Digital Technologies and Cognitive Development

Or

Can our theories of learning help us understand what people are doing when they learn through interaction with networked, integrated, interactive digital technologies?

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"It is man's participation *in* culture and the realization of his mental powers *through* culture that makes it impossible to construct a human psychology on the basis of the individual alone….To treat the world as an indifferent flow of information to be processed by individuals each on his or her own terms is to lose sight of how individuals are formed and how they function**."**

Jerome Bruner, Acts of Meaning, 1990, Harvard University Press, Cam:Mass. P12

Does a continuous use of ICT have an impact on the development of cognitive skills?

This is a multi-layered question which I will approach by first making some general observations of apparent differences between NMLs and non-NMLS. One key difference between a NML and an OML (Old Millennium Learner) lies in the manner in which they each ***appropriate*** technology.

- OMLs are less likely to absorb the functionality of a device or service seamlessly into what they are doing – it will take conscious effort, and some careful adaptation of approach, method or technique which have all been honed to other ways of working.

- OMLs are also more likely to become preoccupied by particularities of the device they are using. Working out the underlying virtual machine or functionality of devices can be problematic, especially if manufacturers don't stick to the same standards.

- OMLs find some devices are hugely counter-intuitive in the way they work (e.g. well known examples are that most mobile phones are switched on by holding down the 'off' key; shutting down Windows machines by going to the 'Start' menu). These things confuse OMLs who may be used to using a certain type of real-world logic to deduce functionality.

- On the whole, working out how digital devices work is stressful, time consuming, confusing and unpleasant for OMLs. If they can work out how to use one device (e.g. a mobile phone), then they'll try to stick with that one phone for as long as possible. The status of the device means little or nothing to them.

- The NMLs by contrast, operate in a more abstract space where the conventions are less rigid, the models underlying functionality are more fluid.

- Devices are there to be looked at, devoured, tried out and judged to be worthy or not in a matter of minutes.
- NMLs have fewer inhibitions about exploratory behaviour – they are confident they can't damage the device by pressing buttons. There is always a 'reset' button and most data is retrievable in some format or other. The worst that can happen is that you have to download a whole load of stuff again.

- This group is more pragmatically concerned about the cost of services – e.g. phone contracts, costs of sms messaging, costs of connecting to the internet etc.

- But perhaps more importantly, the social environment in which digital media are used is of a very different order. Technology is there to enable you to be connected. If you aren't connected, you aren't cool.

- The projected image of yourself in this digital social space is carefully configured to be hip (but probably conforms to a couple of fairly standard templates that are manufactured through the advertising media).

- Phones are sold on image and lifestyle first, functionality second.

So, the cultural and social context in which activities are taking place is very different between NMLs and OMLs. In that sense, therefore, NMLs are developing (have developed) different cognitive skills than OMLs.

At a surface level, it is commonplace to observe that young people no longer have to remember so many facts and figures – search engines have had a similar effect on literacy and knowledge acquisition as calculators have had on numeracy. You can 'google' whatever you want to know. NMLs have access to vast amounts of excellent resources on any topic imaginable, so the research aspect of learning tasks tends not to be how to find the resource, but how to judge quality, how to sift, to eliminate and to integrate myriad resources to produce an outcome fit for purpose.

Do New Millennium Learners learn differently?

This question unpacks into two questions. First, are NMLs engaged in learning processes that are fundamentally, qualitatively or quantitatively, different from those of previous generations in such a way that the underlying substructure of brain/cognitive function is different? Second, do we have theories that can account for

the kinds of learning behaviours that NMLs exhibit, which differ in superficial ways from those of their predecessors?

I do not know the answer to the first question, though I am willing to believe that it is possible for young people to adapt their cognitive function through interaction with complex devices in such a way that they accomplish tasks in very different ways than their parents do. These adaptations may not count very significantly in the overall performance, however, which will depend upon a myriad of factors, only some of which are associated with use of computers.

However, the second question I believe I have something to say about. Mike Sharples, Giasemi Vavoula and myself have been working to propose a theory of learning for a mobile society. It encompasses both learning supported by mobile devices such as cellular (mobile) phones, portable computers and personal audio players, and also learning in an era characterised by mobility of people and knowledge (Rheingold, 2002) where the technology may be embedded in fixed objects such as 'walk up and use' information terminals. For brevity we refer to these together as mobile learning. The attached conference paper provides an account of our theory of learning for a mobile age.

Towards a Theory of Mobile Learning

[paper presented at MLEARN 2005]

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Many theories of learning have been advanced over the 2500 years between Confucius and the present day, but almost all have been predicated on the assumption that learning occurs in a school classroom, mediated by a trained teacher. A few educational thinkers have developed theory-based accounts of learning outside the classroom, including Argyris (Argyris & Schön, 1996), Friere (Freire, 1972), Illich (Illich, 1971), and Knowles (Knowles & Associates, 1984), but none have emphasised the mobility of learners and learning. For example, a search of the extensive and authoritative Encyclopaedia of Informal Learning (www.infed.co.uk, accessed June 2005) shows no reference to mobile learning.

The objective of this paper is to offer an initial framework for theorising about mobile learning, to complement theories of infant, classroom, workplace and informal learning. A related aim is to inform the design of new environments and technologies to support mobile learning, since the work described here has been developed through a series of projects to design technology for mobile learning, including MOBIlearn (www.mobilearn.org), Caerus (www.caerus.bham.ac.uk), Kleos (Vavoula, 2004) and Interactive Logbook (www.il.bham.ac.uk).

A first step in postulating a theory of mobile learning is to distinguish what is special about mobile learning compared to other types of learning activity. An obvious, yet essential, difference is that it starts from the assumption that learners are continually on the move. We learn across space as we take ideas and learning resources gained in one location and apply or develop them in another. We learn across time, by revisiting knowledge that was gained earlier in a different context, and more broadly, through ideas and strategies gained in early years providing a framework for a lifetime of learning. We move from topic to topic, managing a range of personal learning projects, rather than following a single curriculum. We also move in and out of engagement with technology, for example as we enter and leave cellphone coverage.

To portray learning as a labile activity is not to separate it from other forms of educational activity, since some aspects of informal and workplace learning are fundamentally mobile in the ways outlined above. Even learners within a school will move from room to room and shift from topic to topic. Rather, it illuminates existing practices of learning from a new angle. By placing mobility of learning as the object of analysis we may understand better how knowledge and skills can be transferred across contexts such as home and school, how learning can be managed across life transitions, and how new technologies can be designed to support a society in which people on the move increasingly try to cram learning into the interstices of daily life.

Second, a theory of mobile learning must therefore embrace the considerable learning that occurs outside classrooms and lecture halls as people initiate and structure their activities to enable educational processes and outcomes. A study by Vavoula (Vavoula, 2005) of everyday adult learning found that 51% of the reported learning episodes took place at home or in the learner's own office at the workplace, i.e. at the learner's usual environment. The rest occurred in the workplace outside the office (21%), outdoors (5%), in a friend's house (2%), or at places of leisure (6%). Other locations reported (14%) included places of worship, the doctor's surgery, cafes, hobby stores, and cars. Interestingly, only 1% of the self-reported learning occurred on transport, which suggests both that mobile learning is not necessarily associated with physical movement, and conversely that there may be opportunities to design new technology that supports learning during the growing amounts of time that people spend travelling.

A central concern must be to understand how people artfully engage with their surroundings to create impromptu sites of learning. For example, three children with handheld wireless computers disappear under a school table to create a private learning space. Or (in an example from the diary studies) an adult wants to learn how to connect a computer to a printer and so creates a context for learning out of a computer, a printer and a cable on a table in the house, and a friend with some knowledge of computer hardware.

Third, to be of value, a theory of learning must be based on contemporary accounts of practices that enable successful learning. The US National Research Council produced a synthesis of research into educational effectiveness across ages and subject areas (National Research Council, 1999). It concluded that effective learning is:

- *learner centred*: It builds on the skills and knowledge of students, enabling them to reason from their own experience;
- *knowledge centred*: The curriculum is built from sound foundation of validated knowledge, taught efficiently and with inventive use of concepts and methods;
- *assessment centred*: Assessment is matched to the ability of the learners, offering diagnosis and formative guidance that builds on success;
- *community centred*: Successful learners form a mutually promotive community, sharing knowledge and supporting less able students.

These findings broadly match a social-constructivist approach, which views learning as an active process of building knowledge and skills through practice within a supportive community. It comprises not only a process of continual personal development and enrichment, but also the possibility of rapid and radical conceptual change.

Lastly, a theory of mobile learning must take account of the ubiquitous use of personal and shared technology. In the UK, over 75% of the general population and 90% of young adults own mobile phones (Crabtree, 2003). A survey in 2003 at the University of Birmingham found that 43% of students owned laptop computers. These figures mask the huge disparities in access to technology around the world, but they indicate a trend towards ownership of at least one, and for some people two or three, items of powerful mobile technology including mobile phones, cameras, music

players and portable computers. A trend relevant to a theory of learning in the mobile world is that some developing countries, particularly in sub-Saharan Africa, are by-passing the fixed network telephony to install cellphone networks to rural areas. These offer the opportunity for people in rural communities not only to make phone calls, but to gain the advantages of mobile services such as text and multimedia messaging.

We are now seeing a well-publicised convergence of mobile technologies, as companies design and market mobile computer-communicators, combining the functions of phone, camera and multimedia wireless computer. Another equally important convergence is occurring between the new personal and mobile technologies and the new conceptions of lifelong learning (Table 1).

New Learning	**New Technology**
Personalised	Personal
Learner centred	User centred
Situated	Mobile
Collaborative	Networked
Ubiquitous	Ubiquitous
Lifelong	Durable

Table 1. Convergence between learning and technology

Just as learning is being re-conceived as a personalised and learner-centred activity (Leadbetter, 2005), so too are new digital technologies offering personalised services such as music play-lists and digital calendars. Just as learning is now regarded as a situated and collaborative activity (Brown, Collins, & Duguid, 1989), occurring wherever people, individually or collectively, have problems to solve or knowledge to share, so mobile networked technology enables people to communicate regardless of their location. Computer technology, like learning, is ubiquitous: computers are embedded in devices such as photocopiers and televisions that perform human-oriented functions (including basic instruction and user guidance) rather than acting as general-purpose computing devices. They are also becoming more durable, in that although the hardware may last only for two or three years, personal software packages and storage formats (such as PDF) evolve through successive versions, with a large measure of backward compatibility. There are now opportunities for people to preserve and organise digital records of their learning over a lifetime (Banks, 2004).

To summarise, we suggest that a theory of mobile learning must be tested against the following criteria:

- Is it significantly different from current theories of classroom, workplace or lifelong learning?
- Does it account for the mobility of learners?
- Does it cover both formal and informal learning?

- Does it theorise learning as a constructive and social process?
- Does it analyse learning as a personal and situated activity mediated by technology?

As part of the process of developing a theory of mobile learning, the core members of the MOBIlearn European project held a reflection session during its final plenary meeting in January 2005, to discuss what is distinctive about mobile learning and "what do we know now that we didn't at the start of the project". MOBIlearn involved 24 partners from the European Community, Israel, Switzerland, USA and Australia to develop new methods and systems for mobile learning. The list below summarises findings from the final reflection session, representing the collective wisdom of twelve research leaders after 30 months of the project.

It is the learner that is mobile, rather than the technology: Initially we had focused on the design of specific portable technologies, but a series of studies for MOBIlearn of everyday learning indicated that the interactions between learning and technology are complex and varied, with learners opportunistically appropriating whatever technology is ready to hand as they move between settings, including mobile and fixed phones, their own and other people's computers, as well as books and notepads.

Learning is interwoven with other activities as part of everyday life: Learning cannot easily be separated from other everyday activities such as conversation, reading, or watching television, and these activities can be resources and contexts for learning. It is integrated with non-learning tasks such as shopping or entertainment, it is organised into projects that are interleaved with everyday activities, and learning needs emerge when a person strives to overcome a problem or breakdown in everyday activity (Vavoula, 2004).

Learning can generate as well as satisfy goals: Learning can be initiated by external goals (such as a curriculum or study plan), or by a learner's needs and problems, or it can arise out of curiosity or serendipity, prompting the learner to form new goals which may then be explored through formal or informal study.

The control and management of learning can be distributed: In a classroom the locus of control over learning remains firmly with the teacher, but for mobile learning it may be distributed across learners, guides, teachers, technologies and resources in the world such as books, buildings, plants and animals.

Context is constructed by learners through interaction: To explore the complexity of mobile learning it is necessary to understand the contexts in which it occurs. Context should be seen not as a shell that surrounds the learner at a given time and location, but as a dynamic entity, constructed by the interactions between learners and their environment. For example, visitors to an art gallery continually create contexts for learning from their paths through the paintings, their goals and interests, and the available resources including curators and other visitors.

Mobile learning can both complement and conflict with formal education: Learners can extend their classroom learning to homework, field trips, and museum visits by, for example, reviewing teaching material on mobile devices or collecting and analysing information using handheld data probes. They could also disrupt the carefully managed environment of the classroom by bringing into it their own

multimedia phones and wireless games machines, to hold private conversations within and outside the school (Sharples, 2002).

Mobile learning raises deep ethical issues of privacy and ownership: Systems such as myLifeBits (Gemmell, Williams, Wood, Bell, & Lueder, 2004) provide wearable 'experience organisers' that allow people to record their everyday life as sounds and pictures and then to recall them for later reflection. These have the potential to be powerful tools for lifelong learning and aids for those with failing memories. They may also allow parents or teachers to monitor every intimate detail of learning, so that play and leisure becomes an extension of school activity, to be checked and assessed as continuous records of achievement. This could be seen as a deeply disturbing vision of childhood without privacy, and the first steps have already been taken as companies bring to market electronic tagging devices for parents to track the location of their children.

Although some of the issues above apply more broadly to informal and everyday learning, the distinctive aspects of mobile learning are its mobility, the informally arranged and distributed participants, and the interaction between learning and portable technology. But to see mobile learning as just another type of educational interaction is to miss its broader significance (Sharples, 2005). Every era of technology has, to some extent, formed education in its own image. In the era of mass print literacy, the textbook was the medium of instruction, and a prime goal of the education system was effective transmission of the canons of scholarship. During the computer era of the past fifty years, education has been re-conceptualised around the construction of knowledge through information processing, modelling and interaction. For the era of mobile technology, we may come to conceive of education as conversation in context, enabled by continual interaction through and with personal and mobile technology.

A Framework to Analyse Technology-mediated Mobile Learning

In a companion paper (Sharples, 2005) we have developed an analysis of learning as conversation in context, drawing on Dewey's philosophy of Pragmatic Technology and Pask's Conversation Theory as foundations on which to build an account of the process of coming to know in a world mediated by mobile technology. Another related paper describes how an early version of the framework has provided a Task Model for mobile learning in the MOBIlearn project (Taylor, Sharples, O'Malley, Vavoula, & Waycott, 2006). In the remainder of this paper we describe an application of cultural-historical activity theory to analyse the activity system of mobile learning. We describe the dialectical relationship between technology and learning through an adapted version of Engeström's expansive activity model (Figure 1) (Engeström, 1987).

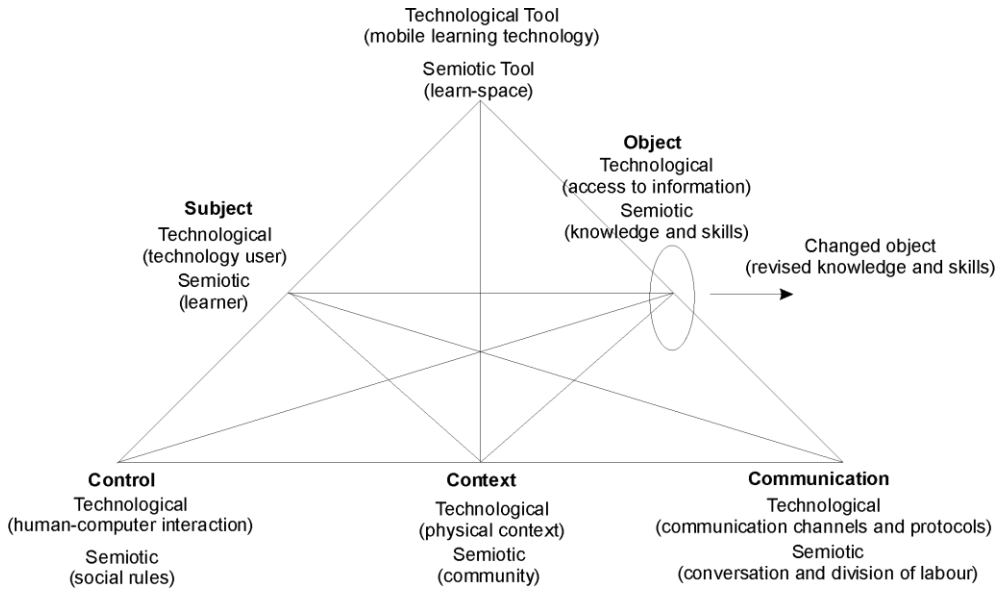

Figure 1. A Framework for analysing mobile learning.

In the tradition of Activity Theory we analyse learning as a cultural-historical activity system, mediated by tools that both constrain and support the learners in their goals of transforming their knowledge and skills. We have found that in analysing the activity of mobile learning it has helped to separate two perspectives, or layers, of tool-mediated activity. The semiotic layer describes learning as a semiotic system in which the learner's object-oriented actions (i.e. actions to promote an objective) are mediated by cultural tools and signs. The learner internalizes public language, instantiated in writing and conversation, as private thought which then provides the resource for control and development of activity (Vygotsky, 1978). The technological layer represents learning as an engagement with technology, in which tools such as computers and mobile phones function as interactive agents in the process of coming to know, creating a human-technology system to communicate, to mediate agreements between learners (as with spreadsheets, tables and concept maps) and to aid recall and reflection (as with weblogs and online discussion lists).

These layers can be prised apart, to provide either a semiotic framework to promote discussion with educational theorists to analyse learning in the mobile age, or a technological framework for software developers and engineers to propose requirements for the design and evaluation of new mobile learning systems. Or the layers can be superimposed (as in Figure 1), to examine the holistic system of learning. Here, the semiotic fuses into the technological to form a broader category of technology than physical artefacts. Following Dewey (Hickman, 1990), we could describe technology as any tool that serves the purpose of enquiry, enabling people to address problems in context and to clarify and transform them into new understanding. Thus, hammers, computers, languages and ideas may all qualify as technologies for enquiry, and there is no clear distinction between the semiotic and the technological.

We need to make clear that, for our framework, we are neither proposing the separation of the semiotic and the technological, nor the fusing of the two. Rather, we

want to set up a continual dynamic in which the technological and the semiotic can be moved together and apart, creating an engine that drives forward the analysis of mobile learning.

Learning occurs as a socio-cultural system, within which many learners interact to create a collective activity framed by cultural constraints and historical practices. Engeström analyses the collective activity through an expanded framework that shows the interactions between tool-mediated activity and the cultural Rules, Community and Division of Labour. As we have adapted Engeström's framework to show the *dialectical relationship* between technology and semiotics, so we have taken the liberty to rename the cultural factors with terms – Control, Context and Communication – that could be adopted either by learning theorists or by technology designers. Of course, this risks the possibility that the terms will be interpreted differently by both groups and simply lead to misunderstanding and mutual incomprehension, so we shall attempt to clarify their meaning.

Control

The control of learning may rest primarily with one person, usually the teacher, or it may be distributed among the learners. Control may also pass between learners and technology, for example in a dialogue for computer-based instruction. The technological benefit derives from the way in which learning is delivered: whether the learners can access materials when convenient, and whether they can control the pace and style of interaction. These are issues of human-computer interaction design.

However, technology use occurs within a social system of other people and technologies. Social rules and conventions govern what is acceptable (e.g. how to use e-mail, who is allowed to email whom, what kinds of document format should be used). A person's attitudes to technology can be influenced by what others around them think about it, for example, whether they are resentful at having to use the technology or are keen and eager to try it out. And individuals and groups can also express informal rules about the way they like to work and learn.

Context

The context of learning is an important construct, but the term has many connotations for different theorists. From a technological perspective there has been debate about whether context can be isolated and modelled in a computational system, or whether it is an emergent and integral property of interaction. Work for the MOBIlearn project has developed an interactional model of context for mobile learning (Lonsdale, Baber, & Sharples, 2004). Context also embraces the multiple communities of actors (both people and interactive technology) who interact around a shared objective. For a fuller discussion of context and mobile learning, see (Sharples, 2005).

Communication

The dialectical relationship between the technological and semiotic layers is perhaps the easiest to see in relation to Communication. If a technological system enables certain forms of communication (such as email or texting), learners begin to adapt their communication and learning activities accordingly. For example children are increasingly 'going online' at home, creating networks of interaction through phone conversation, texting, email and instant messaging that merge leisure and homework activities into a seamless flow of conversation. As they become familiar with the

technology they invent new ways of interacting – 'smilies', text message short forms, the language of instant messaging – that create new rules and exclusive communities. This appropriation of technology not only leads to new ways of learning and working, it also sets up a tension with existing technologies and practices. For example, children can subvert the carefully managed interactions of a school classroom by sending text messages hidden from the teacher. On a broader scale, technology companies see markets for new mobile technology to support interactions such as file sharing and instant messaging. Thus, there is a continual co-evolution of technology and human communication, with each new development creating pressures that drive the next innovation.

Conclusions

The framework described in this paper is a step towards an integrated theory of mobile learning that could inform both the analysis of learning in a mobile world and the design of new technologies and environments for learning. We describe learning as a labile process of 'coming to know' through conversation in context, by which learners in cooperation with peers and teachers construct transiently stable interpretations of their world. Learning is mediated by knowledge and technology as instruments for productive enquiry, in a mutually supportive and dynamically changing relationship. The mediation can be analysed from a technological perspective of human-computer interaction, physical context and digital communication, and from a human perspective of social conventions, community, conversation and division of labour. These two perspectives interact to promote a co-evolution of learning and technology.

We suggest that the implications of this re-conception of education are profound. It describes a cybernetic process of learning through continual exploration of the world and negotiation of meaning, mediated by technology. This can be seen as a challenge to formal schooling, to the autonomy of the classroom and to the curriculum as the means to impart the knowledge and skills needed for adulthood. But it can also be an opportunity to bridge the gulf between formal and experiential learning, opening new possibilities for personal fulfilment and lifelong learning.

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