to SMS text messages. A second set of messages was sent as feedback following the marking and moderating of assessments. A final set of messages provided revision tips prior to the exam. The key features of the SMS interventions were timeliness and appropriateness, such that 'at-risk' learners could be directed as appropriate to either WAP-based support, VLE-based support or in-house support before their academic careers were significantly impacted.

Following the trial, final exam results for the group of students receiving SMS interventions were slightly higher than a non-SMS group taking the same module at the same time, though these results cannot be considered statistically significant.

During the trial, the students provided considerable positive informal feedback to the course leader and a questionnaire administered to the students revealed that the majority of students thought the experiment was worthwhile. In general, the SMS interventions themselves were found to be successful if they were short, personalised and focussed, but there was little take up of the VLE technology and the WAP-based technology was vetoed as being too expensive. Access to large-scale or systematic views was limited due to poor attendance at a proposed focus group and poor response to SMS queries inviting students to comment on aspects of the trial.

Free-text responses from the student questionnaires provided a positive basis for improving the service. A large scale pilot is planned for October 2004.

4.9 Summary

Mobile technology can effectively support a wide range of activities for learners of all ages. While implementation examples can be broadly categorised within the main theories and areas of learning relevant to mobile technology, the most successful adopt a blended approach to their use.

Mobile technologies provide for each student to have a personal interaction with the technology in an authentic and appropriate context of use. This does not mean, however that the use of mobile devices is a panacea. Significant technological and administrative challenges are encountered along with a more ill-defined challenge: how can the use of mobile technologies help today's educators to embrace a truly learner-centred approach to learning.

5. Lessons Learnt and Guidelines Deduced

The previous sections of this report discussed possible theoretical underpinnings of mobile learning. However, the availability of wireless and mobile technologies for the last few years has enabled mobile learning to be implemented in many instances. In 2002 two major conferences, one European (Mlearn 2002 - <http://www.eee.bham.ac.uk/mlearn/>) and one international (WMTE 2002 – <http://lttf.ieee.org/wmte2002/>), hosted presentations from academia and industry where success stories of mobile learning were reported. In 2001-2002 in the US, Palm Inc. introduced the PEP (Palm Education Pioneers) program where sets of handheld computers were awarded to over 175 K-12 classrooms throughout the United States. The program was administered and evaluated by SRI International (Vahey & Crawford, 2002). In the UK, BECTA has published a report on the use of handheld computers (PDAs) in schools (Perry, 2003). Some 150 teachers in 30 assorted schools in England have been given a selection of devices to evaluate. The first phase of the project focuses on senior management teams and how the devices support their work. The final phase involves a small number of schools being equipped with devices for the majority of staff and having access to class sets to support their teaching. Several other mobile learning projects of a smaller scale are underway in numerous parts of the world.

As mentioned earlier in the Introduction to this document, this section reviews such projects, seeking out lessons to be learned both for MOBIlearn and for the implementation of mobile learning in general. These issues will be presented below in the form of guidelines. We should emphasise at this point that, like the rest of this report, the present section should be viewed as dynamic: as more mobile learning projects are examined, more conclusions will be made and more guidelines will be produced.

5.1 Guidelines from Mobile Learning Case Studies and Other Literature

5.1.1 Guideline 1: Costs

Description	Research cost model for infrastructure, technology and services
Audience	Institutions
Basis	(Lehner, Nösekabel, & Lehmann, 2002; Perry, 2003; Smith, 2003; Soloway et al., 2000)
Justification / elaboration	<p>The cost of the technology, the infrastructure and the services and applications is an important issue that needs to be considered when implementing mobile learning. As a general advice, institutions should try to make use of what is already in place in order to keep costs down.</p> <p>With regard to the infrastructure and services, different options imply different cost models. For example, for a WLAN the initial cost lies with the institution as regards the network set up and with the students or the institution as regards the purchase of network cards – but there is little cost to operate thereafter; if WAP is used, the cost lies with the student to pay for access to learning content and services; if SMS is used to provide push-like information, the cost lies with the institution. To keep costs down, services should be designed that do not require special hardware.</p> <p>With regard to the technology, it is generally less costly to equip</p>

	<p>each student with his or her own handheld device than with a desktop or a laptop computer. If the devices are to be used universally on a course or module, the institution needs to provide them, or to require their purchase by the students. Alternatively, students could be 'renting' them from, or pay by instalments to, the institution. The institution can make use of the technology students already have, for example mobile phones (it is expected that almost all students will own a mobile phone by 2005 (Smith, 2003)). This does not hold for PDAs, as it is expected that many students will not own a PDA by 2005 (Smith, 2003), however, students of professions where PDAs are used in practice are likely to own one (e.g. medical students). When choosing a specific device, a decision has to be made between 'minimal functionality–low cost' models and 'higher price–greater range of functions' models.</p>
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5.1.2 Guideline 2: Usability – Systems design

Description	Observe the usability requirements of all those involved in the use of the system in any way (learners, teachers, content creators) to assure system acceptability
Audience	System designers / usability engineers
Basis	(Lehner & Nosekabel, 2002)
Notes	This guideline does not exhaust the issues of usability for small devices. Other literature such as can further inform usability guidelines, as well as the work done in WP2.
Justification / elaboration	<p>Attention should be drawn to the two sets of users that usability should account for: those who will be creating the mobile content, possibly on a desktop machine (this will in many instances be the teacher); and those who will be using the mobile applications and will access the mobile content to learn from, or to teach with (these will be the students and the teachers). Observing the requirements of all those involved in the use of the system will assure that the system is acceptable by all.</p> <p>In designing mobile applications and producing mobile content, one should consider the context where they will be used: the user/student should be able to receive personalised information that is valuable to her in the given context.</p>

5.1.3 Guideline 3: Learner control (general issues)

Description	General guidelines for learner control of content
Audience	System designers / usability engineers
Basis	(Alessi & Trollip, 2001), Ch. 3

Justification / elaboration	<p>Do not use timed pauses (i.e., progression after a fixed time interval).</p> <p>Always allow the learner to review (e.g., via backwards paging) where possible.</p> <p>Always allow the learner temporary termination of a learning session (e.g., via bookmarking).</p> <p>For general features such as navigation, help etc., always provide a consistent global interface.</p> <p>Whenever there are movies, audio, or animations, allow the learner to pause, continue, repeat, or skip them. If a movie is long (more than 10 or 20 seconds), also provide fast-forward or rewind controls.</p> <p>If learners have widely varying skills (e.g., reading age, language skills) provide alternatives to suit them.</p> <p>Provide more learner control for problem solving and higher order thinking skills and more program control for procedural learning and simpler skills.</p> <p>If mastery of content is critical (e.g., when sequences of errors are dangerous), use more program control.</p>
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5.1.4 Guideline 4: Input (screen buttons)

Description	General usability guidelines for the use of on-screen buttons in learning applications
Audience	System designers / usability engineers
Basis	(Alessi & Trollip, 2001), Ch. 3
Justification / elaboration	<p>Limit buttons to a small number of local controls. If a larger number of controls is necessary, use menus instead.</p> <p>Use cursor changes and rollovers to convey the function and meaning of buttons.</p> <p>Use clear feedback (e.g., dimming, colour change) to provide confirmation and status information.</p>

5.1.5 Guideline 5: Input (menus)

Description	General usability guidelines for the design of menus in learning applications
Audience	System designers / usability engineers
Basis	(Alessi & Trollip, 2001), Ch. 3

Justification / elaboration	<p>Use progressive menus to provide for reviewing but not skipping. Give advice and progress information on a menu depicting the sections of a program (tutorial, etc.)</p> <p>Keep the choices in a menu simple and few in number.</p> <p>For hierarchical menus, keep the number of levels few.</p> <p>Complex navigational structures may be better depicted using a map, block diagram or flowchart.</p> <p>Use menus for global controls.</p> <p>Include options to return to directions and exit the section or application.</p> <p>Do not use menus for very frequent actions (e.g., going to the next page)</p> <p>Use full screen or frame menus for applications with simple structures.</p> <p>Use pull-down or pop-up menus for applications with hierarchical or more complex structure.</p>
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5.1.6 Guideline 6: Input (hyperlinks)

Description	General usability guidelines for the design of hyperlinks in learning applications
Audience	System designers / usability engineers
Basis	(Alessi & Trollip, 2001)
Justification / elaboration	<p>Balance text hyperlinks with readability of text.</p> <p>Include an option to turn on/off hyperlinks for readability.</p> <p>Ensure that text highlighting techniques (e.g., for emphasis) or not confusable with hyperlinks.</p> <p>Use cursor change, rollovers and confirmation with hyperlinks, just as with buttons (see Guideline x).</p> <p>Make it clear where pictures and icons include hyperlinks (e.g., with cursor change, rollovers and confirmation).</p> <p>Avoid use of hyperlinks for global controls or frequent controls. Use menus and buttons instead, respectively.</p>

5.1.7 Guideline 7: Output (general)

Description	General usability guidelines for the design of output in learning applications
Audience	System designers / usability engineers
Basis	(Alessi & Trollip, 2001); Ch. 3
Justification / elaboration	<p>Put control options (e.g., for 'next page') at the bottom of the screen.</p> <p>Use a consistent prompt for responses (e.g., "enter your answer here")</p> <p>Start a new screen for a change of topic and label appropriately.</p> <p>Define functional areas for a program and use consistently (e.g., for navigation)</p> <p>Strive for simplicity in design and placement of control buttons (e.g., place 'next' button at bottom right of screen because this is where readers' eyes will be focussed when finishing reading content).</p>

5.1.8 Guideline 8: Output (text)

Description	General usability guidelines for the design of textual content in learning applications
Audience	System designers / usability engineers
Basis	(Alessi & Trollip, 2001), Ch 3
Justification / elaboration	<p>Ensure that text highlighting techniques (e.g., for emphasis) or not confusable with hyperlinks.</p> <p>The relative advantages of scrolling versus paging are complex, especially when designing across a range of applications and display devices. Generally, Alessi & Trollip recommend paging over scrolling.</p> <p>Signal topic change clearly with information about the new topic (e.g., it is better to have "Click here for next section: How glaciers are formed" than simply "Click here to continue")</p>

5.1.9 Guideline 9: Output (graphics and animation)

Description	General usability guidelines for the design of graphics and animations in learning applications
Audience	System designers / usability engineers
Basis	(Alessi & Trollip, 2001), Ch 3
Justification / elaboration	<p>Since pictures capture attention more than text, reserve graphics and animation for important and not irrelevant or incidental features. Select and design graphic information consistent with and integrated into the rest of the instructional message (e.g., software teaching about a refrigeration cycle is enhanced by a diagram oriented in a circle to emphasise the cyclic nature of that process). Avoid excessive detail or realism unless necessary (e.g., as in art history).</p> <p>Consider breaking up complex diagrams into a sequence of simpler ones (e.g., using overlays).</p> <p>Use animation when dynamic processes or change is important. In animations, allow the learner to pause, continue or repeat the animation (and for lengthy animations consider allowing control over the speed of change).</p> <p>Pictures should not disappear after a fixed number of seconds but remain on the display until the learner has entered some input. Present pictures and text together rather than on separate screens. Speech is often preferable to text when displayed in parallel with pictures, unless conditions are likely to make sound difficult to hear. Where speech is used with pictures allow learners the ability to pause, continue and repeat the speech.</p>

5.1.10 Guideline 10: Output (video)

Description	General usability guidelines for the use of video in learning applications
Audience	System designers / usability engineers
Basis	(Alessi & Trollip, 2001), Ch 3

Justification / elaboration	<p>Like graphics, video attracts attention and should be reserved for important information.</p> <p>As a general rule of thumb for multimedia learning presentations, video clips should be no longer than 20-30 seconds (although in some circumstances there will be exceptions – e.g., clips for second language learning should be shorter and clips showing news items may be longer).</p> <p>As for animations, it is important to provide learner controls for video (e.g., for pausing, playback, variable speed).</p> <p>Global controls (e.g., for program navigation) should still be accessible during video playback and not disabled.</p>
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5.1.11 Guideline 11: Output (sound)

Description	General usability guidelines for the use of sound (including speech) output in learning applications
Audience	System designers / usability engineers
Basis	(Alessi & Trollip, 2001), Ch 3
Justification / elaboration	<p>As for video, it is important to provide learner controls for sound (e.g., for pausing, playback). Scanning is not as useful or easy with sound as with video but being able to jump directly to sections during longer audio presentations can be useful.</p> <p>Global controls (e.g., for program navigation) should still be accessible during audio playback and not disabled.</p> <p>Use speech for getting attention and for directions – particularly where the learner is being asked to pay attention to environmental features (e.g., as in museum guides).</p> <p>Provide both speech and text as options.</p>

5.1.12 Guideline 12: Questioning (multiple choice)

Description	Guidelines for the design of multiple choice questions
Audience	System designers / usability engineers / teachers
Basis	(Alessi & Trollip, 2001), Ch 4
Justification / elaboration	<p>The incorrect alternatives (foils or distracters) of an MCQ must be plausible. The learner should not be able to determine the correct answer by eliminating obviously wrong ones.</p> <p>Three or four alternatives should usually be given. Although more questions decreases the likelihood of guessing, the more questions there are the more likely it will be hard to understand for the learner and hard to construct for the question designer.</p> <p>The correct answer should not be revealed by irrelevant features of the alternatives.</p> <p>The stem of the question should be a complete sentence.</p> <p>Provide only one correct alternative; avoid choices such as 'none of the above' or 'all of the above'.</p>

5.1.13 Guideline 13: Questioning (completion or cloze)

Description	Guidelines for the design of completion or cloze questions
Audience	System designers / usability engineers / teachers
Basis	(Alessi & Trollip, 2001), Ch 4

Justification / elaboration	<p>Only words of significance should be blanked out. Questions become artificially difficult if unimportant words are blanked out. A question should not contain too many blanks otherwise the entire meaning of a statement may be lost.</p> <p>Blanks should be at or near the end of a question. Blanks near the beginning of a question cause the learner to hold the location/context of the blank in memory, possibly reducing the comprehensibility of the question.</p>
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5.1.14 Guideline 14: Questioning (general)

Description	Guidelines for the design of questions
Audience	System designers / usability engineers / teachers
Basis	(Alessi & Trollip, 2001), Ch 4
Justification / elaboration	<p>Designers of questions should be clear about whether the question is testing recognition, recall or comprehension (understanding). Testing of comprehension can be done using paraphrase (i.e., provide synonyms rather than verbatim responses), application to new contexts, or categorical questions, requiring the learner to apply principles or rules to superordinate and subordinate classes. Negative words should be avoided in questions.</p> <p>Question interactions should be designed so that the question, response and feedback are displayed on the same screen, allowing the learner to reflect on the feedback.</p>

5.1.15 Guideline 15: Choice of technology

Description	Assess suitability of device / technology for learning task, and examine advantages and disadvantages of each technology before making a decision on which one to use
Audience	Institutions, teachers, system designers
Basis	(Alexander, 2003; Perry, 2003; Smith, 2003)

Justification / elaboration	<p>Attention should be paid to the choice of mobile technology. (Perry, 2003) reports that even the most sophisticated PDAs are not yet suitable for all of a school's mobile computing needs. Complex tasks like writing essays can be done on a PDA; however, they are easier and more efficient to perform on more powerful devices. The suitability of the technology for the learning task should therefore be examined.</p> <p>In deciding whether to use PDAs or not, one should consider the advantages and disadvantages that this technology offers. The following two lists provide a starting point for assessing the situation:</p> <p>Advantages</p> <p>They assist with discussions when used in conjunction with exercises/lectures – better than laptops, which are obtrusive in such settings</p> <p>Useful means for accessing reference materials, like dictionaries</p> <p>They can provide instant, in-class feedback to tutors on understanding, when on wireless connection</p> <p>They help motivate students, they have proved light up their enthusiasm and to inspire children, even influence their choice of career</p> <p>PDAs allow flexible class configuration (easy to form small work-groups) and students can find their own comfortable seating</p> <p>PDAs allow the blurring of the isolated class with the outside world with access to libraries and other information sources</p> <p>PDAs allow students to work anywhere on campus and still use their favourite tools (as long as there's network available)</p> <p>PDAs could offer great benefits to the disadvantaged: they are the cheapest way for a school to offer a computing device to be taken home and to access the Internet.</p> <p>PDAs are a good solution in classrooms where size is a problem</p> <p>Laptops are useful for a range of tasks and more usable than PDAs, but PDAs are better in contexts where laptops are not safe, e.g. PE, when laptop safety is not high during lesson, etc.</p> <p>Disadvantages</p> <p>Loss of data and applications on battery run-down è backup systems required</p> <p>Battery life decrease with add-on cards/wireless communications enabled</p> <p>Stylus suitable only for short notes (generally short usage)</p> <p>Synchronising station necessary</p> <p>Need to consider students with visual or physical impairments, and potential difficulties</p>
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5.1.16 Guideline 16: Roles

Description	Assign / assume necessary roles for initiating and thereafter supporting mobile learning
Audience	Institutions, decision makers, staff, users, beneficiaries of mobile learning
Basis	(Lehner & Nosekabel, 2002; Perry, 2003; Vahey & Crawford, 2002)

Justification / elaboration	<p>A combination of teachers, technical experts and educational visionaries is necessary to ensure that opportunities are sought, spotted and developed, and that the resulting applications are appropriate and effective in the school's context. (Perry, 2003)</p> <p>Different roles within an institution are necessary for the implementation of mobile learning at different phases. For mobile learning to be adapted by institutions, two roles are helpful:</p> <p>a) A technical promoter: a person who can demonstrate the capabilities of the system to decision makers</p> <p>a) A promoter in power: a person(s) of influence who will support the technical promoter's views and will make sure those views will be heard by those in charge.</p> <p>The technical promoter and the promoter in power can be the same person. Students can also act as 'promoters in power'. Once mobile learning is in place, the following are necessary:</p> <p>a) Technical experts: includes personnel who will deal with technical problems such as equipment failures, as well as appointed person(s) who will receive bug reports and suggestions for improvements to the system</p>
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5.1.17 Guideline 17: Equipment management

Description	Develop procedures and strategies for the management of equipment when it is provided by the institution
Audience	Institutions / teachers
Basis	(Perry, 2003; Smith, 2003; Vahey & Crawford, 2002)

Justification / elaboration	<p>The in-class management of the equipment, in the case where the equipment is provided by the institution, is an issue that needs considering. A number of important tasks relate to this:</p> <p>Strategy for assigning equipment to students</p> <p>Possible options as reported by (Vahey & Crawford, 2002) are shared strategies or personal strategies. Under shared strategies we can find the 'shared set' strategy where a set of devices is available for the classroom to share at set times or for set activities; and the 'assigned classroom' strategy where each student uses one device for a set period of time or for set activities but then returns it to the class's 'pool' (students don't always use the same device). Under personal strategies we can find the 'personal use at school' strategy where each student has a personal device to use at any time but only at school, and the 'full personal use' strategy where each student has a personal device and can take it home. To choose between the different strategies teachers/institutions need to consider (a) the number of available devices; (b) the frequency and the kind of use students are expected to make (for example, to use as a personal organiser students need to have a personal device, whereas episodic instructional activities can work on shared devices); and (c) the benefits and drawbacks specific to the teacher's teaching style. The 'full personal' strategy has the advantage that students get to integrate the device into other parts of their lives. Personal strategies are easier for the teacher to track and they do not bear the overhead of the teacher being responsible to 'reset' the device and extract any data after each use. Tracking mechanisms are needed for shared devices to reduce loss and theft.</p> <p>When sharing equipment, important issues are privacy (the device should be secure enough for the user/student to trust for personal information), reliability (all users should be able to retrieve work whenever needed), and access (a student returning to use a device should be able to find it configured and personalised as she left it).</p> <p>Restricting students off-task use</p> <p>The teacher can employ a number of strategies to monitor and restrict students' off-task use of the equipment. For example, they can monitor the students during the class, they can occasionally check the devices for games, or they can use software like "Invisible" or "Restrictor" that hides any applications that are not relevant to the learning task (the teacher would have to handle each device in this latter case to set up the controls). Another strategy is to establish policies and rules that make some space for off-task use of the devices. Finally, advance prevention can be employed, by sending letters to students and parents regarding penalties for off-task use. It should be noted, however, that off-task use reduces as the novelty of the device wears off.</p> <p>Synchronise handheld to desktop for set up and follow through of learning activities</p> <p>The teacher can take up the task of synchronising, using his or her own computer or multiple computers at school: the students 'beam' their work to the teacher, who then does the synching. This can be time consuming for the teacher, especially if large files like pictures are included. Alternatively, the teacher can schedule specific days/times for the students to do the synching, in various patterns: a small group of students sync the entire class' devices, one student in each group syncs the group's device, or students take turns in syncing on the classroom's computer during class. It is also possible that the teacher and the students can share the synchronisation task.</p>
	<p>Track, review and collect students' work</p>

5.1.18 Guideline 18: Support for teachers

Description	Provide training and (ongoing) technical support to the teachers to enable them to use mobile technologies to enhance current, and to enable new instructional activities
Audience	Institutions, educational authorities
Basis	(Alexander, 2003; Lehner <i>et al.</i> , 2002; Perry, 2003; Smith, 2003; Vahey & Crawford, 2002)
Justification / elaboration	<p>Mobile technologies can be used to enhance current instructional activities or to enable new activities. The mode of use depends a lot on the nature of the software application and on the teacher's intentions. To integrate mobile technologies in the classroom, teachers need to research available software and peripherals and find applications that are appropriate for their classes. They must allocate time to learn about available software and evaluate its appropriateness, they need to ensure resources to purchase it, and then take time to learn how to use it and understand how to integrate it into their classroom. In some cases teachers may need to develop new, or modify existing, applications and/or content (for example some applications may require localisation to be used in a given classroom).</p> <p>Support should be provided to the teacher for the aforementioned tasks. In particular, we found in the literature strong suggestions for increased teacher training: teachers comfortable with the technology can better employ it and integrate it in their classes. Continuous technical support is also necessary, as is dissemination of good practice. Issues that need to be addressed for technical support include where the support comes from, what is supported, how it is supported, how much of it is in the form of on-line help. For the dissemination of good practice, pools of information with examples of use and available software are an option.</p> <p>The main advice for teachers, though, would be that they need to familiarise themselves with the technology: "Adequate levels of competence will not be attained unless users push themselves through the familiarity threshold and providing them with support in doing so is vital"</p>

5.1.19 Guideline 19: Admin

Description	Consider the use of mobile technologies for student administration tasks
Audience	Institutions, teachers
Basis	(Lehner <i>et al.</i> , 2002; Perry, 2003)

Justification / elaboration	<p>A number of administrative tasks can be performed in a better way with the use of mobile technologies. Mobile devices have been reported to be used for the maintenance of accurate lists of classes, which, combined with rich information sets about the students, can help to draw attention to the individual student's needs. Truancy control is one immediate application: when a student is seen outside class, it can be instantly checked whether that student should be in a class at that moment or not.</p> <p>In the classroom, mobile devices can be used to mark students' work, to monitor quality and to provide immediate feedback: 'beaming' has proved a very useful feature in the process of assessing student work.</p> <p>With mobile technologies, teaching and classroom management/administration need no longer be two unconnected tasks: the teacher has instant, dynamic access to student data and can respond flexibly to patterns that are revealed minute-by-minute.</p>
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5.1.20 Guideline 20: Collaboration

Description	Consider the use of mobile technologies to support collaborative and group learning
Audience	Teachers
Basis	(Lehner <i>et al.</i> , 2002; Perry, 2003)
Justification / elaboration	<p>Student collaboration is reported to be enhanced by the use of PDAs. They can be very useful for supporting the scheduling of meetings and for providing facilities to locate fellow group members. During collaborative work, they enable students to co-operatively edit and exchange documents via beaming, they enable a student to display her work to a group, and they have even been used for writing collaborative poems. Impromptu sharing of data between teachers and/or students is enabled, as the user always carries the device with her.</p>

5.1.21 Guideline 21: Services / applications

Description	Discover and adopt suitable applications that match the needs of your specific classroom and map directly to your curriculum needs
Audience	Teachers
Basis	(Alexander, 2003; Lehner <i>et al.</i> , 2002; Perry, 2003; Soloway <i>et al.</i> , 2000; Vahey & Crawford, 2002)
Notes	<p>This guideline is connected to the work carried out in other workpackages, like WP3, WP6 and WP7. A 'pool' of references to available mobile applications could be developed and maintained, where teachers and learners in Europe could locate applications and services that match their needs.</p>

Justification / elaboration	<p>For PDAs to be fully integrated in schools, powerful applications are needed with direct mapping to curriculum needs. The use of PDAs can in principle enable educational 'swarming': teachers, students, libraries, experts from around the world can be brought together via (mobile) connectivity. Furthermore, PDAs are powerful devices when used as data stores in the hands of teachers (pre-stored or 'live' web material make it a huge, readily available encyclopaedia). The ability to 'download' material onto the device enables the teacher to bring to class material they have prepared at home, and the students to bring other material and resources they discovered on their home computers. Materials and files can easily be beamed from the teacher or from a student to the whole class, by beaming directly to the students in the front row who then pass it back. In addition to these learning-related services, further campus or school services can be available to students, providing information that support the students' everyday life (such as campus maps, library and cafeteria opening hours, etc.)</p> <p>With regard to learning-specific services and applications, teachers and students have reported using PDAs for:</p> <ul style="list-style-type: none"> Concept mapping (PicoMap) Worksheets (Palm Sheets) Simulations (Cooties, Critter Ville) Augmented reality via digitally tagged real world objects (34 North, 118 West) Word processing – with keyboard or stylus input Participation to discussion forums Data collection and analysis sensors and software (ImagiProbe) Web access/search and/or off-line web content (AvantGo, Fling-It) E-mail Beaming Reference material (dictionaries) Quizzes and assessments Synchronisation Direct, IR-enabled printing (PrintBoy) Voice recording Note-taking Access/explore on-line class material Store, annotate and share information
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5.1.22 Guideline 22: Security / privacy

Description	Ensure security and privacy for the end users
Audience	System designers
Basis	(Alexander, 2003; Lehner <i>et al.</i> , 2002)
Justification / elaboration	Security and privacy are important issues in the implementation of any network-based system or sharing-based system. In the case of mobile technologies in schools and institutions, one needs to consider (a) who has access to the educational materials (for example, implement password-enabled access), and (b) applying

	security levels to student information (for example lower to higher security levels for names, addresses and phone numbers, grades)
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5.2 Guidelines from Relations and Links with WP2, WP6 and WP9

The work in WP4 is closely related to that of other workpackages in MOBIlearn. In this instance, deliverables 2.1, 6.1 and 9.1 were consulted with the aim of retrieving further guidelines for learning, teaching and tutoring in a mobile environment. The respective guidelines are listed below, with cross-references to relevant guidelines presented in the preceding sections.

5.2.1 Guideline 23: User consent for collecting user data

Description	Require user consent when collecting data about the users; give users control over this data and store it securely
Cross-references	Guideline 22: Security / privacy
Audience	System designers, institutions, teachers
Basis	MOBIlearn Deliverable 6.1
Justification / elaboration	<p>Deliverable 6.1 proposes an architecture for a context aware subsystem for MOBIlearn. Such a system needs to be collecting and using contextual data and information and therefore the following should be considered when implementing it:</p> <p>Informed user consent for the system to collect and use personal data</p> <p>Control: users have control over the collected data</p> <p>Security: gathered data is stored securely, preventing misuse from third parties</p>

5.2.2 Guideline 24: Adapting mobile technologies

Description	Explore the potential of mobile technologies in supporting old, and enabling new activities
Cross-references	Guideline 6. Support for teachers
Audience	Institutions, teachers
Basis	MOBIlearn Deliverable 2.1
Justification / elaboration	<p>Ensure that mobile technologies are used appropriately to exploit their potential and to support activities that might not be possible without them</p> <p>Observe the introduction of new tools (mobile systems) to see what new possibilities for action they offer and how they might change the performance of old activities. Adapt learning practice accordingly.</p> <p>Support learning before (orientation), during (exploration, sharing, explanations, context, background, analytical tools, suggestions for related experiences) and after (reflection) the learning activity</p>

5.2.3 Guideline 25: Selection of hardware in relation to CSCL

Description	Select hardware that fulfils the requirements for supporting CSCL activities
Cross-references	Guideline 27: Flexibility in technology use
Audience	Institutions, teachers, system designers
Basis	MOBIlearn Deliverable 9.1
Justification / elaboration	<p>Hardware features checklist:</p> <ul style="list-style-type: none"> Sufficient display (graphics rendering) Pointing device (point location on screen) Connectivity Microphone Video streams (video conferencing) <ul style="list-style-type: none"> Audio and video <p>Communication technologies and standards: to decide what to use and when, consider the following:</p> <p>WPAN (Wireless Personal Area Network), use within ten meters</p> <ul style="list-style-type: none"> Bluetooth, IrDA, HomeRF Support ad-hoc networks Streaming multimedia communication among mobile, wireless and fixed terminals Neighbour discovery issues Suitable for group communication for persons located within a range of a few tens of meters or less Allows high bit rate Free of charge, no supporting terrestrial infrastructure <p>WLAN, use within campus, more than 10 meters</p> <ul style="list-style-type: none"> IEEE 802.11a, IEEE 802.11b, HiperLAN/2 Operation mainly within campus environment Terrestrial network of access points supports connectivity High bit rate Can be provided free of charge or billed according to business and service model <p>WWAN, use on the go</p> <ul style="list-style-type: none"> GSM, GPRS, UTMS Allow participation to collaborative work session in lack of other connectivity Voice, SMS, MMS, GPRS (data) communication anywhere

	<p>Limited bandwidth --> hard to support all types of real time communications and content Usage of network is charged</p> <p>Consider what types of collaboration services are needed: Conversational service: bi-directional, real time, end to end information transfer Interactive service: bi-directional, can be conversational, messaging or retrieval Streaming service: one way, multimedia feeds to live audience for immediate consumption Background service: destination is not expecting data at a certain time</p> <p>Consider what applications for collaboration are needed: voice conversations, videophone, telnet, voice messaging, web surfing, e-mail header access, medium and high quality music, movie clips / surveillance / real time video, (bulk) file transfer, still image retrieval</p> <p>Choice of technology can be influenced by: When is collaboration evoked? (ad-hoc peer-to-peer, scheduled, etc.) Type of exchange: personal perspectives exchange (facilitate relationships and conversations), objects exchange (share local knowledge) Type of moderation Actors involved (learners, teachers, resources, groups)</p>
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5.2.4 Guideline 26: Roles

Description	Assign roles within the mobile learning environment to facilitate CSCL
Cross-references	Guideline 16: Roles
Audience	Institutions, teachers
Basis	MOBIlearn Deliverable 9.1
Justification / elaboration	The following roles could be required in a CSCL environment: End-users / collaborators (teachers and learners) System administrators Moderator / coordinator

5.2.5 Guideline 27: Flexibility in technology use

Description	Be flexible in the configuration of technology to make upgrades easier
Cross-references	Guideline 25: Selection of hardware in relation to CSCL
Audience	Institutions, teachers, system designers

Basis	MOBIlearn Deliverable 9.1
Justification / elaboration	Progress in wireless and mobile technologies is rapid: the trendy and powerful technologies of today become obsolete in a matter of months. Therefore, in choosing a technology to use it is recommended that provisions are made for taking advantage easily of forthcoming technologies. For example, use GSM technology but foreseeing the how to take advantage later of UTMS.

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