Education in the wild

Education in the wild:
contextual and location-based mobile learning in action

A report from the STELLAR Alpine Rendez-Vous workshop series

Edited by Elizabeth Brown

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Learning Sciences Research Institute

The University of Nottingham

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The STELLAR Network of Excellence represents the effort of the leading institutions and projects in European Technology-Enhanced Learning (TEL) to unify our diverse community. This Network of Excellence is motivated by the need for European research on TEL to build upon, synergize and extend the valuable work we have started by significantly building capacity in TEL research within Europe, which is required to allow the European Union to achieve its goals via the Bologna Agreement and the execution of the Lisbon Agenda. The European TEL agenda has been set for the last 4 years by the Kaleidoscope network – with a huge strength in pedagogy and scientific excellence and the Prolearn network – with a complimentary strength in technical and professional excellence. Integrating this excellence and moving on to the higher strategic formation of policy based in leading research is the key challenge for the next stage. STELLAR moves beyond the earlier networks by setting a new and critical foresight agenda for Technology Enhanced Learning. The Network is executed via a series of integration instruments designed to increase the research capacity of European TEL at all levels. STELLAR's instruments will act upon the backbone of an interlocking set of 3 Grand Research Challenge actions, themed as Connecting People, Orchestration and Context.

LSRI
Learning Sciences Research Institute

The LSRI at the University of Nottingham is a world-leading centre for research into the science and technology of learning. Its objective is to explore the cognitive, social and cultural aspects of learning and to design innovative technologies and environments for learners. The Institute brings together staff from the founding Schools of Computer Science and IT (CSIT), Education, and Psychology, as well as expertise from other disciplines. The Education in the Wild workshop formed part of the 1st STELLAR Alpine Rendez-Vous, held in Garmisch-Partenkirchen, Germany.

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Foreword

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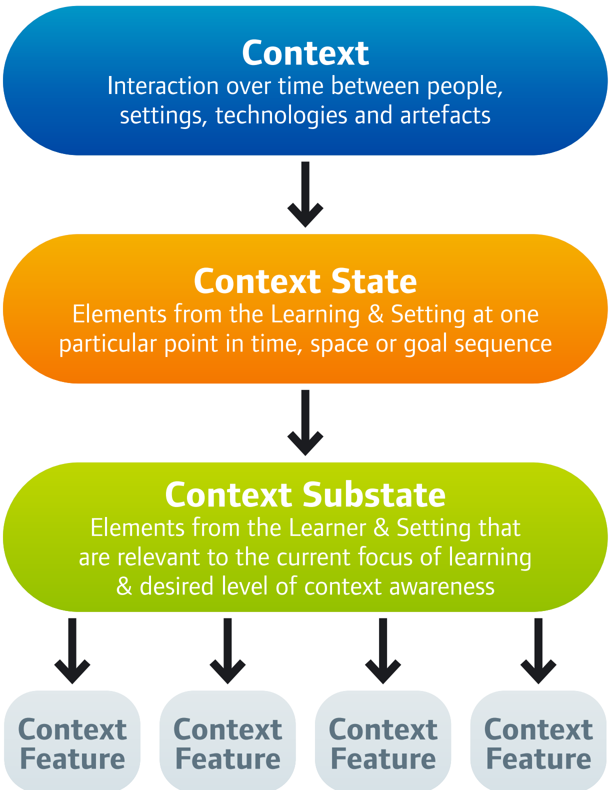
Mobile phones are becoming context-aware, with GPS positioning, recognition of objects by infrared or wireless tags, and automatic interpretation of images. They are offering opportunities to support new forms of learning through contextual support for field trips, location-based guides, environmental studies *(Squire & Klopfer, 2007)* and to assist everyday learning activities *(Vavoula & Sharples, 2001)*.

The main barriers to developing these new modes of mobile learning are not technical but social. We have little understanding of context and learning outside the classroom, and even less about how this can be supported through new mobile technologies. Consider a group of children on a field trip to a museum. One child in the group is holding a multimedia guide and they are all viewing and discussing a museum exhibit. Their learning context embraces not only the location and museum exhibit, but also interactions between the children and material on the multimedia guide, the conversation of the children, their prior knowledge of the exhibit and its personal, cultural and historical meaning, the route that each child has taken through the museum to arrive at the exhibit, and people around them including museum guides, teachers, and other children. Their context is continually unfolding, as they move, talk and engage with the surroundings of the museum to create personal and shared meaning. This is just within the relatively structured confines of a museum; learning as part of everyday life is even more complex and diverse.

Figure 1: Context hierarchy (from Lonsdale et al., 2004)



Falk & Dierking (1992; 2000), from studies of museum learning, have proposed a relevant 'Contextual Model of Learning' in which learning can be conceptualized as a continuous effort by individuals to make meaning in order to survive and prosper within the world, through a process of interaction over time between three contexts: the Personal, Sociocultural and the Physical. Although the 'model' has been influential in analysing the nature and scope of learning outside the classroom, Falk and Dierking state in a recent paper that:

> *"the Contextual Model of Learning is not a model in its truest sense; it does not purport to make predictions other than that learning, or as we prefer to say these days, meaning-making, is always a complex phenomenon situated within a series of contexts."*
> **(Falk & Dierking, 2008: p20)**

As part of the MOBIlearn EC 5th Framework project we developed and implemented an interactional model of contextual learning (Lonsdale, Baber & Sharples, 2004) whereby learning not only occurs in a series of contexts, as proposed by Falk & Dierking, it also creates context through continual interaction. This follows a distinction made by Nardi:

> *"Context is not an outer container or shell inside of which people behave in certain ways. People consciously and deliberately generate contexts (activities) in part through their own [objectives]; hence context is not just 'out there'."*
> **(Nardi, 1995: p38)**

A learner's context can only be fully described by taking an historical perspective, to understand how it has been shaped and transformed by previous ideas and practices *(Engeström, 1996)*. This is particularly true of mobile learning, where both the immediate history of physical activity and the wider historical process of coming to know merge to create new understanding. One useful analogy is to see context as an ever-playing movie: a continually unfolding interaction between people, settings, technologies and other artefacts *(Figure 1)*. The movie is composed of a sequence of scenes, or context states, that represent a specific point in time, space, or sequence of learning goals. Each scene of current context is a progression from earlier ones and within the scene some elements are emphasised as relevant to the focus of learning and level of context awareness. The entire movie provides a resource for learning. But this is a movie that is continually being constructed by its cast, from moment to moment, as they share artefacts and create mutual understanding through dialogue and physical interaction.

In MOBIlearn, we implemented this interactional model as part of a software system called CAGE to support learning through context *(Lonsdale, et al.,, 2005)*. Users carried a handheld device that tracked their location indoors to within 10cm accuracy, using ultrasonic positioning. The device stored the users' learning profiles, the history of their movements, and their current location and their activity, such as moving or standing. From this information it first filtered information that would not be relevant to the person's context (such as high resolution images on the small screen) and then offered relevant support for learning. In trials at an art gallery, as the visitor walked past a painting that had not been seen before CAGE gave a short audio description of the work of art. Then, if the person stopped, it offered a longer spoken introduction based on the learner's profile. If the user waited longer, it offered an interactive presentation to explore aspects of the painting.

The CAGE system was successful in provoking discussion among groups of visitors, encouraging them to appreciate paintings in more detail. But this was at the cost of a complex model of context. Fundamental research is needed on whether explicit modelling and representation of context can offer clear benefits to learning and, if so, to design new ways to model and integrate the human and technical aspects of context awareness.

"The main barriers to developing new modes of mobile learning are not technical but social. We have little understanding of context and learning outside the classroom."

An alternative is to view context as an emergent property of interaction. According to this approach (see e.g., *Suchman, 1987*), technology should augment human activity in context, but not model it. Rather than designing over-complex technology that fails to support the subtleties of human-computer and social interaction it might be better to provide the learner with more generic 'awareness' tools, and visual

> **"Imagine the context of each person in the world as a movie that plays throughout their lifetime. Scenes from each person's movie will overlap and merge with those of other people."**

displays of social networks. Thus, we can enhance the natural environment to enhance learning through a combination of digital artefacts (such as 'viewscopes' that display the workings or history of an object or location), interactive objects, and visualisation tools such as interactive maps *(Nova et al., 2005; Rogers et al., 2005; Kay et al., 2006)*. The aim is for this environmental richness to promote new forms of learning and engagement.

To return to the movie analogy, imagine the context of each person in the world as a movie that plays throughout their lifetime. Scenes from each person's movie will overlap and merge with those of other people, then disconnect, to produce an inter-weaving textuality – a super movie that is played across the world in billions of locations as people come together to create ephemeral 'micro sites' for learning. The challenge for mobile learning research is to supplement these sites for learning with appropriate tools and materials, enabling people, individually and together, to create and maintain their own rich contexts for learning.

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Introduction to location-based mobile learning

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The distinguishing aspect of mobile learning is the assumption that learners are continuously on the move. This is not just their physical mobility, but also how learners are active in different contexts and how frequently these might change, depending on an individual's location.

Contexts important to the learning process

Throughout this report, an overarching context is that of location. This might be related to the physical location of a learner and how the properties of, or a change in, this location can lead to a learning experience (learning in the environment). Alternatively it might be considered from the perspective of the natural environment and the affordances it offers to educate visitors (learning about the environment).

However, as we spend more time physically on the move, it is essential to realise that other contexts might change rapidly; this is also true in the more long-term sense of change, which might encompass lifelong learning. A big question for technology-enhanced learning is how contextual mobile learning can be supported by various learning scenarios and the technologies/devices being used.

Other contexts may include social activity or learning goals. It is imperative to examine how contexts for learning are artfully created through continual interactions between people, technology, and settings *(Sharples et al., 2009)*, and how these ephemeral learning contexts might be supported and maintained through new context-aware technologies.

Furthermore, an analysis of what parts of context are important for effective and efficient instructional design and how they can be used is of critical importance. Beside the selection of certain context parameters for learning support, the issue of transfer between learning situations and the role of contextual support is of concern to both teachers and learners.

Context can be defined as "the formal or informal setting in which a situation occurs; it can include many aspects or dimensions, such as environment, social activity, goals or tasks of groups and individuals; time (year/month/day)" *(Brown et al., 2010: p4)*.

The MOBIlearn project examined context in detail and developed a Context Awareness Subsystem (CAS), intended to provide a way of recommending content that was context-

dependent and also to store these recommendations. Context was seen as "a dynamic process with historical dependencies" *(Beale & Lonsdale, 2004: p243)* – in other words, a changing set of relationships that may themselves be shaped by those relationships. An example of how this might be enacted in location-based learning can be seen in outdoor field trips, where context can be seen as interactive negotiation by the learner with their natural environment, including locale-specific activities or tasks such as data collection, recording or analysis. A first-time, occasional visitor to a particular site may engage in tasks (such as familiarisation activities or identification of plants and animals in the locale) that are different to those of a frequent visitor (such as navigating a new route or observing any recent changes in the local landscape).

It should be clear to all those who are working in this area (practitioners, researchers, end-users) that context, and how we model it or how it changes, is a critical aspect in location-based mobile learning. It is something that is core to the learning experience and thus integral to how we interact with our environment.

Location as context

In this research, location is taken to mean our outdoor environment or landscape. There have been several fascinating projects based in the outdoors, such as Ambient Wood *(Rogers et al., 2004)*; Savannah *(Facer et al., 2004)*; Frequency 1550[1]; Butterfly Watching *(Chen et al., 2005)*; CAERUS

1 *http://freq1550.waag.org*

(Naismith et al., 2005); Environmental Detectives *(Klopfer & Squire, 2008)* and Riot! 1831 *(Reid et al., 2004)*. These projects have been inspired by biological or historical aspects of the environment and presented an engaging user experience for tourists and students alike.

People have always taken an interest in their natural environment. From the early days of the hunter-gatherer, to modern farming methods and the desire for many to live in the countryside (or at least visit it), our fascination with, and dependency on, our surroundings has remained.

The romantic poets such as William Wordsworth and Samuel Coleridge were inspired by the natural world, in their creative attempts to reconcile man and nature. Wordsworth in particular was inspired by the landscape surrounding his place of birth (Cockermouth in the Lake District, England). He wrote that poetry is "emotion recollected in tranquillity" *(Jeffrey, 1989: p74)* to describe his emotional response to the landscape that was later recalled and noted down in textual form *(Jeffrey, 1989)*.

Wordsworth and his fellow poets were some of the early advocates of enjoying the landscape. Today, over 50 million tourists visit the countryside each year[2] in the UK, especially the National Parks such as the Peak District, Lake District, Dartmoor, Brecon Beacons and Snowdonia. This trend is continued across Europe, with an average of 6% of all European holiday-makers seeking destinations based purely on their natural heritage, with a location's environmental attractiveness being the main determinant of almost a third of tourists in the EU *(The Gallup Organisation, 2010)*.

Most of these visitors go to enjoy the scenery and landscape and for rest/recreational activities; other reasons include enjoyment of the peace and quiet, or to visit friends and family.

However, not all such visits are organised through social or family groupings. Educational excursions such as field trips are a popular way to get school pupils or university students to experience their natural surroundings first hand, through a variety of subjects including biology, geography, history and geology. There are also a burgeoning number of "ecovolunteer" projects, where "ecotourists" can participate in wildlife conservation and fieldwork activities at the destination of their choice[3]. There are also European organisations such as PanParks[4], who help to protect areas of wilderness whilst integrating sustainable tourism development.

"In the early days of environmental awareness, it was all about saving the rainforest, it was the environment that was out there somewhere distant. Now, there's much more of a focus on one's immediate environment and how you affect it and you're affected by it. I think that mobile contextual learning can have an important role to play in helping people of all ages to understand their context and their environment, to model it and to have control over it… For 1000 years, we've been able to annotate text, we are now developing the tools to annotate our environment."

Mike Sharples, University of Nottingham, STELLAR Alpine Rendez-Vous, Dec 2009.

It is also essential to consider how information in the landscape (location-related but not necessarily about a specific locality) differs from information about the landscape (such as the underlying geology or the visibility maps of the immediate locale.)

Information about the landscape can be further sub-divided into two aspects:

1. Objective/scientific information: biological/geological information; mining or engineering data; geographical features and land use data

2. Aesthetics of the landscape: how can we truly learn to appreciate the landscape? How do we do this and describe the landscape "correctly"?

This latter aspect could prove to be an interesting and potentially controversial issue, that parallels the opening-up of visitors to the countryside, facilitated by the expansion of the railways during 19th century, which led to mass tourism. Should we in fact be encouraging people to interact with their natural heritage or is this something that should be reserved for the special few?

2 *www.nationalparks.gov.uk/learningabout/whatisanationalpark/factsandfigures.htm*

3 *http://www.ecovolunteer.org/*

4 *http://www.panparks.org*

Summary

If learning becomes mobile, location becomes an important context, both in terms of the physical whereabouts of the learner and also the opportunities for learning to become location-sensitive. The properties and affordances of one's location vary enormously and hence other contexts become even more important, such as the task or goal or the user; the ubiquity of network access (GPS, wifi etc); the time of the year or day or even the weather. Seasons can change the visual nature of the landscape whilst inclement weather can turn an enjoyable day out into a disappointing and demotivating trudge along a wet and muddy footpath.

It is apparent that there are many challenges for those who would seek to create artful learning experiences with the natural environment. How do we construct these interactions effectively, taking into account the mobility of the learner, the device and/or the context(s)? How can we produce genuinely effective educational interventions, when ubiquity of information creates a challenge in its own right, that of managing the creation and use of the appropriate content or data at the most appropriate time and place?

This report aims to provide a comprehensive snapshot of current location-based research projects and also presents some issues and challenges that we know exist – or anticipate becoming more prominent in the next few years.

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Informal learning with mobile and social technologies: frameworks for analysis

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Background

This research investigated how mobile and social technologies influence the ways that members of a distributed online community create, store and share information. In particular, it looked at whether these technologies facilitate or encourage collaborative informal learning.

Informal learning has been identified as a widespread phenomenon since the 1970s *(Tough, 1979, Livingston, 1999, Bekerman et al., 2006)* however there has been little research into whether and how the increasing spread of powerful mobile technologies (mobile phones, Personal Digital Assistants, mobile gaming devices) and interconnected social networks (photo sharing, video sharing, wikis, web forums, web logs) have affected the ways people go about informal learning. In particular, the development of mobile technologies that use Global Positioning System (GPS) data to pinpoint geographical location alongside Web 2.0 applications that support the creation and consumption of content suggest a potential for collaborative informal learning focused around location. This research explored whether and how this potential has been realised.

Contribution to current work

The study focused on the activities of members of the Geocaching community. Geocachers are a geographically dispersed group who use mobile and Web 2.0 technologies to link the virtual social spaces of the Internet with the physical spaces that surround them, co-ordinating their activities via a website and web forum. Geocaching is based around the hiding and finding of hidden packets, or Geocaches, guided by GPS enabled mobile devices. Geocaches are hidden by Geocachers who then upload a description and the co-ordinates of the location to the Geocaching website to share with members of the community. Other Geocachers download the coordinates to their GPS devices and use these to guide them to the general location. Having found the Geocache, they then sign the log book in the cache and log the fact that they have found it on the website along with a short description of the experience and any images they want to upload.

The online Geocache description together with its associated logs builds up to form a temporal narrative of the cache location, developing a virtual network of relationships that are created as people find and log each other's Geocaches. This network is centred on the location of the cache, as described and identified on each Geocache's webpage.

This research builds on insights from the Mobilearn project that found that mobile learning is connected to the mobility of the learner moving between different sources of technological and social resources, rather than the technology *(Attewell & Savill-Smith, 2004)*. The research therefore focused on the activities of community members rather than on a particular piece of mobile or social technology and uncovered detailed information about innovative informal and collaborative learning activities that were embedded into the practices of the community.

Online survey participants were recruited from the Geocaching forums. From the 659 responses, five linked case studies were selected for interviews. This data was supplemented by information collected from the Geocaching website and forums and analysed using qualitative techniques. The analysis revealed that individual community members went to considerable efforts in order to create and engage with a variety of location-based informal learning opportunities. These findings were organised using the Preece and Shneiderman *(2009)* four-stage Reader to Leader model and showed how informal learning opportunities are built into the community membership trajectory *(Clough, 2009a, Clough, 2009b)*. These informal learning opportunities were then categorised according to the adapted framework for assessing meaningful learning with technology, adapted from Jonassen et al., *(2003)*. Jonassen's framework subdivided meaningful learning according to five attributes; Active, Constructive, Intentional, Authentic and Cooperative. Each attribute had a rubric that could be used to identify whether and how the learning opportunity conformed to that attribute.

In order to apply to an informal setting, explicit references to formal learning were removed from the rubrics. Unintentional informal learning, in which individuals encounter a learning opportunity and take advantage of it, and implicit cooperation, where community members use resources created for them by other members without consciously interacting with those members, were not fully accounted for by these assessment rubrics for formal learning. Therefore the rubrics for assessing intentional learning and cooperative learning were modified to cater for informal learning opportunities connected to incidental or unintentional learning and implicit cooperation.

Table 1 shows how the informal learning opportunities identified at each stage of community membership were classified according to Jonassen's adapted attributes for meaningful learning with technology.

Table 1: Informal learning opportunities

Johannsen's attributes of meaningful learning with technology	Preece & Shneiderman's Stages of Community Membership: Reader	Contributor	Collaborator	Leader
Active		✓	✓	✓
Intentional	✓	✓	✓	✓
Authentic		✓	✓	✓
Constructive		✓	✓	✓
Cooperative	✓	✓	✓	✓

Each stage of community membership is characterised by a particular activity. The Reader stage occurs when somebody reads the Geocaching website but has not yet contributed anything. They learn about Geocaching by absorbing information created by other Geocachers and shared via the website and forums. The Contributor stage is reached when Geocachers hunts for, finds and, most importantly, logs their find on the Geocaching website. This is a first contribution to the "persistent digital narrative of location" *(Clough, 2009b)* that signifies that they have joined the community. The Collaborator stage occurs when Geocachers decide to give back to the community by hiding Geocaches for others to discover, with the additional informal learning opportunities that this activity entails. Leaders are a small subset who take on more organisational roles within the community, such as creating and running a national Geocaching Association.

Each of the five attributes that characterise learning with technology is made up of a set of characteristics *(Clough, 2009a, Clough, 2009b)*. If the learning activity matches these characteristics, it can be said to conform to the rubric for that attribute and therefore merits an x in the appropriate field in Table 1.

Table 2 illustrates how this works by showing how one rubric, that for assessing intentional learning, was applied to the informal learning opportunities identified during Collaborator stage of Geocaching community membership.

Table 2: Intentional learning opportunities when creating a Geocache

Rubric for Assessing Intentional Learning Opportunities		
Goal-directedness	Deliberate research in order to learn more about a location in order to create an engaging Geocache.	✓
Setting own goals	Geocacher chooses location to place the cache and upon which to focus the research.	✓
Regulating own learning	Hiding Geocaches is an optional activity, therefore Geocachers set and regulate their own learning.	✓
Learning Environment Promotes Articulation of Learning Strategies with Others	Cache descriptions seldom contain details of how the research was undertaken by the cache creator, therefore this characteristic is not explicitly represented in this setting.	x
Articulation of Goals as Focus of Activity	Researching in advance of creating a Geocache represents the enactment of a goal.	✓
Technology Use in Support of Learning Goals	Web 2.0 resources may be used in conjunction with GPS technology in order to provide and supplement the information on the cache page.	✓

When hiding a Geocache, its creator needs to put together a web page describing the location. This often requires research into the location, although the nature of the research depends on the location and type of Geocache. For example, Earthcaches need geological or geographical knowledge:

"I had to do research to find out why these areas existed so I could craft my pages to educate the visitors. I knew nothing going in, so everything I learned about karst geology and piedmonts is a direct result of these caches."

(Survey response 71)

Setting traditional Geocaches or multi-caches may require research into the history of an area:

"I have begun researching ghost towns in Texas after visiting a cache located at one and as a result have placed caches in 20 ghost towns in my area to bring others to visit them. Am working on more currently."

(Survey response 460)

Also, the Geocache creator needs to use mobile technology (GPS devices) to correctly identify the location and Web 2.0 technology (the website) in order to upload the details, coordinates and images that will form the Geocache webpage.

When creating a Geocache, external resources such as links to related websites or additional information obtained through research are brought into the community by the Geocacher hiding the cache. This results not only in the creation of new learning opportunities for other community members as they seek the cache, but in an altruistically-motivated learning opportunity for the Geocache creator with the aim of creating further learning opportunities for others. However, although this is evidence of learning on the part of the cache creator, it does not represent a clear "Articulation of learning strategies with others" which is why that row in Table 2 remains un-checked. Nevertheless, because five out of six characteristics were clearly represented in this learning opportunity, the Collaborator stage of Geocaching membership was said to conform to the rubric for assessing Intentional Learning with technology.

Summary and challenges for the future

This research demonstrated the impact of mobile and Web 2.0 technologies on informal learning. Geocachers use mobile and social technologies to blur the boundaries between the virtual spaces of the Internet and the physical spaces that surround them, creating persistant digital narratives of location that provide a temporal record of place made up of the accumulated experiences of community members. The analysis revealed a growing undercurrent of collaborative and cooperative informal learning taking place among distributed networks of connected individuals, supported by innovative use of both mobile and social technologies, and gave rise to an initial set of rubrics to identify and classify informal learning with technology.

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Towards the use of Smartphones for the contextualized teaching of mathematics

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Background

In recent years much debate has taken place regarding the quality of the secondary mathematics curricula worldwide and their effectiveness in helping to produce graduates who are capable of using their knowledge of mathematics in a constructive way to power the economies of the future. Research has argued that graduates of secondary school systems are leaving school with a fragmented view of mathematics and are unable to put their knowledge to constructive use in the workplace *(Grossman Jr, 2001; Davies, 2003; Goos, 2004; Keating, 2007; Goss, 2009)*. It is argued that a number of interlinked approaches to the teaching of mathematics lie at the root of the problem. Issues identified include: an overemphasis on didactic teaching, in which the teacher is commonly seen by students as an absolute authority on the subject whose role is to transmit the knowledge that is needed to master the problem and students are discouraged from exploring possible alternative solutions or finding their own *(Muis, 2004; Conway & Sloane, 2005)*; a behaviourist approach to learning in which complex problems are commonly presented as aggregations of one-dimensional tasks which are then mastered discreetly; an overemphasis on procedure, in which mathematics is presented as a 'highly fragmented set of rules and procedures rather than a complex highly interrelated conceptual discipline' *(Garofalo, 1989)*. Most importantly from the point of view of this work is the decontextualised way in which mathematics is often taught. Students rarely are exposed to real world data, situations or problems and have extreme difficulty relating the decontextualised material they are exposed to any aspect of their lives.

Recent authoritative investigations of research on teaching and learning mathematics with technology, such as that by *(Zbiek, et al., 1992)*, focus chiefly on work reflecting constructivist rather than behaviourist approaches. Thus, they consider software that provides cognitive tools, rather than drill-and-practice packages. Examples can be found for many areas of mathematics, and a few of the best known are mentioned here. One prominent instance is provided by dynamic geometry systems such as Cabri Géomètre[1] and Geometer's Sketchpad[2], in which the user can construct geometric figures and investigate (say) invariant properties of the class of figures they represent by dragging vertices and observing the results *(Goldenberg et al., 2008)*. Hence, students can take an exploratory approach and engage with a subject often seen as abstract and difficult; ideally, though not necessarily, they make conjectures and ultimately look for proofs. Similarly, function graphing programs (including those on handheld devices) can be used to explore the properties of individual functions or of function families, and may enable students to focus on important concepts rather than on the procedures that would be involved in drawing the graphs manually. A third area is that of statistics. Students can use standard statistical and spreadsheet packages with advantage, but may construct the basic statistical concepts better through experimenting with purpose-written programs such as TinkerPlots[3], designed to help them to organise and structure data *(Konold & Lehrer, 2008)*. In all cases there are opportunities for cooperative work among students, helped by appropriate scaffolding provided by the teacher.

The MobiMaths approach

Not surprisingly, a social constructivist pedagogy is advocated by many active in the field of mobile computer supported cooperative learning (mcscl) *(Patten et al., 2006; Sharples, 2006; Kukulska-Hulme et al., 2009)*. However many mcscl applications still focus very much on delivering content (admittedly in innovative ways) rather than on creating innovative learning scenarios. In the area of mobile mathematics tools, following on from the success of the cognitive tools mentioned above versions of such tools are appearing for mobile devices. Examples include Pocket Autograph[4], Maths4Mobile[5], and MobileMaths[6]. Such tools generally do not support collaboration or contextualization, are applicable to a limited

1 *www.cabri.com*
2 *www.dynamicgeometry.com*
3 *www.keypress.com/x5715.xml*
4 *www.developerone.com*
5 *www.math4mobile.com*
6 *www.mobile-sciences.com*

section of the curriculum and do not leverage of the affordances of smartphones.

More recently *(Kukulska-Hulme et al., 2009)* have been exploring ways in which mobile technology is extending our notion of the "context" in which learning takes place. The current, and future, generation of smartphones provide functionality for: location awareness; peer to peer communication between devices; any time any where internet access; accelerometers; touch screens; image and video capabilities; and data capture. Smartphones offer an opportunity to greatly extend the contexts within which learning takes place and allow for the creation of innovative constructivist learning experiences which can overcome many of the issues with traditional mathematics education outlined previously.

The goal of this research is to create a toolkit and associated learning resources that can be used to change classroom practice in the teaching of mathematics. Following a social constructivist approach as outlined above means that: learning and problem solving occurs (where possible) in real-life contexts; learning takes place in an environment which is rich in information; learning involves performing authentic tasks in ill-structured domains; learning involves interactions with others; there is an emphasis on learning processes rather than solutions; and a cognitive apprenticeship teaching model is followed.

The research is proceeding by first analysing the affordances of smartphones and then systematically reviewing a mathematics curriculum (in our case the USA NCTM Principles and Standards for School Mathematics and the Curriculum Focal Points – **http://nctm.org/**) to identify how activities based around those affordances can be developed in each of the main areas of the curriculum. A layer of communication middleware is being developed to allow seamless communication between mobile devices and PCs across a variety of changing communication networks. A collection of tools is being developed to provide functional components to aid in the development of end user learning applications which in turn are being designed to support learning activities arising from the analysis of curriculum and smartphone affordances. Sets of teacher handbooks will also be developed to assist teachers in implementing learning activities and to scaffold the teachers in devising their own activities.

Figure 1: The MobiMaths Approach

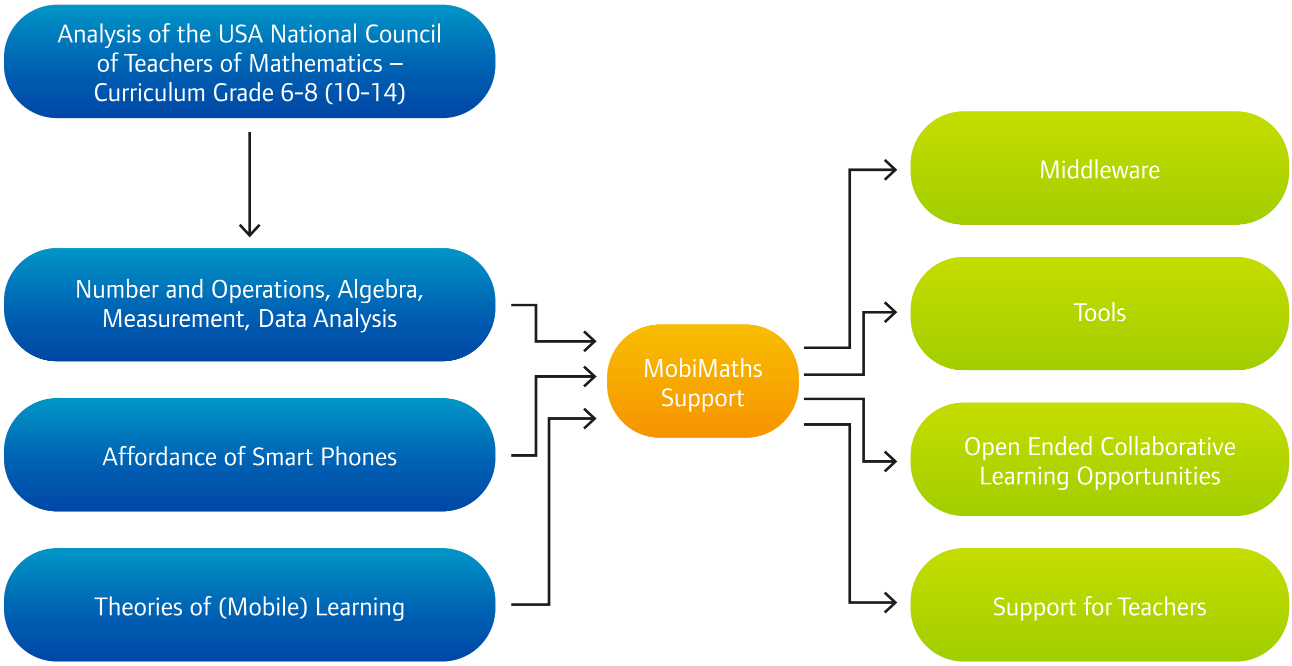
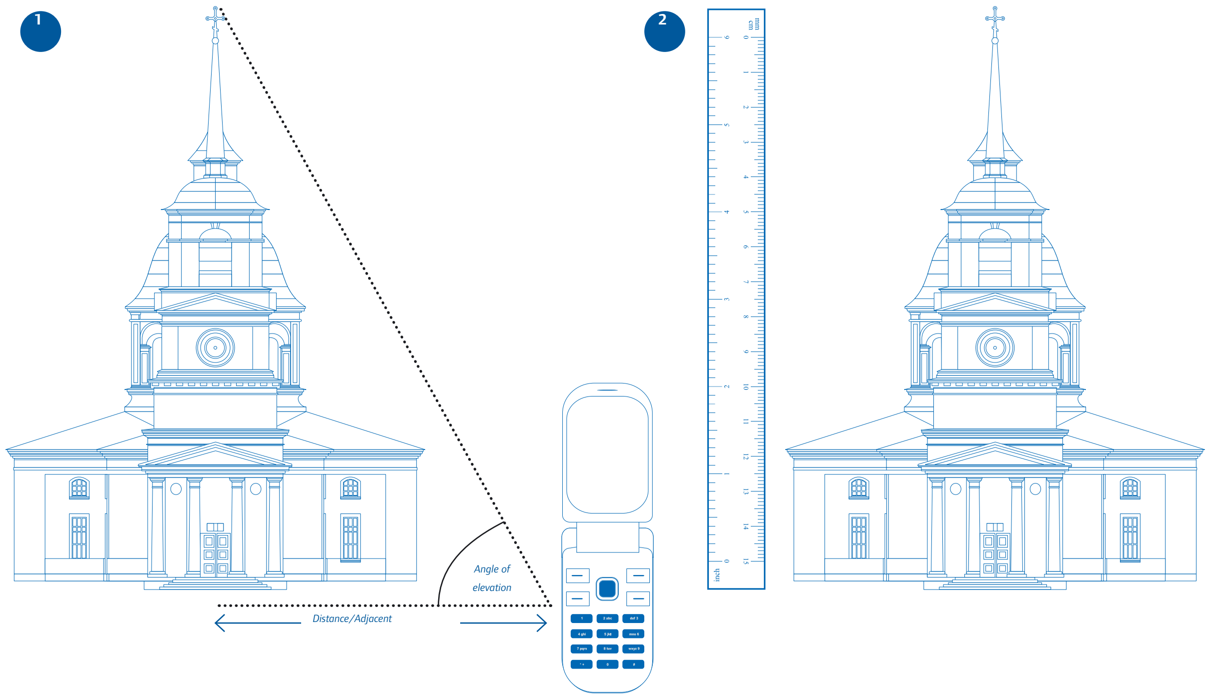


Figure 2: Two ways to measure the height of a structure



Sample learning activities

It is outside the scope of this short paper to describe in detail different areas depicted in Figure 1. Instead, by way of illustration, the following scenario is described whereby students are asked to measure the height of a tall building or monument. One way of tackling the problem would be use the accelerometer function of the phone to measure the angle of elevation and to use the GPS functionality to measure horizontal distance. Another approach would be simply to photograph the building and then measure the separation of two points on the ground and use this to calibrate a scale in the photograph and hence estimate the height (see Figure 2). The MobiMaths application toolkit will contain applications to support both these approaches and a wide variety of other activities arising from the curriculum analysis. Key to design of these applications is that they will support open-ended collaborative learning experiences of the type characterised previously.

That there are a variety of ways of tackling the same problem is good from a learning perspective, and if the "correct" answer is known beforehand this is all the better, as it allows the opportunity for the teacher to moderate a deeply engaging conversation about the underlying mathematical concepts, the relative accuracy of the different measurements and approximations etc. The whole thrust of the research is not to produce a neatly packaged set of tools to deliver mathematical content but rather to create an open ended toolkit which will allow purposeful and engaging learning activities to be designed which will act as the springboard for deep engagement with key mathematical skills.

Current status and future work

At the time of writing, an initial analysis of the curriculum has been completed and 4 key areas have been identified which need to be supported – Number & Operations; Algebra; Measurement; and Data Analysis. A preliminary assessment of the affordances of smartphones has been carried out and as a result of these two steps a set of learning activities has been specified. A technical architecture has been designed with the following features: provision of a suite of components to aid in application development; platform independence across different mobile devices; and communication across heterogeneous networks. We are currently implementing selected aspects of the technical architecture and are creating the first learning applications.

An iterative user-centred design process is being followed, including both teachers and learners. Initial testing will be in out of class settings in a computer outreach activity run by our university *(Lawlor et al., 2009)* but subsequent iterations will be evaluated in schools.

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The need to plan ahead for social and ethical challenges in contextual and location-based learning

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Background to the work

I have long been interested in how ICT can support student learning, both inside and outside formal education contexts. I view handheld devices as having the potential to both deliver contextual information at point of need and provide assessment challenges relevant to context. In 2004 I obtained a grant from the Teacher Training Agency in England to evaluate their potential for student teachers who need access to various kinds of information at multiple locations to scaffold their learning during their training. This work concluded that, for science trainee teachers, use of PDAs can match their advertised potential *(Wishart et al., 2005)* particularly where there are opportunities to bring the outside world, the science context, into the science classroom. Handhelds with integral cameras and the ability to bring out the PDA when it is needed and hide it in a pocket or handbag when it is not were important features for this *(Wishart et al., 2007)*.

Things don't always progress so well. A similar evaluation project with a group of Modern Foreign Language initial teacher trainees showed that they did not take as many location-based opportunities for supporting their and their pupils' learning with PDAs as the science teacher trainees had *(Wishart, 2008)*. Looking into these different groups, their subject cultures and the clashes between pupils' use of mobile phones and teachers' intentions for learning inside and outside the classroom has led me to question our current social and ethical practices with respect to mobile devices *(Wishart, 2009)*. This concern is shared by Traxler5 who notes we are in a state of flux with respect to changing social etiquettes and codes of practice about the use of mobile devices in different subcultures. We have ever more fantastic learning opportunities to look forward to as handheld devices gain acceptance, reliable and affordable connectivity and even the ability to project images on nearby walls or screens. Yet we are in danger of losing such opportunities through collective fear of cyber-bullying and irresponsible use by pupils of a technology whose potential their teachers haven't been given time to fully explore.

Feeling that I was working at the cusp of introducing new practices in teaching and learning I set up the University of Bristol funded network and series of workshops on "Adding a Mobile Dimension to Teaching and Learning" **http://www.bristol.ac.uk/education/research/networks/mobile**. We worked with speakers conducting exciting work on location-based learning such as the 'Wildkey' team who developed software that enabled pupils to identify 'minibeasts' and then use Google Earth in follow up science lessons to investigate their distribution *(Hughes, 2007)*. Also the 'Mudlarking in Deptford' team whose innovative use of PDAs enabled pupils to research and develop interactive, multimedia tours of their local environment *(Sutch & Sprake, 2006)*. As a result I obtained details of different research projects that together support a combination of cognitive approaches to learning theory as being sufficient to explain the concept of deep engagement seen in location based learning *(Wishart, 2007)*. We need now, to work together on and share clear, achievable codes of practice for students, teachers and researchers engaged in location based learning to ensure that these opportunities for engagement and learning are successfully integrated into educational systems across Europe.

Contribution to current work

The mobile learning community is facing challenges applying current ethical guidance. A researcher may have, for example, run his or her enquiries into mobile learning in the workplace past a research ethics committee only to discover that investigating the contents of a worker's mobile phone memory throws up details of intensely private activities. Participants can be unaware of exactly what information is stored on their phone which makes us question how researchers can plan for issues of "informed consent" in advance. My current work is aimed at investigating whether it would be more helpful for the mobile learning research community to examine the root values that underpin codes of ethical practice in research and in computing and to focus on these rather than aim to address every item in whichever published code of ethical conduct is most applicable.

The following framework, see Table 1, based on previously published key ethical issues for researching work based mobile learning *(Wishart, 2009)* and the four fundamental ethical principles *(Beauchamp & Childress,1983)* was drawn up to aid researchers in planning for ethical considerations. Each cell in the table where a key ethical issue intersects with an underpinning ethical principle becomes an opportunity for reflection as to what is current practice and what is good practice.

Not all intersections will give rise to relevant concerns depending on the situation under consideration and in some instances it will be hard to balance principles. For example with using mobile devices to capture and share images 'avoid harm' may conflict with 'respect user choice' however, the act of considering the ethical issues involved will alert the researcher or educator to the need to come to an agreement with participants or students respectively with respect to that key issue.

This framework was piloted with the other eight mobile learning researchers at the "Education in the Wild: contextual and location based learning in action" workshop at the Stellar Alpine Rendez-Vous. It became quickly clear that 'sharing resources fairly' was less helpful a principle except in consideration of ownership and where user generated content or resources could be shared with the community. The most frequently considered principle was 'avoiding harm' present in 16 of the 35 comments whereas the consideration amongst the group of key issues was much more evenly spread with each gaining between 6 and 8 comments. The most frequently completed cells, each by four participants were avoid harm:personal information and images, avoid harm:ownership and avoid harm:data storage and protection. Examples given of these were mostly focused on ensuring anonymity for participants through cropping images or removing identification from log files. However, one particular example reported, that of the researcher deliberately not reporting a personal life blog as it identified a participant managing two lovers, brings Sharples *(Sharples, 2007)* comment on deleting inappropriate data found on pupils' netbooks in his

Table 1: Framework for prioritising ethical issues for consideration before engaging in research into mobile learning.

Key Ethical Issues in Mobile Learning	Fundamental Ethical Principles			
	Do good	Avoid harm	Respect user choice	Share resources fairly
Personal information, privacy and images				
Informed consent				
Ownership				
Data storage and protection				
User generated content				

Personal Inquiry project to mind. Both incidents raise the question of who is it who decides when something is inappropriate.

The framework proved to be usable and useful, especially in forcing researchers to consider potential benefit of being engaged in research for the participants. Examples included creating location based content for others to access and engaging in personally relevant learning activities. However, participants found it difficult at times to distinguish between key issues as images are personal data and often a key part of user generated content.

Challenges for the future

For me, challenges for the future focus on supporting young people to develop ethical and responsible practices for the use of personal, mobile devices so that they can be deployed to their full potential in educational situations. Currently, education ministries or boards in countries such as India, Brunei and Sri Lanka and in states such as New York and Toronto are banning mobile phones outright in schools blaming irresponsible use by students. This is a sad reflection on the state of current education systems when there is so much that mobile devices can be used for to support learning *(McFarlane et al., 2008; Hartnell-Young & Heym, 2008)*.

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MobileMath: a location-aware game for mathematics

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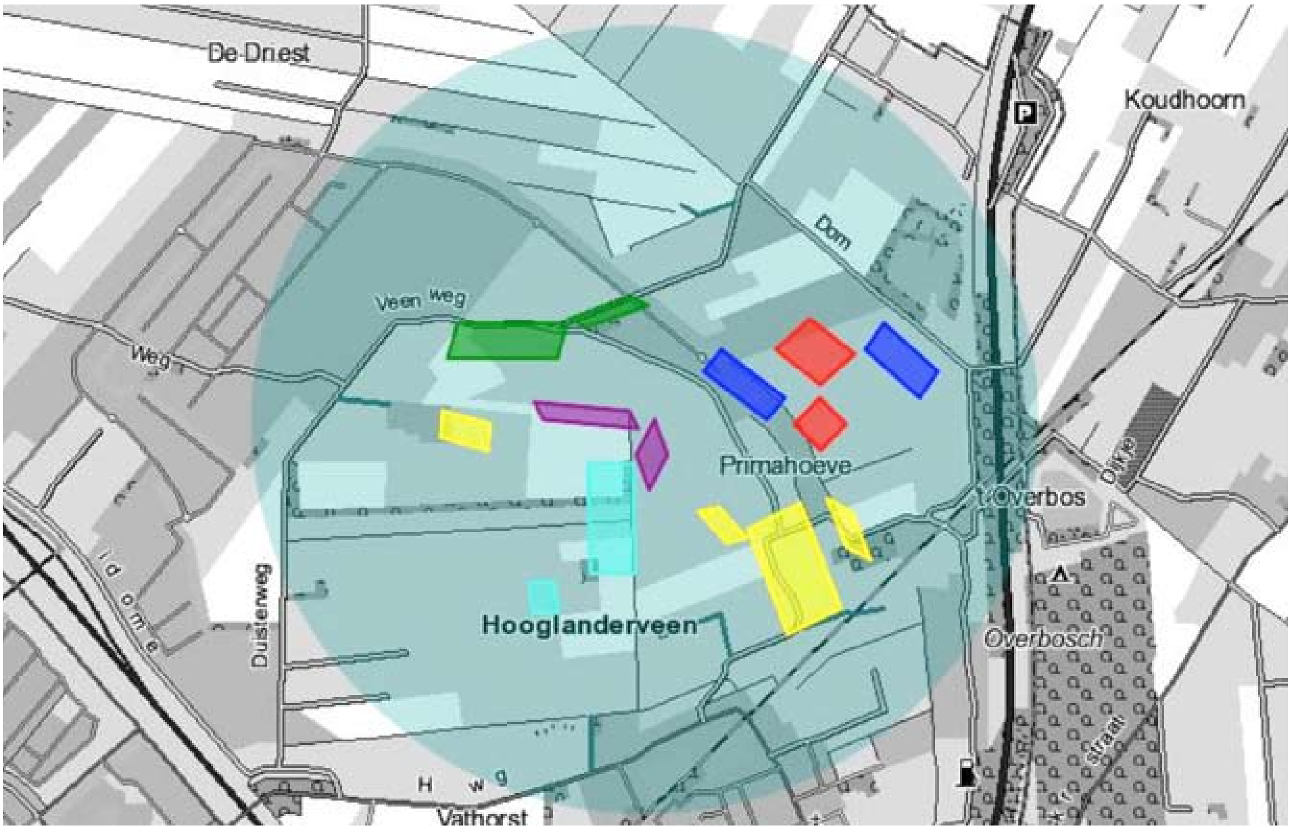

Figure 1: MobileMath

Background to the work

Mathematics is traditionally seen by a lot of secondary school students as a boring, difficult subject with not much personal involvement, creativity or social aspects. A lack of motivation and engagement leads to less effective learning. In order to be effective, the mathematics should become meaningful to the students. The theory of Realistic Mathematics Education (RME), that originated in the Freudenthal Institute, stresses that problem situations presented in learning activities should be 'experientially' real to students *(Gravemeijer, 1994)*. Other important tenets of RME are that students' own productions and constructions should be used and that social interaction is a necessary condition for learning mathematics *(Freudenthal, 1991; Treffers, 1987; Treffers, 1991)*.

Mobile devices rapidly open up new contexts for learning. A key characteristic of mobile learning is that it enables knowledge building and constructing understanding by learners in different contexts *(Winters, 2007)*. It is a small step from mobile learning to mobile gaming. Recent research has shown that the use of mobile location-aware games can contribute to engagement and meaningful learning with several school and academic subjects such as science *(Squire & Klopfer, 2007; Squire, 2008)* and history *(Admiraal et al., 2007)*. Whether this is possible for mathematics is the central question addressed in the design-research on MobileMath and other mobile gaming applications for mathematics.

Contribution to current work

Researchers/designers of WaagSociety[1] and Freudenthal Institute[2] investigated in a small scale design research how a modern, mobile and social game could contribute to students engagement in learning mathematics. In 2007/2008, a location-based mobile game that integrates concepts from mathematics and geography was designed and piloted on three secondary schools. The prototype was called MobileMath (see Figure 1).

MobileMath[3] is played on a mobile phone[4] with a GPS receiver. Teams compete on the playing field, which can be defined anywhere. The goal of the game is to cover as much area as possible by constructing squares, rectangles or parallelograms. This is done by physically walking to and clicking on each vertex

1 *http://www.waag.org/*

2 *http://www.fi.uu.nl/en/*

3 *http://www.waag.org/project/mobilemath and http://mobilemath.nl*

4 *HTC running Windows Mobile 6.0*

(point). The constructed shapes are virtual elements added to the real world. As the game proceeds the free playing space gets smaller. It is possible to 'hinder' other teams and to deconstruct their shapes. Points are gained relative to the area of the shapes constructed or deconstructed. During the game, in real-time the locations of all teams and all finished quadrilaterals are visible on each mobile phone.

The game play promotes interaction and asks for strategic thinking. The tracks of all teams as well as the constructed shapes can be viewed online during the game. The game data are stored and can be reviewed later, providing the opportunity to discuss the game play as well as the math involved.

In a pilot study the usability of the game was tested in three different secondary schools with students aged 13-14 years. Four one-hour games, each with seven or eight teams of two students (n=60), were played around the schools. Data were gathered by means of (participatory) observation, storing game data, a questionnaire for the students and interviews with students and teachers. The results from data analysis indicate that these were highly motivated students, who enjoyed playing the game. Students indicated that they learned how to use GPS, how to read a map and how to construct quadrilaterals. The experience of using MobileMath was very engaging and interactive, which itself is an important positive result. One student noted: 'It felt as if I where a ruler (measurement instrument) myself.'

Summary and challenges for the future

The pilot made clear that MobileMath is a mobile location-aware game that can be played in a school setting. Since MobileMath was also successfully played by adolescents at a music festival, we can conclude that it is also a fun game in a totally different, out-of-school context.

A strong feature of the game is that it integrates mathematics and game-play in an intrinsic way. Often games for mathematics lack this intrinsic integration: mathematics and the game-play are often only superficially connected. Design research on the integration of game-play and mathematics within the mobile gaming platform Games Atelier[5], is part of the current and future work of the Freudenthal Institute and Waag society. This includes the design of scenarios for mobile games for mathematics in Games Atelier. Within Games Atelier, pupils can create, play, share and view their own locative mobile games.

One aspect of the future work directly connected to previous work is to fully exploit and research the potential of MobileMath for learning.

Another challenge is transferring the affordances of MobileMath to other, more accurate, location-based technologies such as RFID. MobileMath is played within an area of about 3km^2 , and thus outside the 'safe' environment of school. This may be an

5 *http://www.waag.org/project/gamesatelier*

obstacle for using mobile technology, especially for younger children (aged 6-11). We are thus investigating the possibilities for using RFID or other near-field technologies in the immediate environment around school. The schoolyard (area about 30 x 60 metres) may thus become the context and the playing field for mobile (math) games, when all children have an RFID-tag (passive or active) and three RFID readers are placed around the playground. All geo-positions can then be logged, for example during a 10-20 minute game-play. Ideas for such mini-games are:

- Making geometrical patterns like squares, triangles (based on the game-play of MobileMath);
- Enacting and studying the development of an epidemic virus;
- Measuring and playing with density during a game where all children move from one place to another on the playground.

In both cases (GPS and RFID) an important requirement is access to log-files to replay the mini-games afterwards using a computer/projector (beamer) or on an interactive whiteboard. Debriefing sessions with discussion and reflection on the games played are necessary to enhance learning.

Apart from the technical and design challenges involved, the biggest challenge may be to connect the 'mobile' learning experience to the formal learning context of school in such a way that the best of both worlds is preserved.

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Mobile phones as mediating tools within augmented contexts for development

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Figure 1 (inset): Screen shot of wire-frame movie reconstruction of Nine Altars.
Figure 2: Students interacting at the Cistercian Abbey (Fountains)

Background to the work

In this paper I argue that the context for learning in the 21st Century has brought about the need to re-conceptualize or extend theories from the past if we are to develop an approach to learning design for the present and the future. Such an undertaking would appear to be timely as the nature of learning is being augmented and accelerated by new digital tools and media, particularly by mobile devices and the networks and structures to which they connect people *(Pachler et al., 2010)*. In the 1930's Vygotsky proposed the Zone of Proximal Development (ZPD) as follows:

> *"It is the distance between the actual developmental level as determined by independent problem solving and the level of potential problem solving as determined through problem solving under adult guidance or in collaboration with more capable peers."*
>
> **(Vygotsky, 1978/1930, p. 86, my bold)**

However, society is currently witnessing a significant shift away from traditional forms of mass communication and editorial push towards user generated content and augmented communication contexts. This has led me to conclude that Vygotsky's notion of a Zone of Proximal Development, which was developed in the context of 20th Century Industrial Revolution, needs to be extended to what I am calling an Augmented Context for Development. Specifically, I use the case study below in a Design Research context *(e.g. see Bannan, 2009)*; a location-based mobile learning field trip is used to explain my approach to learning design (i.e. a qualitative analysis foregrounds process and explanatory perspectives, with a focus on looking at the inner features of the situation; this is supported by questionnaire data).

Priestnall et al. *(2009)* have already articulated several issues for geography field trips using location-based 'mscape' software running on a GPS-enabled mobile phone. One issue was that the mobile devices used in the trials gave poor screen visibility in the field. Other related work is that of Beddall-Hill *(2009)* who describes a study involving intensive observation of two field teaching settings. Non-participatory observation was decoupled from the assessment process so that students could freely discuss their experiences, difficulties and learning processes while in the field and during a post assessment focus group. During one of the field trips (again Geography), Beddall-Hill reports that she "was able to use a head mounted camera to collect multimedia data of the students using the devices. This has proven to be an excellent tool with good quality sound of the student's discussions and a visual picture of the environment the interactions with and around the device".

My contribution to current work: Augmented Contexts for Development (ACD)

One educational problem that mobile learning tries to solve is the design of Augmented Contexts for Development; these place context as a core construct of the ZPD (described above), enabling collaborative problem solving where learners generate their own 'context for development'. The demonstrator project for this concept was conducted as part of the EC CONTSENS project (**www.ericsson.com/contsens**). The multimedia designer for the project (Carl Smith) made use of rich 3D visualizations and multimedia (see example in Figure 1) to augment the context for learning in such a way that would, we predicted (i.e. the development team of *Smith et al., 2009*), would allow collaborating learners to interact: with each other, with the mobile phones and with the physical environment in order to generate their own context for development (Figure 2). Tasks were devised with an archaeology tutor from Sheffield University, UK, that gave students a framework within which to operate when on a field trip to a Cistercian Abbey in Yorkshire, UK. One task, which is triggered on the mobile phone by being in the correct GPS location on the site of the Abbey, stated: "Look at a movie (see Figure 1) of the reconstruction of the interior of the church including the Nine Altars. Discuss the evolution of the structure of the abbey. Make a video blog of your discussion using the Nokia phone." The collaborating pairs had two phones, one with the 3D/multimedia visualizations running the location-based software MediaScape (**http://www.mscapers.com/**) and another mobile device for recording the video blog. Students were videoed on the site carrying out the task and a questionnaire was used gathered feedback after the session.

An evaluation of the 10 MA Landscape Studies students involved in this small trial *(Smith et al, 2009)* obtained encouraging results. All the users made extremely positive comments about what they thought of the mobile learning course, describing it as "more fun" than expected, "I enjoyed it", "interesting", two said it was "very interesting, it was a "good idea", "good!", a "fantastic experience", and "very stimulating lots of good ideas". 80% rated it as being useful for learning the subject. 60% thought the mobile device enhanced the learning experience. On the negative side, three found that having to look at the mobile devices was a distraction from engaging with the archaeology site itself, and one would like more archaeological and historical explanation. However, 80% agreed that the mobile learning experience was fun, and 9 out of the 10 users would take another mobile learning course if it was relevant to their learning needs and would recommend mobile learning as a method of study to others, which is a good indication that most of them had a positive experience. Indeed, one student commented: "The ability to be in a particular position but get a variety of views/different visual perspective was a very useful opportunity. The whole thing also got everyone talking in a way I hadn't experienced on field trips to Fountains before."

The analysis in Table 1 (of a video captured on site) illustrates the emergence of a 'co-constructed area' linking the physical world (i.e. what is left of the Cistercian Chapel) and the virtual world that is visualised in 3D on the mobile devices (Figure 1); this 'area' is inhabited by a shared representation – or what Vygotsky calls a 'time field' (see below) – that is jointly developed and owned by the students.

Table 1: Transcribed interaction of video clip captured on site

(Lots of pointing at screen and abbey; student 1 is female, student 2 is male).

Student 1: So those windows, up there isn't it, still? Is that right? So those have all changed since then.
Student 2: Yeah there was like another stage between this one and this one.
Student 1: High up.
Student 2: With three vaults.
Student 1: There's three on that side at the moment and three on that side.
Student 2. Yes.
Student 1: So three have come down haven't they, along with the window.
Student 2: And from this? (points screen). *That one is equal to that one, and actually we can not see that one (points). We can see three vaults there …*
Student 1: There must have been …
Student 2: That's the big one there. Can you see that? (points at screen)
Student 1: Do mean with the pillar?
Student 2: Yeah, you can see it's this way (?) but it's stopped there.
Student 1: That's right (makes gestures for a pillar and they both stare into the space where the missing pillar should be).

Student 2 frequently uses the word 'see', indicating that the physical and digital representations interact and inform one another in real time. Also, I suggest that the use of the word 'see' and the gestures in the video indicate that the students are arriving at a co-constructed area/ visualisation plus explanation that solves the problem of what changes have occurred to the abbey over time. There is a rapid interplay between external, tool-based and the learners internal representations.

It is noteworthy that the Augmented Context for Development that we have created for the students appears to act as part of a substitute for what Vygotsky calls the 'more capable peer'. To summarise, the elements of an Augmented Contexts for Development (ACD) are: (i) the physical environment (Cistercian Abbey); (ii) pedagogical plan provided in advance by the tutor; (iii) tools for visualisation/augmentation oriented approach that create an umbrella 'Augmented Context for Development' for location based mobile devices (acts as part of the substitute for Vygotsky's "more capable peer"); (iii) learner co-constructed 'temporal context for development,' created within wider Augmented Context for Development through (iv) collaborative learners' interpersonal interactions using tools (e.g. language, mobiles etc) and signs; (v) these aforementioned elements (i-iv) lead to intrapersonal representations of the above functions.

Within our design (the ACD) the learners generate and embed their own 'co-constructed area', or to be more precise a 'temporal context for development', as they evolve their understanding of the architectural form under investigation. Indeed, Vygotsky has already pointed out that there is a temporal dimension to development revolving around attention and perception:

> *"Attention should be given first place among the major functions in the psychological structure underlying the use of tools … the child is able to determine for herself the "centre of gravity" of her perceptual field; her behaviour is not regulated solely by the salience of individual elements with it … In addition to reorganizing the visual-spatial field, the child, with the help of speech, creates a time field that is just as perceptible and real to him as the visual one. The speaking child has the ability to direct his attention in a dynamic way. He can view changes in his immediate situation from the point of view of activities, and he can act in the present from the viewpoint of the future."*
>
> **(Vygotsky, 1978/1930, p. 35-36, original italics, my bold.)**

The above notions of attention, perception and temporality seem key processes in the Augmented and Temporal Contexts for Development and worthy of further investigation. Consequently, the CONTSENS case study will be used below to explore various key questions pertaining to the design of location-based mobile learning.

Challenges for the future

In this section I discuss the above case study using two key questions (adapted from *Bannan, 2009*) with a view to using these insights in future co-constructed or participatory research efforts. The questions are:

1. What does the use of mobile devices for informal and formal learning mean for the collection and analysis of data and what methods might we employ in a systematic, iterative and interventionist Design Research effort?

2. How do we employ the theoretical frame of the 'Augmented Contexts for Development' in a systematic process of identifying, generating and determining directions for design and research cycles? Specifically, are the notions of perception / attention / temporality a useful way forward for Design Research into mobile learning?

With respect to question 1, Grounded Theory and narrative case-study technique have already proved successful in earlier work investigating the relationship between mobile learning for on-campus learning and the learning that takes place more informally off campus *(Cook et al., 2008)*. These approaches could be used as methods to obtain a longitudinal perspective as we track communications, attention, perception etc. across multiple contexts. It may be possible to use applied ethnographic methods as well as other techniques to capture and learn from issues surrounding Augmented and Temporal Contexts for Development.

Regarding question 2, in the above case study, I captured and then analyze an instantiation of an aspect of the situatedness of learning, learner generated content and temporal contexts for development. This approach has the potential to inform both mobile learning design and research outcomes. The situated and temporal dimensions of attention and perception identified in the case study will require innovative data collection methods in follow-up work. Specifically, Mike Sharples has commented *(Personal communication in closed discussion Ning forum, November, 2009)* on the above Augmented Contexts for Development proposal as is stands as follows: "I like the core concept of "Augmented Context for Development" (ACD) in raising context as a core construct of the ZPD. One issue in relation to "time field" is whether, and how, the context can be maintained such that it persists as a scaffold. A concern would be that the ACD is both so salient and so ephemeral that it captures immediate attention (perhaps to the detriment of other more relevant visual cues and representations) but does not support a continuity of learning over time and across contexts." This is an insightful comment. Indeed, as the above evaluation showed, three study participants found that having to look at the mobile devices was a distraction from engaging with the archaeology site itself. This issue will need further consideration in the future. However, in a sense we are hitting the granularity issue; my aim in the above analysis was to provide a qualitative analysis from a process and explanatory perspective. I was therefore looking at the inner features of the situation from a development perspective (Vygotsky sees development as lying within the wider structure of learning). The temporal issues involved in terms of perception and attention took place on a minute by minute basis. However, having now related this 'insight' back to theory (i.e. Vygotsky's 'time fields') a longitudinal study is called for, as mentioned above, that looks at these issues across contexts. In further studies the LTRI research team will use a head mounted camera in order to capture 'first person' video data of learners in and across contexts. However, it should be noted that ethical considerations abound in relation to tracking learner movements and activity on tasks. Head mounted data capture is also an invasive technique and until it becomes the norm it may 'skew' data collected. Finally, how all this mass of qualitative data can be used in the design and research process in a meaningful way is still also an issue.

I now conclude by briefly outlining the questions that will help LTRI colleagues and myself, in future work, to move towards some preliminary generalised design principles and implications for broader theory.

- What similar work has been carried out on attention, perception and temporality in learning? How can the positive and deficit aspects of attention be designed for in the mobile learning environment?
- Has the Augmented Context for Development that we (the design and research team) have created for the students acted as part of a substitute for what Vygotsky calls the 'more capable peer'?
- During their continuing learning activities, what will the learning trail left behind by learners tell us as they move from one learning context to the next? How does this relate to lower granularity developmental events (the time fields)? How can we improve our understanding of how elements of context can be maintained over time, so as to scaffold a perceived continuity of learning?
- Can case studies like the above Cistercian Abbey case be used to generate parameters that can in turn be used to build Augmented Context for Development in other areas?
- How does the work described in this paper relate to Vygotsky's *(1978/1930)* notion of the functions of intention and symbolic representations of purposeful action?
- What are the implications of the above conceptually driven notion of Augmented Contexts for Development for the emerging field of mobile augmented reality (which tends to be driven by commercial developments)?

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Mobile informal learning

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Introduction

Mobile devices are gradually becoming ubiquitous and useful for personal information management and communication through different channels, such as instant messaging, social networking, or news feeds. This mobile revolution depends on two paradigms: firstly, the mobility of people and information, and secondly, the personalisation and contextualisation of information. This leads to new understandings of connectedness, interaction, participation, and context. In the field of distance education these paradigms have been reflected by the concept of flexible learning *(Collis & Moonen, 2004)* and situated learning in the field of communities of practice *(Lave & Wenger, 1991)*. Flexible learning has been the key concept of distance education for many years and focuses on the flexible organisation of learning tasks in the context of formal education. Situated learning has its background in workplace learning and refers to arranging and to embedding learning experiences in real life or authentic environments. Both concepts play an important role for the different approaches of mobile learning.

While the majority of flexible learning approaches have been related to formal education with predefined learning goals, the situated learning approaches have been linked to informal and incidental learning. With regard to acquisition of domain knowledge and skills, informal and incidental learning is characterised by its learner centred, weakly structured, and incidental nature. This type of learning is triggered by and situated in activities, experiences, and events. These "learning fragments" are usually not isolated to the learner, but part of a long-term learning process in which different learning goals are followed in parallel. Furthermore, learning processes have been identified as tightly coupled activity and reflection phases *(Butler & Winne, 1995)*.

The main benefit of mobile technologies in this context is their availability, when learning and learning needs occur to people. Thus enables people to connect their fragmented learning experiences to their long-term learning goals. This raises the question on the aspects and dimensions that are key parameters influencing learning processes, and on the technical consequences of these aspects for developing mobile solutions to support informal and incidental learning. Besides of appropriate educational content, contextualisation, personalisation, interaction, awareness, and reflection are the main aspects that need to be explored in greater detail.

Background

Sharples, Taylor, & Vavoula *(2007)* define mobile learning as "the processes of coming to know through conversations across multiple contexts amongst people and personal interactive technologies". This definition highlights several aspects of mobile learning. Firstly, mobile learning is not related to technology as such, but refers to learning processes in which technology can be involved. Secondly, mobile learning emphasises the communicative nature of learning, be it as communication between people, as interaction with technology, or as interacting with and exploring environments. Thirdly, mobile learning highlights the learners' mobility in terms of changing contexts and in interaction across contexts. Finally, the technology involved in mobile learning appears to be personal and interactive. This stresses the meaning of learning as a personal constructive activity.

This definition holds for mobile learning in formal and informal settings and it does not limit the meaning of mobility to physical mobility. Instead, the given definition of mobile learning reflects that learning takes place across space, time, topics, and technologies.

Livingstone *(2001)* distinguishes four basic types of learning along the underlying knowledge structure and the primary agency of the learning process (Figure 1). The dimension of the knowledge structure characterises the general nature of the related knowledge presentation. Livingstone distinguishes situational connected knowledge structures on one side and pre-organised knowledge structures that on the other side of this continuum. The extremes of the primary agency of learning are the learners on one hand and the teachers on the other. These two dimensions provide a basic continuum in which educational approaches can be localised. If the primary agency of the learning process is with the teachers, Livingstone defines concepts of education and training: Formal schooling if the principal knowledge structure is pre-established, and informal education and training if the knowledge structure is mainly situational. If the primary agency of learning is with the learners, Livingstone distinguishes between non-formal education for pre-established knowledge structures and of self-directed learning and collective informal learning for situational knowledge structures. These basic dimensions of learning suggest different forms and modes of communication and interaction that are specific for each type of learning.

Figure 1: Basic types of learning (based on Livingstone, 2001)

	Primary Agency	
	Learner (s)	Teacher(s)
Pre-organized knowledge structures	*Non-formal education*	*Schooling, formal education*
Situational connected knowledge structures	*Informal learning*	*Informal education and training*

Within this framework informal education refers to those forms of intentional learning activities that link mostly to situational knowledge structures and not highly structured processes, in which the teachers are the primary agency of learning, whereas "informal learning is any activity involving the pursuit of understanding, knowledge or skill which occurs without the presence of externally imposed curricular criteria" *(Livingstone, 2001: p4).*

Marsick & Watkins *(2001)* highlight the connectedness between informal and incidental learning and the relevance for lifelong learning. While informal learning is intentional, incidental learning refers to unintended learning experiences. The concepts that were identified by Marsick and Watkins in the literature can be categorised regarding the intention of learning. Theories related to informal learning are for example "social modelling", "self-directed learning", "experimental learning", and "communities of practice". Incidental learning is mostly related to theories on "learning 'en passant'", "reflection in and on action", "critical reflection", "situated cognition", and "tacit knowing". Given to this distinction informal learning can be characterised as "learner centred", "intentional", "related to practice or experiences", and "loosely structured learning processes". An expert, trainer, peers, and even the learners themselves can guide informal learning. Contrasting informal learning, incidental learning can be characterised as "unguided", "embedded into practice", "unplanned", and "unstructured". Marsick & Volpe's *(1999)* characterisation of informal learning as integrated with daily routines, triggered by an internal or external jolt, not highly conscious, haphazard and influenced by chance, linked to learning of others, and being an inductive process of reflection and action, would mostly match the revisited definition of incidental learning.

According to Marsick & Watkins *(2001)* informal and incidental learning relate to the similar learning processes. These processes include the following activities or events.

- Internal or external Triggers
- Interpreting the experience
- Examine alternative solutions
- Follow (learning) strategies
- Produce proposals for solutions
- Assess intended and unintended consequences
- Lessons learned
- Framing of the context

Central to this perspective on informal and incidental learning processes is the close relation to the contexts in which the learning takes place. Additionally, the awareness on the learning processes, prior knowledge, and the conditions is an important factor not to "become trapped by blind spots about one's own needs, assumptions, and values that influence the way people frame a situation" *(Marsick & Watkins, 2001: p31)*.

Although the two perspectives on informal learning and informal education appear to be contradicting with regard to the prime agency of learning, both clearly indicate the situational nature of informal learning. Our interpretation of the difference perspectives is related to the source that initiates learning processes. Marsick & Watkins relate informal learning to those processes that are initiated by the learners themselves, while Livingstone's perspective on informal education is related to learning processes that are not initiated by the learner but triggered externally. Later we discuss how two perspectives are related to the some contextualising principles that are applied to provide different forms of contextualized learning support.

Context occurs as a central part in the definitions of mobile learning and of informal and incidental learning. Therefore, it appears to be necessary to analyze the nature of context for designing solutions for supporting mobile informal learning. The nature of context can be analyzed from a technological and from an educational perspective.

The technological perspective originates from ubiquitous computing and relates to context-aware computing. A general definition of context is provided by Dey *(2001)*: "context is any information that can be used to characterise the situation of an entity. An entity is a person, place, or object that is considered relevant to the interaction between a user and an application, including the user and the application themselves" *(Dey, 2001: p5)*. Based on this definition Zimmermann et al. *(2007)* provided a pragmatic context model. This model focuses on the following five contextual dimensions that are relevant for context-aware systems.

- Identity
- Time and Duration
- Location
- Activity
- Relations

The identity dimension includes information about objects, people, and groups in the real world. The time dimension ranges from time-stamps through time intervals to complete histories of events. The location dimension refers to the physical positions of people and objects. This can be absolute positions or relative information such as proximity. The activity dimension reflects goals, tasks, activities, and processes of an entity. The relation dimension includes the relations between entities including social, functional, and compositional relations.

Compared to the pragmatic and implementation focused definitions of context-aware computing, context has been used loosely in the educational domain. Although the context of learning has been identified as an important factor for successful learning, only a few systematic approaches to context can be found in research. Wenger *(1998, 2007)* connects practice, learning, and context to the concepts "identity" and "meaning". Identity refers to self-identity, including knowledge and skills, the personal history, and the role in a social community. Meaning refers to the personal model of the world, which is used for physical and social orientation, sense making, and navigation. Both concepts are part of "socio-cultural production" *(Lave, 1993)* and are actively constructed by the learners.

This construction process is contextualized by six dimensions *(Lave, 1993)*, which can be summarized as following.

- Process
- Group or peers
- Situation and event
- Participation
- Concept

Organization or culture (the contextual "world" of the learners)

Wenger, White, Smith, & Rowe *(2005)* analyse the role of technology for communities of practice. This analysis mainly focused on social software that is used by online communities of practice. While this analysis focused mainly on integrated (commercial) platforms, a newer research of the authors take a wider perspective on social software by analysing the use of tools and tool sets in terms of the Web2.0 *(Wenger et al., 2009)*. The authors identified the following thirteen functional elements: "presence and visibility", "rhythm", "varieties of interactions", "efficiency of involvement", "short-term value", "long-term value", "connections to the world", "personal identity", "communal identity", "belonging and relationships", "complex boundaries", "maturation and integration", and "active community building" *(Wenger, 2001: p45f)*. These context elements can affect the success of technological applications and services of a community of practice *(Wenger, 2007)* – and thus influences the learning processes within *(Wenger et al., 2005, p. 45)*. These elements have contextual functions within the collaborative learning process that can be related to the Lave's contextual dimensions *(Glahn, 2009)*.

The AICHE model *(Specht, 2009)* is an attempt to integrate concepts of context-aware computing and of informal learning. It describes generic patterns of contextual interactions and contextual learning support. These patterns include context matching as well as context construction. Context matching approaches refer to Marsick & Watkins' perspective of informal learning, in which learners are the prime agency of learning and the learners and their situation determine learning processes. Context construction approaches refer more closely to Livingstone's reception of informal learning, in which the teacher is the primary agency of learning and learning processes are externally initiated.

The AICHE model abstracts information channels from physical artefacts. This allows abstract modelling of the arrangement and re-arrangement of information channels depending on a learner's context. The arrangement of information channels means that a channel can be temporarily bound to physical artefacts, e.g. a TV set, a mobile phone, or a desktop computer. The underlying contextualisation pattern is based on the process of aggregation, enrichment, synchronisation, and framing of information. Aggregation refers to the collection and processing of low-level sensor data into operational information. The enrichment process connects the operational information to the related entities of a process. During the synchronisation process related (enriched) entities are identified. This process results in a matching of entities. E.g., the location of a learner is matched with the location of artefacts through related location metadata. The framing process is mostly related to feedback and the stimulation of meta-cognitive processes. This process is related to the construction of educational contexts.

We can combine the perspectives on mobile learning, informal and incidental learning, and context into a working definition of informal learning. In this sense, mobile informal learning reflects the dynamics of communication and activities in unstructured and unconscious learning processes, which are embedded into practices or that span across social contexts. The AICHE model can be used to define adaptive learning environments that support informal and incidental learning. From the viewpoint of this model mobility is not only defined as the transitions between contexts, but also as the changing meanings of information channels in different contexts.

Supporting mobility

The separation of devices and information channels in the AICHE model opens a new perspective on mobile learning: the mobility of learners takes place in an ecosystem of technologies. In the last decade devices and technologies were increasingly converging. The "Internet of Things" *(Sarma et al., 2000)* and ubiquitous computing *(Weiser & Brown, 1996)* slowly become part of normal life in industrial nations. An increasing number of home entertainment devices, including TV sets and digital picture frames, are already equipped with network connectivity and can integrate seamlessly into home computing networks and connect to services on the Internet. Following the AICHE model the different devices are possible endpoints for information channels. However, the setting of the different devices varies and creates specific requirements for information provisioning. These requirements go beyond the personal computing paradigm *(Thacker et al., 1979)*.

We propose a simple framework for categorising different approaches to mobile learning that reflects the different characteristics of information technologies. This framework has two main dimensions that characterise a device: the mobility dimension and the ownership dimension. The mobility dimension distinguishes between mobile and stationary technologies. Mobile technologies are easy to transport by a single person and allow the usage while being mobile. Stationary technologies refer to technologies that require some installation before they can be used or transported. The ownership dimension separates personal and social technologies. Personal technologies are designed for being used by a single person. E.g., mobile phones, PDA, and personal computers are personal technologies. Social technologies allow simultaneous information access for groups. Interactive billboards and public information screens are examples for social technologies.

By connecting the two dimensions, four technology clusters can be indentified (Figure 2). The first cluster is related to stationary personal technologies. This cluster is directly related to personal computing. The second cluster is the mobile personal technology cluster. This cluster groups technologies such as PDA, mobile phones, and mobile gaming devices. The third cluster integrates stationary social technologies, such as electronic billboards or interactive information walls. Finally, the fourth cluster refers to mobile social technologies. As an example for such technologies may serve portable speaker systems through which sound experiences can be shared.

Figure 2: Dimensions of mobile learning support

		Primary device usage	
		Personal	**Social**
Device mobility	Stationary	Personal Computer	Smart board, public information screen
	Mobile	Mobile phone, PDA	Mobile Audio Speaker System (excl. head-phones)

Research challenges

Related to mobile learning we identified three main research challenges. The first research challenge is to understand how mobile content delivery and injection can be contextualised. The related research problems are connected to sequencing information and to integrating user contributions. The term injection refers to contextual selection and provisioning of content. In other words: content is injected into the communication of a learner depending on the situational conditions of the learning process. The ContextBlogger prototype by Tim de Jong targets this challenge at the level of mobile personal devices. This work is related to the synchronisation process in the AICHE model.

The second research challenge is how to support reflection in context. Christian Glahn, Dominique Verpoorten, and Dirk Börner have developed prototypes for mobile and stationary personal devices as well as for stationary social interfaces. These prototypes analyse how meta-cognition can be supported in informal settings and knowledge sharing. Furthermore, the current work addresses the question how mixed reality mash-ups of distributed information channels influence the personal sense-making process across contexts. This work is related to both the synchronisation and to the framing process of the AICHE model.

The third research challenge is the relation of motivational aspects and contextual learning. This challenge is related to the question, how the motivational power of games can be applied to contextual learning support. The prototype augmented reality game Locatory by Stefaan Ternier is used to analyse how games can be integrated with real world activities and learning experiences. This work is mainly targeting framing processes of the AICHE model.

The prototypes related to the three research challenges are early stage research. They are first approaches to structured research for understanding mobile informal learning that can be used for designing solutions for supporting informal and incidental learning.

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Psychological and contextual issues in technology-enhanced learning: individual differences and the student emotional experience

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This research will highlight the need to consider the psychology of learners (e.g. emotional experience and individual differences) and the role of the learning context in designing Technology Enhanced Learning (TEL). In the 'contribution' sections, I will integrate a review of current research in these areas with my own findings from two projects: one project illustrates the role of context in online student academic discussion and the other project shows the impact of context in remote project management training. Both projects initially set out to consider individual differences in learning style with remote TEL, but with the rapid technological advances, the impact of the learning context became an important and unpredicted factor in the use, experiences and outcomes of learning. In the section on 'challenges', I will summarise with some key psychological and context-related issues that require further research and consideration in the design of TEL experiences.

Background

As an academic, teaching and conducting inter-disciplinary research in Educational Technology and Psychology, my early work focussed on evaluating individual differences regarding student engagement with online seminar discussions *(Taylor, 2001)*. In these online discussions, students could contribute at any 'time' and from any 'place' and initially, I focussed on the 'time' dimension; identifying both advantages and disadvantages resulting from the asynchronous nature of communication. For example, many students developed enhanced skills in critical reflection due to the time between messages to reflect and research. However, some students expressed dissatisfaction with the lack of immediacy and presence in this form of interaction. Now it is clear that the 'place' dimension of online communication is as important as the 'time' dimension when considering learning outcomes and student experiences.

In the early 2000s, increasingly students, rather than educators, were choosing the environment in which learning took place *(e.g. Mifsud, 2002)*. This was as a result of technological advances (the size and price of laptops and faster and cheaper connections) and educational initiatives towards blended learning and student independence. An early study set out to identify the impact of the context of the home environment on learning and interactions between undergraduate students *(Taylor & House, 2003)*.

This research showed that it was important to consider the context and location, e.g. the position of the computer (in a shared area or private room) was significant in the types of interactions it promoted (social or academic) and the resulting benefits of the learning experience. As technology developed, learning from any location became a realistic possibility and research into mobile-learning, where learning was not taking place within formal learning settings, was undertaken. These early m-learning researchers highlighted the impacts of incidental learning, e.g. Vavoula, Sharples, O'Malley & Taylor *(2004)* investigated the ways in which mobile learning enabled learning throughout the day and not within scheduled time-periods. The impacts of incidental learning were also highlighted by Holzinger et al. *(2005)* as being of 'vital importance' in enabling novel and meaningful learning and resulting in long-lasting retention. An analysis of a series of online discussions (Taylor, in preparation) has identified many examples of incidental learning. Online discussion transcripts were content-analysed for indications of context of learning and revealed numerous examples where students had related material covered in lectures to personal context-based experiences. For example, one student was watching TV and related a news item on illegal downloading to lecture material regarding online deviance; another student was listening to the radio and heard a song relating to misrepresenting online identity and related this to a lecture on deception. Also, indications of time and place of learning were noted, e.g. a student related a discussion she had overheard an hour earlier while working in a bar, providing examples of male and female differences in communication style to a theory of gendered communication recently covered in the lecture. All these examples were submitted within postings to an asynchronous online discussion at the point of occurring and therefore illustrate incidental learning and the 24/7 nature of learning, where learning is taking place in contexts when/where it suits students. Although Holzinger et al. *(2005)* proposed that mobile phones would expand incidental learning possibilities, they could not have imagined the significant impact that the introduction of the iPhone two years ago has had on working and living. However, research is still scarce relating contextual TEL using such devices to their psychological impact on learners. The next two sections will highlight research that shows examples of the interaction between psychology and contextual TEL.

Contribution of psychology to inform the design and implementation of technology-enhanced learning in student-determined contexts

Although educational psychologists maintain that teachers should acknowledge and accommodate the individuality of their students, this is not always easy when implementing TEL, where the context of learning is unknown. Individual differences such as age, gender, technology experience, communication skills, personality, and learning style can affect engagement and ultimately learning outcome. For example, it may be that the change in physical learning context may encourage participation for some students, while others may be unsettled by the less structured and dynamic environment. Age and gender are important demographic factors potentially affecting learning outcomes, although their association with context and TEL is largely unexplored. Older students may be less willing to learn in new flexible and informal learning environments however, they do have more diverse knowledge and experience than younger students and may be able to apply these attributes to new learning contexts. Messmer & Schmitz *(2004)* evaluate the way males and females approach and use TEL, but do not consider context, although they suggest the role of multitasking as a factor in females' stronger engagement with learning in captive contexts. Research evaluating differences in learning style has proved to be useful for many academics implementing e-learning *(e.g. Taylor, 2002)*, however, as highlighted by Liu et al. *(2007)* none have considered context as an interacting factor, for example what aspects of the context are necessary to enable deep learners to engage effectively.

Psychologists can offer much regarding the cognitive nature of learning; for example, the research regarding context-dependent memory could be usefully drawn upon when designing an assessment strategy *(Grant et al., 1998)*. The nature of the assessment has an important influence on the potential of that material for encouraging reflection. For example, competency-based materials encourage students to focus on the knowledge they can gain and will be tested on, rather than how they reframe and conceptualise the information (reflection). However, there is a lack of research investigating the longer-term learning impacts of context-based learning and how it relates to context-dependent memory.

Contribution of psychology to understand how the context of TEL can impact on learners

There are clearly many potential benefits of students determining the context for their TEL, e.g. it can empower students by allowing them to bring information into their own learning environment making them active learners *(Hayes et al., 2003)* and it can enhance a sense of being connected to a learning community *(DuVall et al., 2007)*. However, there is little evidence that educators understand the ways that any time/any place access are impacting on learners' well-being. A study by Sharples et al. *(2005)* indicated that students felt universities were encroaching on their personal time, and Gemill & Peterson *(2006)* found that 25% of students felt stressed by the disruptions from mobile technology. However, the research reported so far specifically focuses on the psychological impact on student's time, rather than interruptions to specific context-based activities. Although there is a move in recent pedagogical research towards understanding the emotional impacts of learning *(e.g. Efklides& & Volet, 2005)* and 'positive psychology' is having an increasing influence in pedagogic research, context has not been specifically considered. For example, Morgan & Taylor *(2007)* evaluated computer-based flow and online learning but focus on impacts relating to the temporal nature of mobile learning. Research is needed to build upon this recent interest, to explore the positive emotional experiences (e.g. flow), as well as negative emotional experiences (e.g. stress, overload) associated with the context in which learning takes place.

Cognitive psychologists have shown that material delivered via multiple sensory modalities (e.g. auditory and visual) and multimedia sources (project slides, whiteboard and video) lead to more stable encoding and enhanced retrieval through multiple cues *(Moreno & Valdez, 2005)*. However, recent work shows that consideration must also be given to individual differences in learners. Taylor, Pereira & Jones *(2008)* evaluated the relationship between preferred modal learning style and adult learners' use of online project management software. The study used a measure of sensory modality preference known as the VARK Preferences Inventory *(Fleming, 2005)* which categorises learners according to one of four modal preferences for learning (Visual, Auditory, Learning, Read/Write and Kinaesthetic). Varying levels of learning resources relating to each of these modes were provided, for example: a virtual tutor (Visual), audio narration (Auditory), an online discussion and hypertext links (Read/Write), and a simulation of a model to allow interaction (Kinaesthetic). Measures collected included: completion rates; patterns of use, and performance. Although many of the outcomes of this project were based on the quantitative data *(e.g. Pereira et al., 2009)*, the qualitative data have proved to be illuminating in suggesting potential areas for further research regarding the impact of context on learning. Evidence showed that learners chose different modal features according to the context of their learning and their learning needs: for example, audio-only was used for travelling and for consolidating learning prior to testing, while full multimedia features were used for initial interactions with the learning material. Software updates and a revised design of the underlying technology now allow improved access for learners and we are about to start investigating learning across various contextual environments: desktop; web-based (with collaborative capabilities); mobile (in a format similar to YouTube), and iPhone applications.

Challenges for the future

It is clear that psychology has a lot to offer in all areas of TEL, but the most under-researched area is perhaps the psychological impacts arising from learning using hand-held devices, where the incidental learning possibilities are endless with devices such as the iPhone. However, psychological research is still scarce. There is very little evaluation of the ways that any time/any place learning are impacting on learners' well-being and emotions. Research is also needed to develop understanding of the interaction between individual differences in learners and the context in which TEL takes place; which is challenging when context of learning can be unknown! Finally, a challenge lies in developing measures and methods for assessment; in some cases this will be formalising some of the informal and incidental learning experiences, but in other cases this will require a serious re-think of assessment strategy.

In summary, there is a need for a meta-analysis of research relating psychology and the context of TEL. This analysis would help to answer questions, such as: How useful are psychometric measures for evaluating learner experience and effectiveness in different contexts of learning? Do some learners with specific learning styles perform better in field or location-based or traditional formal learning environments? How can traditional teaching/assessment methods be adapted for contextual learning to enhance learner performance and experience? How can we assess the longer-term learning impacts of context-based learning? The meta-analysis would also identify areas for further research, e.g. to develop a measure that has predictive power in identifying positive and negative combinations of individual differences, context of learning and impact on learners and their learning.

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Instrumenting zoos to bridge formal/ informal learning opportunities

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Mobile devices (especially those augmented with extra components like compasses, GPS sensors and wifi or cellular data connections) dramatically expand both the temporal and spatial circumstances under which learning can occur. As with any medium, though, the ability of mobile devices to support meaningful learning depends on how they are employed – ideally, their unique affordances, like location-awareness, should be aligned with learning challenges. The learning challenge in question here is how to enrich a typical zoo visit, which tend to produce outcomes that are more affective than educational. To attain this end, however, educational designers must be realistic about the depth of the learning goals made possible by incorporating mobile devices into a zoo visit, where opportunities to engage in deep reflection are rare. In prior work, this author found that when adapting the use of mobile devices from a classroom to a museum context, it became more useful to think of the devices as "opportunistic user interfaces," more important for the just-in-time access they provided than the activities they supported *(Lyons, 2009)*. All-in-all, the depth of the activity suffered in comparison to what was possible in a classroom environment.

This work proposes to introduce learners to the study of a genuine scientific phenomena unfolding within a zoo via authentic science practices by asking them to join a Public Participation in Scientific Research (PPSR) endeavour. Most zoo visitors are, practically speaking, only prepared to engage with the relatively lightweight "contributory" style of PPSR, which asks participants to opportunistically contribute observations. To avoid limiting the PPSR proposed here to relatively shallow, short-lived activities like making observations, this project proposes to implement the PPSR differentially, "offloading" richer scientific practices (like data analysis, hypothesis generation, and research question formation) to learners who are better-prepared to engage in such activities: students in a formal classroom context. Students will be engaged in a richer "co-created" style of PPSR, and location-aware technology will be used to bridge the activities of students in the formal context and the activities of zoo visitors in the informal context.

Background: The nature and value of learning experiences provided by zoos

Informal learning institutions have received increased attention in the past decade as being sites of legitimate science learning *(Bell et al., 2009)*. That said, the goal of many zoos is not so much to bring about increases in content knowledge or changes in skills as it is to affect visitor attitudes towards issues like conservation *(e.g., Mikenas, 2001)*. Likewise, the majority of academic research on zoos tends to focus on their capacity to induce affective changes in visitors *(Falk et al., 2009)*, and all of the key findings of a report commissioned to study the impact of zoo and aquaria visits were associated with affective rather than science learning outcomes *(Falk et al., 2007)*. This focus on affective outcomes stands in sharp contrast to what is presented and studied in other informal science institutions like hands-on science museums, which, while certainly not excluding affective experiences from consideration, certainly seem to be more focused on scientific issues and outcomes.

Some of the privileging of affective outcomes of zoo visits over scientific learning outcomes may lie in the degree of authenticity of the experiences to be had in zoos. By way of contrast, consider the nature of visits to hands-on science centres, which contain exhibits explicitly designed to bring visitors into close contact with actual scientific phenomena, and to encourage interactive exploration that resembles that of genuine scientific practice *(Oppenheimer, 1968)*. For example, a hands-on science exhibit on the scientific phenomenon of electric current might provide visitors with a working electrical circuit. To give them exposure to scientific practice, the exhibit designer might give visitors the opportunity to derive Ohm's law for themselves, by allowing visitors to substitute materials with different degrees of electrical resistance in an electric circuit and observe the effect on the circuit's current and voltage. Unlike hands-on museums, however, little about the average zoo visit resembles authentic scientific practice, and much of the scientific phenomena studied by biologists and ecologists are hard for a visitor to perceive in a zoo. Such phenomena are either hidden (e.g., the genetic characteristics of animals), prevented from occurring (e.g., predator-prey relationships), or don't take place within the confines of a regular visit (e.g., behaviours that take place on temporal or spatial scales that require multiple extended observations to perceive). It cannot be said that zoos are opposed to making such phenomena and accompanying scientific practices accessible to visitors; rather, the challenge has been that the most common media found in zoos, weather-proof signs, affords support for little more than expository text and images. With little or no capacity to support interaction and individualization of content, such signs can do little to support the individual inquiry learning processes known to be a part of scientific practice.

The use of mobile devices to support learning in zoos

Informal learning institutions of all types have been employing mobile devices to support individualized, highly-interactive experiences *(Exploratorium, 2005)*, and although slower to adopt such technology than other institutions, zoos have been no exception. One project is designed to deliver the same type of content that traditional signage would provide, augmented with audio and video recordings *(O'Hara et al., 2007)*. This approach has the advantage of making otherwise unavailable scientific phenomena (e.g., animal behaviours like capturing prey or fighting for mates) accessible to visitors. Another more recent project is designed to introduce students on school field trips to certain aspects of scientific practice by engaging them in a study of the morphology of animals in the zoo *(Suzuki et al., 2009)*. Couched as a multiple-choice quiz, however, some might argue that this is not a very authentic presentation of the activities of scientists – while scientists do make morphological comparisons, they are not driven to do so by the desire to earn points on a quiz.

Both of the projects mentioned above take advantage of the location-awareness afforded by mobile devices: content is selected and delivered to visitors based on their current location within the zoo. This capacity allows both projects to fulfil the function of traditional printed signs, with the additional benefits of presenting audio/video media and opportunities for interaction. These projects still suffer from a limitation of printed signage, however: the content is developed ahead-of-time, and is not sensitive to the current circumstances of the animals under study. Thus, neither project truly takes advantage of the temporal affordances of modern devices: their ability to receive "live" data on an as-needed basis.

The impact of "live" data streams on scientific practice

Researchers interested in studying animal social behaviours and movements have traditionally relied upon making manual observations in the field to gather data *(Altmann, 1974; Whitehead, 1996)* but modern technology like GPS sensors, heart-rate monitors, Bluetooth devices, video cameras, and RFID tags and readers are allowing scientists to collect data concerning animal interactions that has a wholly different character *(Ropert-Coudert & Wilson, 2005)*. The ability to collect nearly continuous streams of data has fundamentally changed the kinds of questions biologists might ask. For example, rather than using the rough direction and distance estimates possible through older radio collars to establish animal ranges, they can begin to use the new high-resolution data, e.g. animal-animal proximity measures *(Sherman, 1980)*, to build pictures of animal social relationships *(e.g., Lahiri & Berger-Wolf, 2008)*. Biology is far from alone: other disciplines, like ecology, are also emplacing continuous data streams to address questions that could not have been posed otherwise *(Keller et al., 2008)*. Although continuous data streams allow scientists to pose new questions, these questions may still not be answerable via instrumentation alone. For example, algorithms used to process such data to infer interaction patterns *(Lahiri & Berger-Wolf, 2008)* or social networks *(Tantipathanan&h & Berger-Wolf, 2009)* are very sensitive to "oddities" in the data, as when an unmeasured variable (e.g., the presence of a threat) affects animal behaviors. Observations made by real people are invaluable in disambiguating such episodes.

Mobile devices and public participation in scientific research (PPSR)

Public Participation in Scientific Research (PPSR) or "citizen science" projects invite members of the general public to engage in active scientific research projects, by collecting data (called a "contributory" project, e.g., recording rain- fall in one's backyard), analyzing data or reporting findings (called a "collaborative" project, e.g., when birdwatchers work with scientists to write journal papers), or even co-designing research (called a "co-created" project, e.g., a community-suggested effort to monitor regional water quality designed to inform future development) *(Bonney et al., 2009)*. Many PPSR projects have sprung up to engage people in making observations of local fauna (e.g., **http://www.projectsquirrel.org/**, **http://lostladybug.org**/) or flora (**http://www.whatsinvasive.com/**), and given the location- and time-sensitive nature of these observations, many of these projects have unsurprisingly been ported over for use on smart phone platforms. Although merely "contributory" in nature, many such observation-gathering PPSR projects have been around for years, engaging thousands of people in authentic scientific inquiry, and contributing to scientific knowledge *(van der Merwe et al., 2005)*.

Contribution of current work

This project proposes to take advantage of both the location-awareness and temporality of mobile devices to support a contributory PPSR project within the Brookfield Zoo in the metropolitan Chicago area. It further proposes to differentially engage two populations of learners, zoo visitors and middle-

school students, in authentic scientific practices (namely, making observations) in the service of studying a real scientific phenomenon. We are proposing to make real animal behavior the phenomenon of interest by placing GPS collars on peafowl, which are free to roam anywhere within the zoo grounds. Unlike other animals at the zoo, whose enclosures allow them to be easily monitored, the daily (and nightly) activities of the peafowl are largely unknown.

"Researchers interested in studying animal social behaviours and movements have traditionally relied upon making manual observations in the field to gather data but modern technology like GPS sensors, heart-rate monitors, Bluetooth devices, video cameras, and RFID tags and readers are allowing scientists to collect data concerning animal interactions that has a wholly different character."

Students will engage in a "co-created" PPSR, where they are responsible (with the collaboration of the zoo personnel and research scientists associated with this project) to help generate research questions, analyze data, and propose and test hypotheses. They will remotely track and study the movements of birds over time in their classrooms. The GPS devices worn by the birds will provide a running record of their movements, and examining this data should allow the students identify "oddities" that require further data collection to explain. During field trips, they can examine hypotheses originally devised from afar (e.g., do the birds prefer areas with vegetation cover or open areas? Are they affected by the presence of people? Do noise levels disturb the birds?). GPS-equipped mobile devices will allow them to locate specific places and the devices' audio and video recording capabilities will allow them to further document locations.

Regular zoo visitors will engage in the PPSR in a lower-effort "contributory" fashion, using their devices as "opportunistic user interfaces." Instead of being presented with a learning activity made artificially shallow to suit the visitor's timeframe, they will be engaged in the longer-term endeavor undertaken by students. Students will post location-specific "job tickets" – when participating visitors come within range of one of these locations, they will have the option of taking on the associated ticket (e.g., "report the number of people at location X"). Time-and location-sensitive tickets can also be issued, where visitors will be asked to collect a certain type of data at a certain place and time (for example, the students might have noticed that the peafowl congregate near the zebra enclosure at 2pm every day, and wish to understand what other factors are present). Unlike prior uses of mobile devices in zoos, this project encourages visitors to engage in authentic (if shallow) scientific practices, and takes full advantage of both the spatial and temporal affordances of mobile devices.

Summary and challenges for the future

In this project, location serves as the connection point between formal and informal, augmenting the impact of the "shallow" activities of visitors and extending the reach of the "deep" activities of the students. Researchers and developers interested in using mobile devices to enhance learning must always be cognizant of what activities are and are not afforded by such devices. In the case of the PPSR project described here, visitors are asked to engage in a subset of tasks that are better-suited to the context of a casual zoo visit. The differential nature of this project was explicitly designed to avoid the pressure to artificially "dumb down" the nature of science learning when designing for mobiles. Owing to the nascent nature of this work, however, it remains an open question if the approach proposed here is an effective way to avoid the trap of promoting ever-shallower scientific content. It may very well be the case that the dominant influence over the shallowness/depth of the learning activities is not the form-factor of the technology, but rather the social circumstances would-be learner finds herself in – whether the learner is alone, is accompanied by children or adults, or has just arrived or is near the end of a visit. Research in formal learning has long been exploring how to reach learners who are at different degrees of mastery, often adapting the technology to support the learner's current level; perhaps research in informal learning will need to explore how to reach learners who are in different social circumstances.

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Witnessing learning in mobile settings using a head mounted camera

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Background to the work

The focus of this research is upon learning with mobile devices in case-based activities on field trips. It is investigating the influence that mobile devices have on learning processes and outcomes, but also how these might influence the use of the device itself. This research does not deliver an intervention or new form of technology but is instead a case study into current practices of technology-enhanced learning use on field trips. It sets out to reveal the finer details of the complex interactions that take place in a setting with a huge variety of actors (including students and staff), actants (non-human influencers such as learning outcomes and the environment) and artefacts (such as technology and maps). From this we may be able to identify themes, practices and objects that may encourage and/or inhibit learning processes to take place.

The fieldtrip setting is a highly complex semi-formal learning environment. It usually employs case-based learning strategies with problem-solving elements to design for collaborative tasks in a real-world setting. The implicit learning aim is to experience the processes of conducting research or work-related activities in the real world. Students have to successfully negotiate the natural environment and its constraints while trying to fulfill the educational outcomes. This is a unique situation for many students, whose learning is primarily conducted in highly structured and controlled artificial settings, i.e. the lecture hall. However natural science subjects such as geography need their students to be able to incorporate the theory and skills they have learnt into work in the 'field'. Of specific interest to this research is the deployment of these skills and knowledge in a real world setting (albeit still artificially organized) when combined with technology.

When using technology in the natural environment, many issues such as battery life, processing power, visibility, durability and usability become apparent. During the data collection already undertaken different students placed varying levels of trust and reliance on the different technologies in their use. Students are tasked with using the technology supplied to aid them in negotiating the environment, achieving the learning outcomes stated and so completing the given project. As more courses begin to take up the many advantages of using technology in the wild such as real time digital recording and analysis, location based services, GPS, augmented reality, multimedia creation and manipulation. It seems necessary to consider what challenges currently occur while using this kind of technology and therefore how these challenges might be better designed for pedagogically.

Research questions

The aim of this research is to investigate the use of brought-in teaching devices and some personal mobile devices in case-based fieldwork settings. This elicited the following questions:

What social interactions are occurring around the mobile devices on the field trip? Is the device influenced by and/or does it influence these interactions? If so, how?

What concepts and framework are most useful for description and interpretation of the learning processes and social interactions observed in this setting with special emphasis upon the mobile device's role? How can these interpretations enhance design for learning with mobile technologies?

This brief report however concentrates on assessing the use of a head-mounted camera for data collection purposes. The aim of this technique is to try and capture the social interactions with the least amount of researcher interference possible in order to obtain suitable data for the first question. The report also briefly considers (towards the end of the contributions section) a working part of the conceptual framework (boundary objects) which influences the latter half of the second question.

Methodology and data collection

Research in this setting is made difficult by its social complexity and the fact that the setting is not fixed in time and space. A field trip will traverse different contexts, not always following a set plan. During this, many actants may influence the course of actions taken. Time is limited as it is short residential course and each project is allotted a fixed amount of time within the week. Students and lecturers are likely to continue working throughout the day and evening without the usual constraints and routines of their home life. Hence when, who, what and where is important and must be observed. And how?

Initial data was collected during two separate postgraduate geographic information systems (GIS) field trips with City University and Kingston University, in collaboration with the JISC funded MORSE project. Intensive observation was conducted of the two field-teaching settings supported by video, audio, photography, field notes and focus groups *(Beddall-Hill & Raper, 2009)*. Naturalistic observation was used in order to follow and become a peripheral member of the student groups while on the residential field trips. The research was not undertaken as a participant of the activities of the projects but as an observer so as to minimize any effects on the assessment results. However, the researcher became a honorary member through following, observing and interacting with the groups in a supportive manner in order to gain trust and insider information on the group's thoughts and activities. The data collection strategies were kept as discrete as possible and the students were given full control in terms of what was recorded.

Visual methods

It is extremely challenging to achieve discretion and be unobtrusive when observing a group's behaviour – especially when observing as an outsider to the group and within the natural environment. Due to the nature of the mobile setting and length of time spent observing (often eight hours a day) video was used to capture the learning stories as they unfolded alongside field and observational notes. Visual methods in research have been widely used, with advancements in audio-visual technology; more projects are beginning to use video cameras as part of their observations. These may be highly structured or naturalist, stationary or following the action. However, at present, little has been published on using digital video in social research settings *(Pink, 2007)*. It is difficult to know when it is the right moment is to record a particular event in a social setting and do so without unduly disturbing the participants. When observing the students working back at the residence, they remained mostly in one room so a stationary camera was set up. The students were encouraged to control this recording as they saw fit. However when observing the groups outside, a more imaginative method was needed.

A recent development in visual methods is the use of a head-mounted camera – a recording method commonly used in the field of extreme sports. Most research with this tool has focused on sport and decision-making *(Omodei & McLennan, 1994; Unsworth, 2001)*. It takes a realist stance, in that the visualizations produced by the camera are true representations of how the participants see the world. However more recent work *(Brown et al. 2008)* disputes this and asserts that, similar to film-making, the representations are culturally constructed. Brown et al., *(2008)* made use of this technology with walkers and mountain bikers to explore the environments they travelled and their reflections upon the experience. They concluded that "by evoking a dynamic, in-situ, 'inside' perspective, headcam brings a new dimension to exploring how bodies, senses, technologies, thoughts and feelings become entangled in the experiences of places, spaces, landscapes and environments." (Section 7.1). This opens up a new avenue in visual methods, data collection and its subsequent analysis. This project used a head-mounted camera in an exploratory case study to assess its suitability for observing a mobile learning setting. Its success and constraints as a data collection tool in this setting will be discussed as contribution to current work.

Coniston case study

In April 2009, City University, as part of their MSc GIS, undertook a week-long residential fieldtrip based at Coniston, in the Lake District. Six students attended (two female, four male) of predominately international status, varying in age and experience. Also on the trip were one researcher (female) and three male members of staff each in charge of one of the three two-day projects the students had to complete. Each project was divided into stages: brief, planning, data collection, analysis, presentation and assessment. Mobile devices were brought in for the students to use. They consisted of sensitive GPS enabled mobile devices with Windows mobile operating systems enabling them to run the GIS software ArcPad (a mobile version of the software being taught on the course, ArcView). The students also had their own devices, which included cameras, laptops and a Garmin Gecko (GPS tracker) that they had been given as part of the course. However, despite 'owning' and using the Geckos for practice before the field trip, few had become familiar with them.

Contribution to current work

The head mounted camera was a POV.1 Action Camera which retails for approximately £500. This equipment proved ideal for this setting as it is waterproof, dustproof and shock-resistant. The system included a mountable camera bullet style camera, with a built-in recorder and external microphone. There was also a wireless remote control that is effective up to several metres allowing the researcher to remain at a distance but still 'tag' any scenes of interest for later analysis. The system uses SDHC Cards (up to 8GB) and software for managing videos and accessing the 'tags' created. However, this project successfully used other programs (VLC and iMovie) to open and edit the output (AVI.). 8GB provided up to sixteen hours record time, and the standard AA batteries lasted around eight hours of record time. The quality was near DVD standard, taking only minutes to transfer from the SD card and could be viewed immediately. The angle set up on the helmet reduced the need to blank out faces. The camera may have also been attached to other parts of the body or equipment if needed. In comparison a Panasonic digital camera (with video capabilities) was also used but operated by the researcher. The audio when used outdoors was of poor quality and the 4GB SD cards could only capture fifteen minutes of video at a time. Carrying and operating this camera was a dangerous activity at times when negotiating the varied terrain. A stationary Sony HD video camera was used for filming inside and this produced excellent quality video output. But it took hours to convert the mini DV tapes to a usable format and had it been used outdoors would have suffered similar failings to the Panasonic although the audio quality may have been better.

Figure 1: Head camera mounted and in use

Throughout the fieldwork components of their project, the students took turns in wearing the head-mounted camera (see Figure 1 with camera and microphone circled) at the same time as operating the brought-in teaching mobile device. The camera was mounted on a cycle helmet with its power pack in a pocket or a backpack. This made the equipment quite lightweight and secure. It seemed at first this might be a very obtrusive method. However during the focus groups, all the students reported initial apprehension at wearing the camera but felt that they quickly forgot about its presence and were able to get on with their activities with very little hindrance. The camera was secure so did not impede them physically or cause danger to them. The camera was focused along the student's line of sight so the use of mobile device and discussions around it and any other artifacts was clear. The sound and visual quality was excellent, although often, editing was needed to find events of interest, and passers-by were also filmed.

Care must be taken when transporting and setting up this system as, despite it being outwardly robust, the connecting pins can easily be damaged. The amount of footage produced gave a large visual data set to search, but 'tagging' sections can ease this job. It can be difficult to get the correct angle to view what is of interest and unfortunately, when mounted on the head, it is not possible to see what is exactly happening on the device's screen. If this was the goal of the research mounting it on a shoulder maybe more appropriate. To unlock its potential as a social research tool, it is necessary to appreciate that the visual representations do not reflect what the participant saw. Even with visual tracking methods, this is not possible, as gaze does not imply attention to an object or event. It is important to remember that the use of these "methods are embedded in socially and culturally situated processes of knowledge production involving researchers, participants, technologies and materialities, as is the use of any video technology in research" *(Pink 2007 cited in Brown et al., 2008)*.

Conceptual framework

During initial analysis, concepts from Actor Network Theory (ANT) and the concept of 'boundary objects' *(Bowker & Star, 1999)* was used as a frame of analysis to investigate the distinctive learning experiences associated with the use of mobile devices. The focus was upon their relationship to the learning aims and their role in influencing actions and decisions in collaborative group learning activities. However this view seems very technologically deterministic. Observing the field trips demonstrated how students mould the technology to fit their needs at that time. This was very dependent upon their confidence in the device and their knowledge of its functionality.

Boundary objects can be material in the form of objects or abstract such as ideas. They retain a common identity across contexts but are flexible enough to meet differing needs *(Bowker & Star, 1999)*. Boundary objects maybe a useful concept to consider when designing for learning with technology from an educational and technological development perspective. Both communities could use boundary objects to achieve common understandings to develop suitable activities with technology. This approach was used with success in the design of cyber cadavers *(Fleischmann, 2006)*. This kind of preplanning collaborative work is not always possible hence it maybe more useful for the educators to be aware of the kinds of boundary objects that emerge when the students use the brought-in devices during group activities. Initial analysis focused upon the brought-in teaching devices and found that they did not demonstrate the features of a boundary object as hypothesised. This may be because many of the students were unfamiliar with these devices. Instead, older technologies and visualisations displayed by the devices may be a more suitable focus *(Beddall-Hill & Raper, 2009)*.

Challenges for the future

At this stage, the teaching devices have been examined and have revealed the co-opted implementation of old technologies – such as notebooks or maps to support, refute and manage the newer teaching device's functions, performance and results. Footage reviewed from the head camera has demonstrated that brought-in teaching devices often present considerable challenges to the students attaining their learning objectives in the field. However, these are not insurmountable and often through negotiation and the use of 'boundary objects' the students are able to make sense of what is expected and move on successfully with the activity to attain the desired outcomes. Boundary objects have been a useful concept (Beddall-Hill and Raper, 2010) as they describe abstract or material objects common and familiar to different individuals who come from a variety of backgrounds, with varying experiences. They enable collaboration as they encourage sense-making within the group across contexts.

Further data is needed and the next set of field trips (planned for April 2010) will observe the use of brought-in and personal devices such as cameras. The later may act as boundary objects due to familiarity. A comparison could be made between the influences on and by 'brought in' vs. 'personal' devices in this setting. Personal devices will be defined as those intimately known to the individual such as cameras and the geckos. It is hypothesised that these may help them to make sense of the activity more quickly and may provide a mediation service for interactions with others and their technologies. It may be that by using familiar technologies as boundary objects, students can more successfully negotiate the challenges of newer forms of technology in an assistive sense. Ultimately the growth of location-based service capabilities (such as GPS and sensors on personal devices) may mean that personal devices become more suitable (and perhaps more appropriate given the intimate knowledge their owners have about them) for working in fieldwork settings.

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Augmenting the field experience: A student-led comparison of techniques and technologies

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In this study we report on our experiences of creating and running a student fieldtrip exercise which allowed students to compare a range of approaches to the design of technologies for augmenting landscape scenes. The main study site is around Keswick in the English Lake District, Cumbria, UK, an attractive upland environment popular with tourists and walkers. The aim of the exercise for the students was to assess the effectiveness of various forms of geographic information in augmenting real landscape scenes, as mediated through a range of techniques and technologies. These techniques were: computer-generated acetate overlays showing annotated wireframe views from certain key points; a custom-designed application running on a PDA; a mediascape running on the mScape software on a GPS-enabled mobile phone; Google Earth on a tablet PC; and a head-mounted in-field Virtual Reality system. Each group of students had all five techniques available to them, and were tasked with comparing them in the context of creating a visitor guide to the area centred on the field centre. Here we summarise their findings and reflect upon some of the broader research questions emerging from the project.

Background

Field trips have proved popular and effective in many disciplines including geography, biology and the natural sciences *(Rieger & Gay, 1997)*; however have been difficult to scale to large numbers of students. The one-to-many model of expert leader describing landscape features to the students can lead to difficulties in engagement, and the adoption of mobile technologies to assist with in-field knowledge construction has many possibilities *(Tinker et al., 2002)*. Other examples include "Wireless Coyote", where tablet PCs were used to record and share environmental information *(Grant, 1993)*; "Cornucopia", where varieties of corn were logged with mobile devices *(Rieger & Gay, 1997)*; "Plantations Pathfinder", an electronic visitor guide to a garden attraction; the augmentation of real environments with locative media in "Ambient Wood" *(Rogers et al., 2004)* and aspects of geospatial awareness explored through "Savannah" *(Facer et al., 2004)*. Location-based projects have more recently exploited the location-aware aspects of mobile devices, in particular various positioning capabilities. An example is the "GUIDE" system, a location-aware electronic tourist guide for Lancaster, UK *(Cheverst et al., 2000)*. The creation of mediascape authoring environments, for example the "mscape" platform *(Stenton et al., 2007)*, allowed users to define trigger regions on a map enabling multimedia elements to be delivered automatically in the field.

Contribution to current work

Many of the aforementioned examples which have a strong teaching and learning context focus on the effectiveness of mobile technologies to engage students in a particular subject-based learning activity. Where digital geographic information is being used in the field, there is an opportunity to focus learning objectives on the effectiveness of both device and data representation in effectively portraying aspects of the real landscapes that are being experienced. This paper summarises such an approach, which forms part of the more technical element of the Geography Undergraduate and Taught Postgraduate curricula, namely Geographical Information Science (GIS).

The project, called "Augmenting the Visitor Experience (AVE)", occupied one day of a four day residential fieldtrip module called "Mobile and Field GIS", based around Keswick in the Lake District, Cumbria, UK. Some of the techniques used in this project were developed through the SPLINT (SPatial Literacy IN Teaching) project, a collaboration between the University of Nottingham, University College London and Leicester University (lead partner). SPLINT was established as a Centre for Excellence in Teaching and Learning (CETL), funded by the Higher Education Funding Council for England (HEFCE). The main focus of activities at Nottingham was an exploration of the use of 3D semi-immersive visualisation and location-aware mobile computing within Geography curricula.

The learning objectives of the AVE project focussed on the design of robust and effective techniques for engaging the user with real landscape scenes. The broader context related to the requirements of tourists to the area (mobile tourist guides) and students on field trips wishing to know more about the landscape (mobile field assistants). More specifically the objectives were:

- To become aware of the variety of techniques available for using Geographic Information and mobile computing devices in the field, which may be used to augment a person's view of the real landscape.

Figure 1: Techniques for augmenting the visitor experience, as used on the fieldtrip in March 2009.

- To identify the types of issues which appear to influence the effectiveness of the various techniques used.
- To acquire practical skills in using all techniques.
- To evaluate the successes and failures of using the various systems, and report using evidence including video.
- To reflect upon those elements of the various techniques which showed most promise, and suggest a design for a location-aware tourist guide for the future.

A number of different techniques and technologies (shown in Figure 1) were made available to the students, who worked in groups of around five. Several hours were set aside in the field centre in the morning for preparatory work, followed by four to five hours in the field.

The five techniques were chosen to provide a wide range of screen sizes, modes of interaction, and levels of information content. A more detailed account of the five techniques used can be found in Priestnall et al. *(2009)*, and details of the Head-Mounted Display (HMD) technique in particular is described in Jarvis et al. *(2008)*.

The field study site is shown in Figure 2, the field centre being located in the village of Stair in the North West corner of the area. The area is significant in terms of the influence of geology and glacial ice action upon the physical landscape, but also rich in culture and heritage. The fell (hill or mountain) called Catbells is a popular tourist destination within easy reach of the town of Keswick, North East of the study area. There are many varied themes of interest which could form part of both mobile tourist guides and mobile field assistants in this area, and the students had to assess the available techniques as to their potential to deliver such information in an effective manner.

Figure 2: The field study area, which measures 2.5km x 2.5km

(image courtesy of Harvey Mountain Maps)

The information content offered by each technique was not intended to be the same, nor was it intended to offer a complete tourist guide experience; rather it represented samples to illustrate the variety available.

The students shared their findings through a presentation on the same evening, using whatever evidence or media elements they felt best represented their experiences in the field.

The exercise offered a useful framework to allow students to develop their own schema for evaluation, the three broad areas emerging related to the device itself, the nature of interaction, and the usefulness of information provided. Many issues arose and Table 1 summarises the capabilities of each system as emerging from the 2009 field exercise. Overall the most important general issues related to the simplicity of design and ease of user interaction, the ruggedness of the device, the size and visibility of the screen, and the richness and relevance of the information provided.

Table 1: Summary of student experiences with the five techniques used.

Technique	Positive observations	Negative observations
Computer-generated acetate	Successful format and simplicity. Electronic acetates offered as a vision for the future.	Difficult in windy conditions. Predetermined viewpoints were a drawback.
Custom PDA application	On-screen sketching facility, interactive legend and audio were popular.	Stability, incl. GPS connectivity. Screen visibility with bright sunlight ahead.
Mediascape on a mobile phone	Easy authoring (control over media placement).	Screen size and visibility rendered graphical media less effective.
Google Earth on a tablet PC	Large screen and Google Earth's data exploration environment popular.	Screen visibility, battery life, penÐbased interaction (Google Earth designed for desktop machines).
HeadÐMounted Display	Fun, engaging, good for heavily graphical information.	Technical complexity, robustness, heavy, not waterproof.

In terms of the curriculum context the exercise proved successful in engaging students in group-based evaluation and led to a critical awareness of the capabilities and limitations of mobile technologies, and the effectiveness of various forms of geographic multi-media as used in a landscape context. Student video diaries were an integral part of the exercise, and were being captured to provide evidence of the successes and failures of the techniques. They also however provided many useful insights into aspects of in-field usability and issues of geographic relevance of locative media, many of which student groups did not directly reflect upon themselves. One example of this would be video clips showing students looking at the wrong landscape feature whilst listening to audio commentaries, or struggling to orientate themselves with the real world counterparts of certain graphical representations.

Challenges for the future

Experiences from these field exercises are helping to shape our research agenda for the near future. One general research challenge is in replicating certain characteristics of the human expert field guide, and their ability to point out features of interest. Challenges in this area relate to the design of mobile applications and interfaces, the data structures used to geo-locate various forms of media, and also the techniques we can employ to observe and evaluate the user experience in the field. Many of the issues experienced with techniques employed in this field exercise related to the reliance upon heavily graphical material delivered on relatively small screens. This is leading to a greater emphasis on the effective use of audio in the field, in the particular context of mobile tourist guides. These will initially focus upon one expert domain, for example the history of mining in the area, basing user requirements around expert-led tours already existing in the study area.

An additional area of ongoing interest is the degree to which handheld Augmented Reality applications such as Wikitude (**wikitude.org**) might assist with in-field orientation, using the digital compass on board the phone. Whilst knowing the orientation of the device can assist in filtering content, interesting challenges will remain in terms of prioritising information and relating it to areas in the landscape which are not necessarily easily defined as single points of interest.

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Does the delivery of contextual and location-based education result in shallower learning strategies?

by **Brendan Tangney, John Cook, Jocelyn Wishart** and **Gill Clough**

This section is an edited transcript of a debate that was held as part of the workshop. The topic was proposed by the workshop participants. Speakers for the motion were Brendan Tangney and Jocelyn Wishart; speakers against the motion were John Cook and Gill Clough.

Speaker 1: Brendan Tangney – speaking in favour of the motion

If you look back at the history of technology and learning, to the radio, the gramophone, language laboratories and then computers/PCs and the Internet, every single one of those technologies came along with a huge big fanfare and was trumpeted as the thing that was going to revolutionise the classroom and do away with the little red school houses around the country. I put it to you that none of those technologies, over the past 100 years, have actually made any serious dint on the Victorian education model and despite hundreds of millions being spent in educational technology research and our best efforts over the past 20 or 30 years, we have made no great impression on it.

The argument I would make is that mobile technology is just another one of these trends, the new technology on the block, that comes along and promises everything and actually delivers very little. If we take the idea of Thomas Kuhn's idea of paradigms and scientific paradigms shaping research agendas, the delivery of education has got built into it an incredibly false view of what education is. Education is a process that the learner has to do themselves, it's about creating things. however the prevailing (simplified) model of education and learning takes a very shallow view, which is about delivering content. I think this is a trap that ICT and education have fallen into for years and the mobile community are in grave danger of falling into it as well, except with more bells and more whistles.

I think a very strong argument can be made that technology is not neutral. Technology has got affordances that come with it. We, as researchers, try to leverage off those affordances. I would argue that the affordance of the mobile device is to do with attention distracting, it's to do with shallowness, it's to do with sound bites. If we take the classic example of satellite navigation systems and the errors created by it – people seem to turn their brains off when they go driving with satellite navigation and find themselves in incredibly different positions. No doubt our colleagues speaking against the motion are going to produce lots of good exemplars (and there are lots of them) but that doesn't mean that the thing itself is good, because as Socrates said many thousands of years ago, "could it be that asking questions is education?" and I've yet to be asked an intelligent question by any mobile device.

Speaker 2: John Cook – speaking against the motion

Thank you to Brendan for your contribution but I think you are doing my colleagues a disservice. First of all, you talk about the history of technology; let's go there. This proposal is a knee jerk reaction as all technologies have produced. When the printing press came out, there were worries that there would be unauthorised versions of the Bible. When radio came out, there were worries of it brainwashing its listeners. When the telephone was invented, there were worries of the disintegration of community life so this is nothing new. Pens and calculators getting banned in the classroom as my eminent colleague, Mike Sharples says in his talks. This is a knee jerk reaction, this motion.

Are you saying it's better to just leave the children in the classroom and deliver to them? Because I think that is what you're saying . You went on to talk about Kuhn and about paradigm shifts. Let me talk about a paradigm shift. When the ATMs (Automated Teller Machines) were invented, we kept the ATMs in the middle of the bank. You couldn't get your money out at the weekend, you couldn't get it out when the banks were closed. Someone had a brave idea, "put them out in the streets" so you could get your money any time. This is what's happened here; the mobiles are out in the wild, they're being used by roughly six billion mobile phones in the world. But they're out there and we can make use of it in formal education, informal education, to hook students. 18% of students around the world can't even read *(the PISA studies*[1]*)*, so we're in a crisis and the mobile phones can help us with that.

What's the evidence? We can cite lots of evidence here, such as the recent *Becta report*[2]. Gill Clough gave some great examples of informal learning. I gave great examples with the Cistercian abbeys project. We're getting people learning about archaeology. Colleagues, why are you here at this workshop if you believe it's shallow?

In summary, the citizens need access to cultural resources, that's a democratic right and the people out there are using these things. Banning them on the doorway is fine for now but people are getting policies that integrate mobile devices into

1 *http://www.pisa.oecd.org*

2 *'Personal technologies for learning': Available at http://tinyurl.com/366fek8* schools and workplace. For example, Elizabeth Hartnell-Young worked with a school that banned them but then they came up with sensible policies of use. It's the way you use the pedagogy. Forget the technology; if the teachers get involved, if the work-based people are getting involved, then if you put the pedagogy first, as Gill and I have shown, then we can defeat this motion totally.

Speaker 3: Jocelyn Wishart [seconder] – speaking in favour of the motion

How can you say that we're trying to leave the children in the classroom? Of course we're not saying that. What we're saying is that delivery of context-relevant information, specifically to the location demands immediate actions, such as "look at this glacier" or "carry out this procedure on the engine" actually leads to a shallower surface learning strategy.

We all know that pedagogy is the way – we all know that learning involves active engagement, reflection, opportunities to review and there's a biological basis for that[3]. We need to repeatedly work with information to develop the synaptic connections within the brain, so that asking questions of ourselves is a way forward and to simply provide information that demands immediate action at a location doesn't enable those opportunities.

Speaker 4: Gill Clough [seconder] – speaking against the motion

I think my colleagues speaking for the motion have presented a rather over simplified view of what learning with mobile technologies is. It's not just delivering instant information that demands instant action, it actually gives you more power than that. You can act on your environment, you can collect information about your environment. You can send it somewhere using the technology in order to reflect upon it later and, in fact, I think what you've described is one of the strengths of mobile technology; the fact that it does promote deep learning and deeper reflection.

It promotes constructivist models of learning in that students interact not only with their technology but with each other, both face to face and through their technology, not only through mobile technologies but through social technologies and fixed technologies. We have a whole raft of technology available to us and, as John quite rightly pointed out, people have been afraid of technologies or what they perceive to be technologies for centuries and they've always been proved wrong. In Brendan's original description, he says "you can produce good exemplars" and I think we can and if those good exemplars aren't enough, then why are we bothering?

Speaker: Jocelyn Wishart

I've actually quite like to support Gill's point about being constructivist. I think that idea of mobile learning, collecting together information at different locations and building is a really important process for the way we understand the world. It's how science actually works so I'm all for the constructivist, collaborative approach to mobile learning at the location but you must allow time for it. I think there are issues with SatNav systems and technical systems that say "this is now how you do it" and people go away to do it and colleagues here have admitted that they turned their brain off when they turned their SatNav on.

Speaker: John Cook

Can I just say that you're taking a commercial model, you're not applying the true citizenship access to democracy, access to cultural resources model. You're perpetrating the kind of "corporates that run the world" model. We need to take control of this agenda and not allow that. If we do use the corporate systems, we change them, we appropriate them, we pervert them (and I think the SatNav is a bad example here).

Speaker: Peter Scott

I'm happy to say that I think you're obviously both right in a way because learning technology can be used badly, that's in its nature, and if you use it badly, it'll do some stupid stuff. For example, the SatNav, I actually found it incredibly useful. It is dis-empowering in a way because it tells you to turn left, you turn left and if you're unplugged and your brain is unplugged, you'll eventually become completely de-skilled but I really love to drive around now with my map on, on the SatNav, with it not telling me to do anything because I find that it gives me much more increased awareness of my context, particularly if you zoom out a little on your map. You get to see all the things you can't see flashing past you either side and, actually, depending on how you use any technology, it can be used in a very empowering way.

But actually, I definitely support Brendan's first, main point is that one of the things that teachers always do is they focus on delivery and that is a very important point; it isn't about delivery, it's about reflection and that only happens in the students, it doesn't tend to happen in the teacher and that's a sad thing.

3 *http://faculty.washington.edu/chudler/plast.html*

Speaker: Mike Sharples

I think one of the things that missing so far from this discussion is the importance of being there, the importance of being in a location, being in an environment and how that contributes to learning. Kids spend far too much time in the bedroom, in a single location, divorced from the world and we make it very difficult for them to go out into the world now. We protect them, we stop them playing outside. Every opportunity to be outside that very constrained environment of their bedroom or the classroom should be enhanced and what technologies can do is start to enhance that engagement with the environment.

It's not just about delivery of content but it's about enhancing one's awareness of the environment and making much more of your surroundings, trying to understand culturally, physically, historically where you are, where you're located and also being able to make a connection with your surroundings, with your physical surroundings. I think technology is starting to do that. SatNav is just one very small step towards making a deeper connection with your environment.

Speaker: Jocelyn Wishart

I think we all would agree with that (nods and verbal agreement from other participants).

Speaker: Leilah Lyons

I think related to that, it's not so much the- what you're describing, these students or learners being tied to these physical locations; I don't think it's just a physical location thing, I think it's also a framing issue; their perception of the range of possibilities available to them is affected by the environment that they're in and getting them outside of their usual range, I think, might actually teach things that we have never tried to teach in school like autonomy and decision making. It provides opportunities for people to frame their own investigations in ways that- they're used to being told what to do all the time but put them in a place where there isn't the support structure for that type of thinking frees them up a bit.

Speaker: Jacqui Taylor

Following on from there, I think it's nice because in the environment, it's very uncontrolled, whereas in the classroom, everything's controlled. The temperature's controlled, everything's quiet and I think it's great for kids to get out into a relatively uncontrolled context.

Speaker: Brendan Tangney

I'll just reiterate the central argument I made because I actually do think there's a huge lot of merit in it. Despite John's observation about the printing press, we as a research community have been promising that we were going to do wonderful things for learning for at least 30 years, if not longer, and by and large, we haven't done it. I think those of us that are in this new emerging community of mobile learning, I think we have to be very careful and be very cognisant of the fact that there's a huge amount of deja vu going on.

The things that we're claiming as a community have been claimed by our predecessors before, whether it was intelligent tutoring systems or adaptive systems. The Internet was going to do it [revolutionise education] or multimedia was going to do it or language labs were going to do it. What we're saying has been said by people before us and I think we need to learn from the mistakes that they made and I think we have to look very closely beyond superficial models of learning, which left to their own devices, I think the mobile technology is imminently capable of supporting a very superficial level. I was debating from the point of view of rhetoric here but I do think there is something substantial that we as a community do have to look at.

Speaker: Gill Clough

Thank you Brendan, that's an interesting point because it reminds me of a hand held learning conference I was at a couple of years ago and the strand I was in was quite teacher focused. A number of the teachers started to discuss the influence of research upon their profession, or indeed, the lack of influence. The general feeling was that researchers came into the schools, they did some tremendous things, the teachers appreciated how good they are but then, when the researchers go away, they may well have made some very valuable findings but the infrastructure isn't there to enable that transfer to continue. So it's not necessarily a problem with the technology. I think it's more a problem with how, perhaps, we structure the relationship between research and teaching.

Speaker: John Cook

I think you're right in the sense that you can just send text messages saying "here's your timetable, here's your next room change" but that's quite useful common ground information. Students find it helps them drop out of school or helps them get to their class, things like that. I think with things like the iPhone or the apps that are available on there, I find the strangest of people doing the strangest of things that you could call "meaning-making in the real world" or informal learning, whatever you want to call it. There is a bit of a shift there because it's personal technology that everyone takes with them everywhere. It's slightly unusual. It's like training shoes; it's become, for young people and for older people, they use it often as well but there is a danger of going into the digital native nonsense. A lot of our students really need help to use technologies in a way that adds criticality, analytical thinking; the things we value in universities. I think there's a challenge there as well, to get the community to investigate that but that's what I see as my challenge.

Speaker: Elizabeth Brown

I'm going to play devil's advocate here a bit and support Brendan because what Gill was just saying about the teachers are very appreciative of researchers going and working with them, that's because teachers have no time. I used to be one and I had zero time at all and that's probably one of the reasons I left. All this modern technology and the gadgets are great but I do wonder if it is maybe a means to an end to get some funding to buy some kit for the school and then the teachers haven't got the time or the resources to be able to use it properly. So all that happens is that the kids go out with a bunch of iPhones or some sort of cool gadget and, in fact, you would have been better doing the same lesson but without the technology.

Speaker: Jocelyn Wishart

Supported.

Speaker: Mike Sharples

I've got a lot of sympathy for that argument, but I do think that it's not just about delivering effective teaching via technology, it may not even be about supporting the teacher in the classroom but it's about enabling learning in different contexts, some of which may be in school classrooms, some of which may be in the home, some of which may be in the wild and it's making connections between those discrete bits of learning, starting to join them all together.

Yes, there will be disappointments, yes, teachers won't get all that they were expecting, yes, the technology won't work all the time but I think what's different is that focus in we're not now expecting that the technology's going to do the delivering, I don't think we're even expecting that the technology's even going to do all of the supporting but the technology is starting to do the connecting and particularly connecting outside and inside, connecting between contexts and that's what I think is different.

Speaker: Elizabeth Brown

We seem to all be assuming that shallower learning strategies are maybe a bad thing. I would say that if there's maybe no learning strategies in place already then shallower learning strategies are better than nothing at all.

If, for instance, you're looking at informal learning, life-long learning, work-based learning, people that are visiting a tourist attraction, a nature reserve, these are people who would maybe just wander around aimlessly, enjoy the sunshine, get wet maybe, but not really learn anything about what they're there for. Maybe giving them some kind of informal shallow learning that might be delivered through a mobile device, it's not going to make them into major scientists or give them very deep thoughts about why things are there and how they got there but it will, at least, tell them a little bit about their surroundings, make them a little bit more self-aware and maybe go on to tell other people about that. In fact, shallow learning strategies are maybe not such a bad idea.

Summing up

Speaker: John Cook – speaking against the motion

What I'm hearing, colleagues, is that you'd like to argue for this motion but I don't think anyone in this room has convinced me fully because of what I call the "outside-in and inside-out problem". People are using these [mobile devices] in very diverse and interesting ways and I love that. I think that's to be celebrated if they do.

I think shallow is a derogatory term but the making-meaning of our environment is giving you access to a democratic right to make use of cultural resources and the texts and the messages that are around us. In a sense, if you call it meaning-making, that's fine, if that's what you mean by shallow learning but I think that if you can use that as a hook and bring it into a more formal institutions and with suitable pedagogy, then we're going to get the kind of learning that suits the task and suits the curriculum or supports work-based learning.

It's whatever that deep learning is needed for the subject, and it's not for me to define that, it depends on what the discipline demands but you need to leave room for the student to contribute. All of our students, when we survey them, have got mobile phones, they buy training shoes, then a mobile phone and maybe they'll eat something eventually, so there's a choice

being made by the students that are coming to our universities but it's a choice being made by a lot of people because of the wide-spread- people like this connectivity, the being connected to your parents, connected to your children, connected to your friends. [Mobile devices are] being used in ways we don't expect and that's why I think you should oppose this motion.

Speaker: Brendan Tangney – speaking for the motion

I realise that to try to get this particular audience, of all audiences, to carry this motion would be nothing short of a miracle of the proportions of Edmund Burke or Winston Churchill so I offer these words with no expectation that I'm going to sway the most partisan audience that could be found anywhere.

I would just counsel against a prevailing mindset that just because they have them, it's important, just because they like them, it's important and just because they use them for lots of other things and ways that we never use them, none of this is in itself education value. I think we have to be very careful about that.

I suppose I'm counselling us as researchers to have that sense of critical thinking, which is crucial to make realistic breakthroughs and to actually get to the core of the problem, we have to step outside the box that we're in and I think at a very superficial level, we're all on a very techno-positivist frame of mind that what we're doing is great and we're going to revolutionise the world. I hope we will and I hope that we'll change – certainly school systems need to be changed. I don't think learning needs to be changed because that's a timeless process that hasn't changed anything from Aristotle's time and it's about people constructing their own knowledge internally. I think we need to be very careful about the way we use technology and the way we stick it in between the relationship between the teacher and the pupil or the pupil and what they're trying to learn. It was Thomas Beckett that said the most dangerous thing to do is to do the right thing for the wrong reason[4]. I think we just need to be very careful about what we're doing.

Outcome:

A vote was held and the motion was defeated.

4 *From "Murder in the Cathedral", a play by T.S. Eliot.*

Reflecting back, looking forward: the challenges for location-based learning

by **Elizabeth Brown**, **Mike Sharples, Jocelyn Wishart**, **Brendan Tangney**, **Jacqui Taylor**, **Nicola L. Beddall-Hill**, **Christian Glahn**, **Dirk Börner**, **Gill Clough, Monica Wijers, Vincent Jonker**, **John Cook** and **Leilah Lyons**

This final section of the report has been reproduced from "D3.1 The STELLAR Rendez-Vous I report and white papers", published in 2009 by the STELLAR Network of Excellence. It is included here for completeness; we, as co-authors, felt that it was important to look back at the main contributions to the workshop and also where the challenges lie for the future.

What has been learned from this workshop, especially in respect to the STELLAR Grand Challenges "Connecting learners", "Orchestration" and "Contextualisation"?

Connecting learners: The workshop examined ways of connecting learning across formal and non-formal settings, such as carrying out work outdoors and later reflecting upon it in the classroom. We also talked about the opportunities for lifelong learning and the fact that mobile learning creates many opportunities for informal learning, such as that in the workplace or for learners who are on the move (on public transport, for example). In this way, mobile and location-based learning provides settings in which new paradigms of education can be explored. This could possibly mean the separation of "schooling" (which seems to be assessment-driven) and "education" (as a more holistic endeavour). We also talked about the role of learner preferences for context-based and classroom-based learning. Another aspect is the technological opportunities for connecting learners in location, such as augmented reality platforms (e.g. Layar; Wikitude) to bring together people and artefacts from their environment, and including contexts such as history as an additional aspect.

We also discussed the ethical implications of mobile learning, such as the inherent problems in being able to track users: this is a potentially more sinister aspect of "connecting learners" and one that requires much more research. Are people happy to compromise on the availability/use of their private data if they are to benefit from this?

Orchestration: Internet users have changed from being mere receivers of web-based content to become that of "prosumers" – both producers and consumers. The quantity of data generated each day by the general public is vast, leading to information overload and difficulties in managing such information. A key challenge will be the appropriate selection of information and the technologies that generate it, so that learners are provided with appropriate content generation and filtering mechanisms.

Contextualisation: Technology has changed dramatically in the last decade and GPS is now standard. Technologically, the world has changed, but we feel that the scientific questions haven't.

Context can be created through interaction between people, settings, and artefacts. A central issue is how to create micro-sites for learning. The environment can be an active agent and resource: we can learn in environments (seizing opportunities for learning), through the environment (employing aspects of the current surroundings to structure and enrich learning), and about the environment (in environmental studies and field trips).

However, we also need to look beyond just the physical environment and look at trajectories of context and how we enable transitions between contexts. In relation to the 'orchestration' theme, where we discussed information management, it is important to realise that data can change context and so it is also crucial to consider versioning and preservation of data.

What are the new research questions and issues for location-based learning, with respect to the Grand Challenges "Connecting learners", "Orchestration" and "Contextualisation"?

Connecting learners:

- As society becomes more consumer-driven, how can we support a growing divergence between formal and informal education? How can we address this conflict (if one exists)?
- How can we connect formal and informal learning experiences?
- What learning connections might there be, between cultures? How might educational innovations connect learners on a global scale?

Orchestration:

- Will new opportunities for personal and mobile learning prompt a transformation of schooling, or will learning in and beyond school be reconciled without any fundamental change to our education system?
- How can learning outside a formal setting be managed and supported?
- How do we decide what information from the WWW should be used for learning? How do we manage this data? How do we preserve it – or how do we decide what to lose? Should we be able to go back and change data? Does this mean we are altering history, and if so, should we try and capture this? How can we capture/revisit rich aspects from the past?
- What are the potential of mobile devices to support assessment, both in formal and non-formal settings?
- In what ways do we need to be mindful of ethical issues relevant to the changing contexts of the mobile learner such as context appropriate behaviours and responsibilities, privacy and informed consent?

Contextualisation:

- Should we model context to enable more adaptive contextual learning, or alternatively should we design rich tools to support awareness and continuity of learning across contexts? If both, then how can they be combined?
- How does adding artefacts from the physical or virtual world enhance learning?

Contributors

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Nicola Beddall-Hill is an ESRC-funded PhD student at City University, London under the supervision of Professor Jonathan Raper. She is attached to the Teaching and Learning Research Programme's Technology Enhanced Learning Ensemble project (http://www.ensemble.ac.uk/). Her research is concerned with field trips in higher education. She is most interested in how the social interactions present in collaborative group work influence or are influenced by the use of mobile devices in this setting and how this may affect learning processes. Her interest in TEL stems from her previous career as a teacher in secondary and tertiary education in the UK and abroad.

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Dirk Börner is a PhD candidate at the Centre for Learning Sciences and Technologies of the Open University of the Netherlands. Working in the Learning Media Programme, he is currently conducting research on ubiquitous learning support, in particular how to utilise ambient information presentation in combination with mobile technology to support learners in authentic situations.

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Elizabeth Brown is a Research Fellow at the Learning Sciences Research Institute at the University of Nottingham. Her current research focuses around interaction with the landscape to provide 'teachable moments' to a wide variety of people who like to explore the countryside, such as visitors to National Parks or nature reserves. In particular, she is keen to find out how we can provide ad-hoc learning experiences relating to the environment, utilising location-aware crowd-sourced content.

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Gill Clough works at the Open University. Her research interests are in the field of educational technology, looking into how mobile and Web 2.0 technologies affect the ways that people collaborate and learn online, with a focus on their impact on collaborative informal learning. She is currently working as a post-doc on the 3-year EU funded xDelia project. This project uses a combination of bio-sensors (to provide data on biometric responses) together with serious games (eg. lab-based simulations, micro-games/iPhone apps) to explore and address the effects of emotional bias on financial decision making among three target groups; traders, investors and private individuals.

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John Cook is Professor of Technology Enhanced Learning at the Learning Technology Research Institute, London Metropolitan University. John has published widely, having a specific interest in four related research areas: informal learning, mobile learning, augmented contexts for development and work-based learning. He has also led on various innovative mobile learning projects for London Met; for example, the LLP CONTSENS project and his current role of providing the conceptual lead for the work-based mobile learning demonstrator within the FP7 MATURE-IP.

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Dr. Christian Glahn has a research background in Educational Sciences and Computer Sciences and has been actively working in TEL research and development for several years at the University of Innsbruck, the Austrian Research Centers, and the Open University of the Netherlands. His research focuses on contextual factors for supporting informal and incidental learning and competence development through technologies. His work combines conventional desktop centred web-based systems, mobile devices, and ambient information displays for stimulating and sustaining self-regulated learning.

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Vincent Jonker is a researcher at the Freudenthal Institute for Science and Mathematics Education (FIsme) of Utrecht University. His research interests includes the use of technology in mathematics education, both primary and secondary level. Another interest is the use of games in the context of mathematics education. His research is carried out on competitive elements, interaction, simulation and animation possibilities.

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Leilah Lyons is an Assistant Professor at the University of Illinois at Chicago with a dual appointment in Computer Science and the Learning Sciences. Dr. Lyons' research focuses on the use of technology as a mediating tool in informal collaborative learning contexts, and how the unique affordances of different form factors, from mobile devices to large displays, can be exploited to encourage pro-social and pro-learning behaviours. Current projects include FieldForward (a location-sensitive mobile application that enhances field data collection); CoCensus (a collaborative census data explorer for museums) and Symbolage (a contributory complex system simulation for ecology education).

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Mike Sharples is Professor of Learning Sciences and Director of the Learning Sciences Research Institute at the University of Nottingham. He inaugurated the mLearn international conference series and is President of the International Association for Mobile Learning. He is author of over 180 publications in the areas of technology-enhanced learning, human-centred systems design and artificial intelligence.

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Brendan Tangney is a fellow of Trinity College Dublin, where he is a Senior Lecturer in the School of Computer Science & Statistics and co-director of Trinity's Centre for Research in IT In Education. His research is concerned firstly with the design and evaluation of collaborative constructionist tools for learning and secondly with developing models for technology mediated group work in formal learning. Current projects include MobiMaths (developing tools for smartphones in the area of mathematics education) and B2C (looking at integrating an innovative technology mediated group work model into the Irish School system).

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Jacqui Taylor has a BSc(Hons) degree in Psychology, a Masters degree in Information Systems and a PhD in the psychology of Internet behaviour. Since completing her doctorate, she has worked at Bournemouth University where she has continued to research the area of social psychology and online behaviour and helped to develop an innovative BSc(Hons) Psychology & Computing degree. Her current research projects range from personality and academic online communication to the use of social networking sites to support communities such as learners, the elderly and those with chronic illness.

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