MOBIlearn

WP 4 – 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.

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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 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:

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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 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. In the different definitions encountered in the literature, it is only the employment of specific types of technology that seem to differentiate mobile learning from other forms of 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 have been taking place while people are on the move.

A definition of mobile learning should therefore be widened to include:

> *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.*

2.2 What are guidelines?

The communication of aphoristic, practical knowledge presents certain problems. Practical books and articles often present advice or research findings as simple guidelines. In their more general form, guidelines have been termed 'slogans' (e.g. 'form is function'). Wright (1985) has been particularly critical of low-level (i.e. detailed) guidelines which, applied without sensitivity to their inevitably numerous exceptions, can do more harm than good. She also notes the sheer number of guidelines needed to cover the range of problems encountered in a given domain (in her case, text design).

Whilst guidelines can obviously be of great value, a major concern is that guidelines should not become detached from supporting evidence. A typical guideline might be 'Use simple language (Some name, some date)', 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 indicating what seems like a good idea. Research references have sometimes been used for persuasive purposes to lend authority to the guideline – indeed, when non-experts seek research references it is frequently for this reason.

Since guidelines are often neither detailed enough for exact application or generalizable enough through reference to a theory, 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 (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."*

Guidelines are often offered in the form of checklists, but there is often little correlation, or systematic comparison, between one checklist and another. The inclusion of a particular guideline, for example, may be due to the author's success with that particular recommendation in a specific instance or application. Other experts, however, may not share this experience, and therefore make no reference to it. Items may appear because of the stated preference of a certain user group. The gap between preference and effectiveness of design in terms of comprehension, recall or usability is often unexamined or justified by empirical evidence.
Recommendations may be present because they have proved to be cost-effective in a particular setting. But in other situations, financial considerations may not be of primary importance. So it is important in the provision of guidelines that we ensure they 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 MOBIlearn 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 healthworkers 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/). Section 5 outlines progress made so far in this area.

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* (e.g. 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	*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.

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, 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 which assess learning gains (see for example, Wood, 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 different between two objects, and (3) apply an operator to an object. One of the key elements need 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 (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 (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, Bruner & Ross, 1976; Wood & 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, Wood & Middleton, 1978; Wood & Wood, 1996).

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 & Wood, 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 and 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 teat 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 and 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 Genter; & 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 and Guzdial 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, Kelson et al. 1996) is a similar approach. It is fairly widely used in medical education (Albanese and Mitchell 1993), business administration (Merchant 1995; Stinson and Milter 1995) and nursing (Higgins 1994), amongst others. As Koschmann et al (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, Kelson 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 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 construct ion of knowledge by l earners. 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.

Conversation theory, developed by Gordon Pask (Pask, 1975, 1976), describes learning in terms of conversations between different systems of knowledge. Such systems can be humans or computers, a construct that makes the theory equally applicable to teacher-learner situations, and to computer-based teaching or learning support systems. The basic premises are that

a) the learner/system converses with itself about what it knows, i.e. reflects on what it knows
b) the learner-system converses with another system by sharing descriptions of the world.

Two such systems – say, two people A and B – share an understanding when person A can make sense of person's B explanation of what B knows, and B can make sense of A's explanation of what A knows. It is through conversation therefore that we come to a shared understanding of the world, while learning is a continual conversation with the external world and its artefacts, with oneself, and with other learners and teachers.

The social dimension of learning has also been emphasised through the theoretical framework of activity theory. Based on the works of the Soviet psychologists Vygotsky, Leont'ev and Luria, learning has been regarded as an activity performed by a subject on an object, mediated by cultural artefacts. This activity is embedded in a collective activity system, where the surrounding community divides the labour of learning in terms of assigning different roles to its members (learners, teachers, educational institutions) and sets social rules on the interactions between them (Engestrom 1999).

The question arising at this point is that of how the theories of learning such as the experiential adult learning described above could be coupled to lifelong learning and actualised in a systematic way both at the organisational and the individual level. The following section reviews recommendations from different sources for the actualisation of lifelong learning as a successful and pleasant reality for learners and the society.

3.1.8 Informal, lifelong 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. As we will see later, 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, are all circumstances that call for learning.

As studies of informal learning show (Livingstone, 2001; Tough, 1971), most of adults' learning happens outside formal education. Tough (1971) found that the average person in Canada carried out 8 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. In the following discussion we will present the case for supporting informal learning using mobile technologies.

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 & Sharples (2002) 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 & Sharples (2002) 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, to household work, to community volunteer work, and to general interests.

Vavoula & Sharples (2002) further examined the location and time of learning. They identify 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. 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 & Sharples, 2002). 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 & Sharples (2002) similarly define learning activities as the distinct acts that the person carries out during learning: reading, discussing, listening, and making notes. They then define episodes 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.

At this point we should have a look at a more detailed description of the process of learning. Vavoula (forthcoming) identifies eight stages in the learning process:

1. *Research into what and how to learn:* the learner identifies the learning needs, improves their understanding of what they want to learn, and investigates the available learning methods.
2. *Decide whether to learn or not:* having found out what and how they want to learn, the learner then makes a decision about whether to continue or not. Several factors may be examined at this phase, such as whether the time schedule of the new learning project fits with their daily routine, or whether it destabilises the balance between work and home.
3. *Generate ideas and develop the project:* after initial research on what and how, and having decided that they want to learn, the learner then develops the learning project. In this phase they will set goals and objectives and make estimates in terms of time, costs, etc. In this phase they may also set assessment criteria.
4. *Plan future action:* in this phase the learner will organise the learning goals and objectives, make estimates in terms of time and costs, outline the tasks they need to perform while prioritising them and taking into account costs and benefits, schedule the tasks, and allocate them to people in the case of collaborative learning projects. The use of plans is mainly to prepare the learner for learning action.
5. *Prepare for and perform tasks:* this phase involves securing the resources necessary for the learning experiences through which the scheduled tasks will be completed. Such resources might be other people, learning materials, access to laboratories, or even funding. Once the resources are identified and access to them is secured, the learner will start performing learning activities. Unless the lack of experience or expertise on a task becomes threatening, the learner will need to continue with their learning, checking on the uncompleted tasks regularly and re-planning - see (6) - where necessary.
6. *Re-plan future action:* even when the learner has gone through the planning phases described above in advance, there may be a need to revisit those plans. Plans afford revisions, during which the learner will need to assimilate the various partial outcomes and, in their light, will review the learning plan by repeating some or all of the procedures described in (4).

7. *Assess outcomes:* once the learning action is over, or perhaps more importantly during the action, the learner needs to assess the learning outcomes and the learning experience as a whole. To do that, they need to have defined a set of success criteria. Assessment exercises are useful in identifying weaknesses and planning action to overcome them; in checking how well one is doing in a project and overall; and also in re-planning and re-prioritising according to progress. Assessment methods may vary from formal progress charting, to informal reflective evaluation.
8. *Apply knowledge and skills learned in future situations:* after a learning project is over, the learner will have acquired some new knowledge and/or skills which they can now put into practice in other situations in the future. In doing so, further learning needs/opportunities may emerge, and new learning project cycles may be initiated.

Any of the eight steps, or parts of them, could be performed with the assistance of mobile technologies. We should stress here that we do not suggest that exclusively mobile technologies should 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, we should highlight the importance of providing integrated, continuous service between fixed and mobile technologies in a way that allows the learner to transfer between environments and settings with minimum effort.

The steps described above are not always followed in sequence and a considerable amount of learning can be performed without any pre-planning taking place. For example, a learner might identify a spontaneous learning opportunity and pursue it in the course of performing some other, everyday activities. Or learning might happen vicariously, without the learner realising it at the time. Such isolated learning episodes, however, may add up to form a significant learning project in the future. Or they may relate to one of the learner's current or past learning projects.

Based on which is the starting point of learning, Vavoula (forthcoming PhD thesis) devises a typology of learning:

Phase	**Initiated by learner**	**Initiated by others or by external situation**
Identify needs	Intrinsic necessity learning	Extrinsic necessity learning
Identify opportunities	Intrinsic opportunistic learning	Extrinsic opportunistic learning
Formulate objectives and plot plans	Self-managed goal-driven learning	Institution-managed goal-driven learning
Learning action	Self-initiated experiential learning	Externally-initiated experiential learning
Evaluation of, and reflection on experience	Self-managed reflection	Externally-managed reflection
Involuntary immersion into learning activities	—	Passive learning

3.1.9 Concerns for the actualisation of 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, 1998b; Fischer, 1998; Fischer & Scharff, 1998; Jarvis et al., 1998; Sharples, 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, 1998a). 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
  - 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 are going to play an important role.

3.2 M-Learning in context: informal, lifelong learning

Having explored the mobile learning context, 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.

4. 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, 2002). In the UK, BECTA has published a report on the use of handheld computers (PDAs) in schools (BECTA, 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.

4.1.1 Guideline 1: Costs

Description	Research cost model for infrastructure, technology and services
Audience	Institutions
Basis	Lehner (2002), Soloway (2002), Smith (2003), BECTA (2003)
Justification / elaboration	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. 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. With regard to the technology, it is generally less costly to equip 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.

4.1.2 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 (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	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. 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.

4.1.3 Guideline 3. 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), Smith (2003), BECTA (2003)
Justification / elaboration	Attention should be paid to the choice of mobile technology. BECTA (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. 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: **Advantages**

	• They assist with discussions when used in conjunction with exercises/lectures – better than laptops, which are obtrusive in such settings • Useful means for accessing reference materials, like dictionaries • They can provide instant, in-class feedback to tutors on understanding, when on wireless connection • They help motivate students, they have proved light up their enthusiasm and to inspire children, even influence their choice of career • PDAs allow flexible class configuration (easy to form small work-groups) and students can find their own comfortable seating • PDAs allow the blurring of the isolated class with the outside world with access to libraries and other information sources • PDAs allow students to work anywhere on campus and still use their favourite tools (as long as there's network available) • 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. • PDAs are a good solution in classrooms where size is a problem • 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. **Disadvantages** • Loss of data and applications on battery run-down è backup systems required • Battery life decrease with add-on cards/wireless communications enabled • Stylus suitable only for short notes (generally short usage) • Synchronising station necessary • Need to consider students with visual or physical impairments, and potential difficulties

4.1.4 Guideline 4. 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 (2002), Vahey (2002), BECTA (2003)
Justification / elaboration	*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. (BECTA 2003) 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: a. A technical promoter: a person who can demonstrate the capabilities of the system to decision makers b. 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. 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: c. 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

4.1.5 Guideline 5. Equipment management

Description	Develop procedures and strategies for the management of equipment when it is provided by the institution
Audience	Institutions / teachers
Basis	Vahey (2002), Smith (2003), BECTA (2003)
Justification / elaboration	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: **Strategy for assigning equipment to stude nts** Possible options as reported by Vahey (2003) 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.

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).

Restricting students off-task use

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.

Synchronise handheld to desktop for set up and follow through of learning activities

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.

Track, review and collect students' work

The teacher has a number of choices on how to access the students' work on the handheld: she can review a student's work directly on the device; or the students can print out their work and hand it to the teacher; or the students can synchronise to specific computers through which the teacher can then pass comments back; or the students can 'beam' their work to the teacher's handheld. In the latter case, it is important that the students observe a clear file naming system so that the teacher knows where a file came from.

Devise and implement parental agreements to be responsible for equipment

The issues of damage, bss and theft are not as severe as one might imagine (add refs). However, the teacher/institution might want to consider devising a parental agreement that will be signed

	by the parents, laying out responsibilities for lost or damaged equipment. **Hardware management** This task relates to task (a) and is further concerned with labelling handheld devices and network IDs, asset registers, charging methods and routines. No example procedures were found in the literature. **Routine backup procedures** The importance of routine backup procedures should also be stressed: PDAs typically have short battery lives and a 'run out of battery' incident can be translated to loosing all data and applications on the device. A possible safeguard for this is synching, preferably with the institutions network, where regular backups are usually already in place.

4.1.6 Guideline 6. 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	Lehner (2002), Vahey (2002), Smith (2003), BECTA (2003), Alexander (2003)
Justification / elaboration	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). 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.

	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”*

4.1.7 Guideline 7. Admin

Description	Consider the use of mobile technologies for student administration tasks
Audience	Institutions, teachers
Basis	Lehner (2002), BECTA (2003)
Justification / elaboration	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. 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. 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.

4.1.8 Guideline 8. Collaboration

Description	Consider the use of mobile technologies to support collaborative and group learning
Audience	Teachers
Basis	Lehner (2002), BECTA (2003)
Justification / elaboration	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.

4.1.9 Guideline 9. 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	Lehner (2002), Vahey (2002), Soloway (2002), BECTA (2003), Alexander (2003)
Notes	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.
Justification / elaboration	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.) With regard to learning-specific services and applications, teachers and students have reported using PDAs for: • 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

4.1.10 Guideline 10. Security / privacy

Description	Ensure security and privacy for the end users
Audience	System designers
Basis	Lehner (2002), Alexander (2003)
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)

5. 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.

5.1.1 Guideline 11. 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 10. Security / privacy
Audience	System designers, institutions, teachers
Basis	MOBIlearn Deliverable 6.1
Justification / elaboration	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: • Informed user consent for the system to collect and use personal data • Control: users have control over the collected data

	• Security: gathered data is stored securely, preventing misuse from third parties

5.1.2 Guideline 12. 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	• Ensure that mobile technologies are used appropriately to exploit their potential and to support activities that might not be possible without them • 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. • Support learning before (orientation), during (exploration, sharing, explanations, context, background, analytical tools, suggestions for related experiences) and after (reflection) the learning activity

5.1.3 Guideline 13. Selection of hardware in relation to CSCL

Description	Select hardware that fulfils the requirements for supporting CSCL activities
Cross-references	Guideline 3. Choice of technology, Guideline 15. Flexibility in technology use
Audience	Institutions, teachers, system designers
Basis	MOBIlearn Deliverable 9.1
Justification / elaboration	• Hardware features checklist: o Sufficient display (graphics rendering) o Pointing device (point location on screen) o Connectivity o Microphone o Video streams (video conferencing) o Audio and video • Communication technologies and standards: to decide what to use and when, consider the following: o WPAN (Wireless Personal Area Network), use within ten meters ▪ 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 o WLAN, use within campus, more than 10 meters - 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 o WWAN, use on the go - GSM, GPRS, UTMS - Allow participation to collaborative work session in lack of other connectivity - Voice, SMS, MMS, GPRS (data) communication anywhere - Limited bandwidth --> hard to support all types of real time communications and content - Usage of network is charged • Consider what types of collaboration services are needed: o Conversational service: bi-directional, real time, end to end information transfer o Interactive service: bi-directional, can be conversational, messaging or retrieval o Streaming service: one way, multimedia feeds to live audience for immediate consumption o Background service: destination is not expecting data at a certain time • 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 • Choice of technology can be influenced by: o When is collaboration evoked? (ad-hoc peer-to-peer, scheduled, etc.) o Type of exchange: personal perspectives exchange (facilitate relationships and conversations), objects exchange (share local knowledge) o Type of moderation o Actors involved (learners, teachers, resources, groups)

5.1.4 Guideline 14. Roles

Description	Assign roles within the mobile learning environment to facilitate CSCL
Cross-references	Guideline 4. 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

5.1.5 Guideline 15. Flexibility in technology use

Description	Be flexible in the configuration of technology to make upgrades easier
Cross-references	Guideline 3. Choice of technology, Guideline 13. 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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