Deliverable Contribution
Small Scale Study

"Location-based and contextual mobile learning"

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Abstract: This study starts from several inputs that the partners have collected from previous and current running research projects and a workshop organised at the STELLAR Alpine Rendevous 2010. In the study, several steps have been taken, firstly a literature review and analysis of existing systems; secondly, mobile learning experts have been involved in a concept mapping study to identify the main challenges that can be solved via mobile learning; and thirdly, an identification of educational patterns based on these examples has been done.

Out of this study the partners aim to develop an educational framework for contextual learning as a unifying approach in the field. Therefore one of our central research questions is: how can we investigate, theorise, model and support contextual learning?

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Introduction

This paper forms a comprehensive review and is intended to act as both an introduction to the field for new researchers and also consolidate aspects of previous publications into a source of critical reference concerned with location-based contextual mobile learning, for those already working in this area.

The distinguishing aspect of mobile learning is the assumption that learners are continually mobile. Rather than seeing learners as physically present in a certain place, such as a classroom or a museum, learners are active in different contexts and frequently change their learning contexts. These contexts can be described in part by a set of parameters, including location, social activity, and learning goals. To gain a fuller understanding, it is necessary to examine how contexts for learning are artfully created through continual interactions between people, technology, and settings, and how these ephemeral learning contexts might be supported and maintained through deployment of new context-aware technologies.

This needs an analysis of what parts of context are important for effective and efficient support of learning. It also requires understanding how learning can be transferred and continued across contexts and life transitions, such as between home and school, or from college to workplace.

A key issue for design of contextual learning technology is whether it is necessary to implement explicit models of context that instantiate and interpret the parameters of location, time, activity, goals and resources so as to offer personalised learning resources; or alternatively whether learning is better enabled by contextual tools such as dynamic maps, guides and probes that offer more generic awareness and support for learners to explore their environment. The best solutions might come from combining model and tool-based technologies, which makes technology integration a central concern.

As a first step to relate the current practice in mobile learning to contextual learning we have performed a concept mapping method with the core question on "What are the educational problems that can be solved with mobile learning?". The method and basic results will be described in the following.

In a second step we have identified current research approaches, projects, and best practices in location-based and contextual mobile learning. Thirdly, we have identified educational patterns based on the best practices and the related educational problems.

Educational problems solved by mobile learning

To identify the main educational problems that can be solved by mobile learning, 20 international high-profile experts have been involved in a Group Concept Mapping Methodology. The structured participative approach combines both qualitative and quantitative methods and makes use of ideas and opinions generated by the experts.

The methodology consists of two stages and a subsequent evaluation and interpretation of the date. In the first stage the experts were asked to generate some ideas on the following aspect: “The educational problem that mobile learning tries to solve is…”.

The experts were free to generate as many ideas as they wanted to, while each statement should describe exactly one specific idea. Thereupon 11 out of 20 experts generated 82 ideas (e.g. “Maintaining continuity of learning across settings, such as between classrooms and museums on school field trips”) elaborating on the given aspect. A complete list of the collected statements see in Annex 1.

In the second stage the experts are asked to sort the generated ideas into groups of similarity, where a group is defined on how similar the contained ideas are to one another. Every group is then described with a short phrase or title. Additionally they are asked to rate the generated ideas on a 1-to-5 scale on importance and feasibility where, for importance, ‘1’ means the statement describes a less important educational problem that mobile learning is trying to solve and ‘5’ means the statement describes a highly important educational problem. Respectively, for feasibility, ‘1’ means solving the described educational problem through mobile learning is not feasible and ‘5’ means it is feasible.

The second stage of the methodology is still in progress. The evaluation and interpretation results will be included in this deliverable later on.

Contextual mobile learning

Context can be broadly defined as the formal or informal setting in which a situation occurs; it can include many aspects or dimensions, such as location, time (year/month/day), personal and social activity, resources, and goals and task structures of groups and individuals.

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.

The field of context-aware computing has developed a variety of context definitions, mostly starting from location or object context. Zimmermann *et al* [1] give a pragmatic definition of context. Following their approach the context of a person or an object can be defined by five distinct parts:

- *identity context*, this includes information about objects and users in the real world. With respect to users, their profile can include preferences, acquired-desired competences, learning style etc. This facet of context can also refer to information about groups and the attributes or properties the members have in common.

- *time context* ranges from simple points in time to ranges, intervals and a complete history of entities

- *location context* is divided into quantitative and qualitative location models, which allow to work with absolute and relative positions

- *activity context* reflects the entities goals, tasks and actions

- *relations context* captures the relation an entity has established to other entities, and describes social, functional and compositional relationships.

Generally speaking the notion of context-aware systems originated out of ubiquitous computing and the adaptation of a computer system to its changing environment. Computers that become mobile or embedded in different environments should basically be able to sense their environment and react to environmental changes. In ubiquitous computing, context is used in two ways: to encode information in order to aid later retrieval; and as a means of personalising the end user experience depending upon events from the user or usage patterns [2].

Early work in context-aware computing was largely directed towards integration and abstraction of data from environmental sensors (such as absolute and relative time and the user's physical setting including location, surroundings, and conditions), plus features indicating the user's current activity, preferences and social surroundings (such as the availability of other users nearby or accessible online), see Want *et al* [3] and Abowd *et al* [4] for some examples. This approach considered the environment as a shell encasing the user, which can be described by scalar properties such as current time, location (positioning coordinates) and a list of available objects and services. The work has led to successful demonstrations, providing context-based content and services. For example, researchers from the University of Birmingham developed mobile technology that can provide location-dependent services that adapt to whether the user is walking, standing or sitting [5].

The problem with this approach is that it models the user as receiving data from an environment, rather than interacting with it. It has been noted that this model is inherently limited, and does not capture some important and useful aspects of context (see e.g. Dourish [2]). The 'environment as shell' approach does not acknowledge the dynamics of interaction between people and their environment, for example as we move or modify objects around us to create a supportive workspace or form an *ad hoc* social network out of people with shared interests either in the immediate location or available online. It leads to the classic 'AI Frame Problem', of determining which aspects of the current situation are relevant, and how these can be operationalised as a set of machine-interpretable features. Furthermore, if we regard context as a negotiated construct between communication partners in the world, then it is likely that context as acquired by sensing mechanisms might not match the continually evolving negotiation.

This study – whilst embracing aspects of ubiquitous computing – has a focus upon ubiquitous, or mobile, learning. We believe these terms to be related but completely distinct from each other, which each having its own emphasis.

Mobile learning is not just about the mobility of the learner or the device, but also mobility across contexts. As we spend more time physically on the move, it is essential to realise that 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.

The MOBIlearn project[1] 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"* – in other words, a changing set of relationships that may themselves be shaped by those relationships. For example, the information presented to someone visiting a museum or art gallery for a second or third time, might not be as appropriate for someone for whom it is their first visit [6]. Context was not seen here as mere data, provided by the triggering of sensors, but more as an interactive negotiation between people and their environment, including local artefacts/resources and activities of the user.

Synchronizing learning activities with the physical environment in that sense can be concluded as a promising approach from various theories of learning and cognition. According to information processing theory [7] and cognitive load theory [8], human working memory has limited capacity and learning content should be structured such that the information load does not overwhelm the learner. Furthermore, multimedia learning theory [9][10] states that each sensory channel (visual and auditory) has limited processing capacity and learning is optimal when the information presented on one sensory channel augments that presented on the other. On the one hand, the limited processing capacity means the information delivered to the learner should be limited to the information relevant in the current learning context. On the other hand the complementary distribution of information given on different channels must be given. The implications for contextual learning are that information with and across contexts must be appropriately structured to reduce cognitive load and thus maximise retention.

Wenger and Lave [11] state that knowledge needs to be constructed by the learner in a realistic context that would normally involve the application of that knowledge. An authentic learning environment often provides a variability in stimuli, or multiple perspectives on the theory learnt, and needs context-dependent, highly interconnected knowledge; several aspects that are emphasised by cognitive flexibility theory [12] as important for learning. Especially, the variability in stimuli and learning tasks available in an authentic context may result in a better generalisation of the knowledge constructed by learner [13][12][14]. As stated with the encoding specificity theory [15], a realistic context would moreover result in improved recall

[1] http://www.mobilearn.org/

because the stimuli presented at the time of recall (the authentic situation) would be most alike to stimuli present at the time of learning (learning in a realistic context).

Conversation Theory [16] is a systems theory of learning that describes the process of coming to know as a continual sequence of conversation within and between individuals, groups, and interactive technologies. Successful learning occurs when the participants are able to engage in a shared conversation about the learning topic itself and about the aims and processes of the learning, continually adjusting their understanding through dialogue and exploration. Learning contexts need to be designed to enable such conversations, by providing learning materials that match the learners' current understanding, and also by provoking and facilitating dialogue and exploration.

Dimensions in contextual learning

To explore the dimensions in designing contextual learning, a review of current systems for mobile contextualised learning support, presented in de Jong *et al* [17], is used. Furthermore the authors introduce a reference model that can be used to classify the current research, to identify limitations of current applications, and to discuss new solutions and challenges for contextualised learning support. Table 1 shows the presented reference model that is comprised of five dimensions: content, context, information flow, purpose, and pedagogical model. For each dimension, the possible values are given in the column below.

Table 1: A reference model for mobile social software

Content	Context	Information flow	Pedagogical model	Purpose
Annotations Documents Messages Notifications	Individuality Context Time Context Locations Context Environment or Activity Context Relations context	One-to-one One-to-many Many-to-one Many-to-many	Behaviourist Cognitive Constructivist Social Constructivist	Sharing Content and Knowledge Facilitate Discussion and Brainstorming Social Awareness Guide Communication Engagement and Immersion

The five dimensions and corresponding values describe the following aspects of contextualised media for learning:

- The content dimension describes the artefacts exchanged and shared by users. In an analysis of the literature the main types of artefacts found were: annotations, documents, messages, and notifications.

- The context dimension describes the context parameters taken into account for learning support. The five values for the context dimension are based on an operational definition of context [1].
- The information flow classifies applications according to the number of entities in the systems involved in information flows and information distribution.
- The pedagogical paradigms and instructional models describe the main paradigm leading the design of contextualised media and the integration of media in real-world contexts.
- The purpose describes applications according to the goals and methods of the system for enabling learning.

Thus, on the one hand, the reference model describes the manipulated knowledge resources, the context in which they are used, and the different flows of information. On the other hand, the higher-level concepts of pedagogical model and purpose define how the content, context, and information flows are used and combined. Hence, by combining different values for each dimension, various forms of contextualised software can be created for different purposes and with different pedagogical underpinnings.

For example, a system with a main purpose of *sharing content and knowledge* between its users, can be described by using *documents* from the content dimension, *relations context* to describe social relations between the users, and a many-to-many information flow. Another example is a location-based information system like RAFT [2], which combines (1) the creation and delivery of documents with (2) locational context, (3) a one-to-many information flow to provide (4) a social constructivist approach for (5) increased engagement and immersion.

During this exploration also some limitations of mobile contextualised learning solutions have become clear. Summarising the following extensions to current state-of-the-art can brought forward based on these limitations provide more integrated systems with a range of functionality:

- better and wider use of metadata,
- more advanced and wider use of notification techniques,
- an improved adaptation to the user's personal preferences and learning environment or situation by using more kinds of context information than location and identity alone, and use of techniques to derive more detailed or higher level context information by a combination of different context parameters,
- more attention to systems aiming at informal and lifelong learning.

Case studies

Location-based (but not location-aware)

It is essential to note that some of the earlier projects into location-based learning were not themselves location-aware in terms of the technology, due to the limitations of the hardware available at the time. However, these projects were important pre-cursors for later research and so they are included here.

One of the first documented computer-supported field trips was “Wireless Coyote” in 1993. Twenty 11-year old children, divided into 5 groups, used modified tablet PCs to record and share information relating to the environment on a school field trip. This allowed students to share data in real-time with their peers in the other groups and challenged the traditional role of the teacher as well as the students’ own expectations [18].

Another example of how mobile computing has been used in field work is shown in the “Cornucopia” project [19] in 1997. This project involved undergraduate students in a formal teaching environment using mobile devices to record data relating to different varieties of corn, grown in a university test plot. Data was stored on flash memory cards, which were then handed in to the class instructor for them to collate data from each device back in the laboratory, and thence uploaded to a shared web space to facilitate future class discussions.

A related pilot application, “Plantations Pathfinder”, was designed to provide information to visitors in respect of a garden attraction [19]. This electronic guide (also circa 1997) could be updated for tourists much more quickly than printed matter and could record a visitor’s interests as they toured the garden with the device. It also enabled collaboration via input of data that was then uploaded to an online discussion forum, allowing users to view previously-inputted information from others as well as share their own experiences.

Location-based and location-aware

As technological advances were made throughout the 1990’s and networking infrastructures improved, so did the affordances for creating truly location-aware experiences. These projects managed to utilise not only location-based work, but also used devices that were themselves aware of their geospatial position.

Cyberguide was a project from 1997 to investigate handheld intelligent tour guides. Early demos were produced that enabled a visitor to locate nearby attractions, including local bars in Atlanta (a variation named CyBARguide) [4].

Another example of how these location-aware technologies were used can be found in the work of Pascoe *et al* in 1998, where a PalmPilot running the “stick-e note” system was used by ecologists in Africa to record contextual data relating to the behaviour of giraffes [20]. Context in this project included data corresponding to location; date/time; number of males, females and juveniles; feeding habits; vegetation type/amount and location of faecal samples.

Another location-aware system is “GUIDE”, an electronic tourist guide for use by visitors to Lancaster [21]. GUIDE provided a means of personalising information in respect of a visitor’s own interests and also various environmental parameters. It consisted of an information retrieval system; a map-based navigation system; and also a guided tour, created by the user, depending on what attractions they wanted to see.

In 2002 came the KLIV project. This explored the effects of self-produced videos, filmed on location in the workplace, on the professional education of nurses. It used barcode-equipped medical devices and PDAs with barcode scanners to provide the videos in context. When needed to be reminded about a piece of equipment or task, nurses could scan the barcode in order to view the video [22][23].

From 2004-2009 a number of environmental education projects have emerged, some of them funded through the MOBIlearn[2] and Equator[3] frameworks. Ambient Wood [24] was an Equator project, in which a playful learning experience was developed where children explored and reflected upon a physical environment that had been augmented with a combination of digital constructs. Savannah [25] was a strategy-based adventure game where a virtual space was mapped directly onto a real space, with school pupils playing at being lions in a savannah, navigating the augmented environment with a mobile handheld device. Using aspects of game play, it challenged children to explore and survive in an augmented space, by successfully adopting strategies used by lions. CAERUS was a context aware educational resource system for outdoor tourist sites and educational centres, consisting of a handheld client and a desktop admin, to provide a visual interface to add maps, define interest regions, etc. It delivered this information to visitors (such as those at the University of Birmingham's Botanic Garden at Winterbourne) through Pocket PC devices with GPS capability [26]. MyArtSpace was a service that let children 'collect' items in museums and galleries using mobile phones and then build presentations with them [27][28]. It was later developed into OOKL[4], which is currently running as a commercial enterprise [29].

In the RAFT project, live video conferences have been used to establish a video link between an expert interview in the field and a classroom from which learners could ask questions. As one important finding not only do the participants in the field trip profit from the excursion, but more importantly students in the classroom develop a more realistic interpretation of application contexts and are more interested in the topic in general. Gender differences in the use of new technology can also reduced by such approaches [30].

Another museum-based project is Ubicicero, a multi-device, location-aware museum guide in which artefacts are tagged with RFID for users to interact with via mobile devices [31].It also takes into account a user's position and their behaviour history, as well as the type of device available.

geoMole was an application developed to support Geographical Information Science (GIS) fieldwork [32]. It presented digital reconstructions of the landscape via a Windows Mobile PDA, allowing on-screen sketching and the delivery of audio relevant to the landscape visible from that point. geoMole was developed as part of the SPLINT (SPatial Literacy IN Teaching) Centre for Excellence in Teaching and Learning (CETL)[5].

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[2] MOBIlearn was a worldwide European-led research and development project from 2002-2006 exploring context-sensitive approaches to informal, problem-based and workplace learning by using key advances in mobile technologies [http://www.mobilearn.org/].
[3] Equator was a six-year Interdisciplinary Research Collaboration (IRC), supported by the EPSRC, which focused on the integration of physical and digital interaction [http://www.equator.ac.uk/].
[4] http://www.ookl.org.uk
[5] http:// www.splint-cetl.ac.uk

Another project with an environmental focus was Environmental Detectives [33][34]. It was an example of a game-based scenario in which students were asked to investigate a spill of toxic waste into the environment.

Language learning has also been a focus of some location-based learning, such as the LOCH project [Language-learning Outside the Classroom with Handhelds]. Paredes *et al* [35] examines how students participate in 'field activities' assigned by the tutor, where everyday tasks take place in real physical locations. Recent work by Fisher *et al* also explored language learning through different modalities, including handheld learning devices [36].

Besides these case studies, important platforms for developing location-based experiences have also been created. These include mScape (that allows media to be associated to geographical points and regions on the Earth's surface, creating location-aware "mediascapes" running on mobile phones or PDAs [37]) and PaSAT (a system to build mobile learning games with physical environments as playing spaces, using GPS-enabled PDAs to create location-based activities). PaSAT has been developed by Peter Lonsdale[6], a PhD student at the University of Nottingham, and used for the underlying framework for the "BuildIt!" game, used by school children to learn about the physical environment of their school in a goal-oriented game to help structure the children's planning and reflection.

Alpine Rendevous workshop contributions

Learning Sciences Research Institute (LSRI), University of Nottingham

At the University of Nottingham, there are several projects surrounding contextual learning in location-based scenarios, including the aforementioned work with PaSAT/BuildIt.

In the PI project[7], secondary school pupils have been undertaking inquiry-based science investigations inside and outside the classroom, supported by a computer-based toolkit that structures their learning activities. In one study the children explored micro-climates in their school grounds, measuring variables such as wind speed and temperature to determine where to site a bench or fly a kite. The toolkit provided a means to probe the environment and collect data, and also to guide them through the inquiry learning process and enable them to present results in the classroom.

The LSRI has also been collaborating with colleagues elsewhere in the University of Nottingham, most notably the School of Geography and the Centre for Geospatial Science. Research is being carried out into how geography students create augmented visitor experiences for tourists to the Lake District, using a range of mobile devices and techniques. This has led to some interesting results relating to affordances of the technologies and end-user experience [38] and has informed future work planned into the placement of media (particularly audio) in the landscape to deliver location-specific information. The most

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[6] http://www.peterlonsdale.co.uk/

[7] The "Personal Inquiry: Designing for Evidence-based Inquiry Learning across Formal and Informal Settings" is a project from the University of Nottingham in partnership with the Open University to help school students learn the skills of modern science, including learning in informal outdoor settings.

important contexts being considered in this research include a person's orientation to their landscape; viewsheds (maps of the visibility of the surrounding area); weather (related to screen visibility of the device and also the behaviour of the visitor); motivation/engagement of the visitor; type of visitor (school children; general public; groups or individuals); type of interaction (informal or formal); the appropriate placement of media related to a visitor's geographical position; and the suitability of different media types used to deliver information.

Previous related research also includes the "Answer Tree" system, a mobile location-based game that used collaborative game card-collecting as a means to teaching children about characteristics of trees [39]. In this project, placement of media related to the technology was an important contextual constraint: GPS visibility is not very good when stood underneath a large tree canopy. Other aspects investigated included the nature of the interaction (both with the environment and with the other groups of learners) and the type of learning taking place ("jigsaw" learning [40]).

There is also ongoing research into informal environmental education, using crowd sourcing as mechanism for creating community-driven media for sharing with the general public. Aspects of this work under particular consideration include the informal learning scenarios that are created by these conditions and other technical and social research questions connected with ubiquitous access, user-generated content, tagging and annotation.

Centre for Learning Sciences and Technologies (CELSTEC), OUNL

The Centre for Learning Sciences and Technologies at the Open University of the Netherlands works on location-based and contextual mobile learning in several national and international projects, such as MACE[8], GRAPPLE[9], or STELLAR[10]. Thereby the focus is on informal and incidental learning, where learners are mobile by changing contexts. Context as such is seen broadly and includes locations, processes, peers, concepts, and events. The projects aim to support learners' physical mobility and transitions between contexts through detecting, linking, and constructing contexts.

Within the MACE project the delivery, creation, and metadata enrichment of architectural content on mobile devices has been researched. The MACE content can be delivered to the mobile device using location-based and augmented reality browser, such as Aloqa[11] and Layar[12] that utilise the available contextual metadata.

On the basis of search filters, where the created content is enriched with metadata specifying certain values of these filters the "ContextBlogger" client uses a GPS location-based filter that provides the users with MACE content about the real-world objects in their vicinity. The client combines social software, a weblog, with information about the context of a learner.

[8] Metadata for Architectural Contents in Europe - http://mace-project.eu
[9] Generic Responsive Adaptive Personalized Learning Environment - http://www.grapple-project.org/
[10] The STELLAR Network of Excellence - http://www.stellarnet.eu/
[11] Aloqa Mobile Service - http://www.aloqa.com
[12] Layar Mobile Augmented Reality Browser - http://layar.com

The information in the weblog can be accessed using a mobile device, and the content can be filtered through the application of search filters based on context information. The search filters for the contextualised blogging application retrieve the content either related to a specific real-world object or to a specific user location. Furthermore, the learner can also choose to create his/her own content and relate it to a real-world object or location. Therefore, the use of contextualised blogging provides a basis for an investigation of the usage of physical artefacts in learning. On the one hand, the combination with a physical object could provide the basis for learning, on the other, shared objects could be used to build communities of practice and couple the creation of learning networks to physical objects.

With "Locatory"[13], an augmented reality game has been developed. The game builds upon an open source augmented reality framework for mobile devices to render virtual artefacts that are laid over an image of the real world. The goal of this project was to explore learning scenarios especially games the make use of Augmented Reality (AR).

Other institutions

A number of other projects and research into location-based contextual learning are being carried out across Europe and North America. These were showcased at a workshop held as part of the STELLAR Alpine Rendez-Vous in December 2009[14], where participants shared their experiences of the work they were carrying out in location-based contextual mobile learning.

Some researchers are focusing specifically on mathematics education. Brendan Tangney [CRITE, Trinity College Dublin, Ireland] is investigating learning mathematics via mobile technology in a real-world setting (e.g. estimating the height of a building/monument using the accelerometer of a phone (angle) and GPS distance, or calculating it with estimates on the basis of photographs). Monica Wijers and Vincent Jonker [Freudenthal Institute, Utrecht University, the Netherlamds] discussed their work with MobileMath, a GPS-based game to help students learn maths and geography by creating a virtual shape in a real world playing field. Jonker is looking to extend this work with an idea called "living points of interest [POI]", The current idea behind LivingPOI is to design gameplays for a set of 6 mini-games that fit within the boundaries of a playground at school where all children have a RFID-tag (passive or active) and where three RFID readers are placed around the playground in order to log all geo-positions during a 10 to 20 minutes gameplay. Jonker's ideas for mini-games include:

- development of an epidemic virus
- making geographical patterns like squares, triangles
- measuring density during a game where all children move from one place to another on the playground

Other projects include research into the use of handheld devices for use by student teachers (Jocelyn Wishart, Graduate School of Education, University of Bristol, UK). Differences in the way these devices were used and accepted by different groups of student teachers (science vs

[13] Locatory: http://code.google.com/p/locatory/
[14] "Education in the Wild: contextual and location-based mobile learning in action", organised by Elizabeth Brown and Mike Sharples (report available Spring 2010).

Modern Foreign Languages) has left Wishart considering the current social and ethical practices with respect to mobile devices. She has also carried out work into location-based learning through collaborations with colleagues from WildKnowledge and the 'Mudlarking in Deptford' project. Wishart's continuing focus remains on investigating 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.

Gill Clough from the Open University (UK) has researched the influence of location-aware mobile and social technologies for creating and consuming content in the field/informal learning. In particular, she worked with the Geocaching community (a geographically dispersed group who carry out hiding and finding of hidden packets [Geocaches] in the physical world, guided by GPS enabled mobile devices) to carry out this work. The research 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 embedded into the practices of the community. It revealed the considerable efforts individual community members went to in order to create and engage with a variety of location-based informal learning opportunities.

Jacqui Taylor from Bournemouth University (UK) is looking at the impact of educational technology on the psychology of learners (e.g. the individual differences in emotions and affect involved in learning). The key focus of her emerging work in this field is to develop our understanding of learning styles/strategies in contextual and location-based mobile learning, including the evaluation of the emotional impact on the learner.

John Cook from the Learning Technology Research Institute, London Metropolitan University (UK) has written about extending Vygotsky's Zone of Proximal Development (ZPD) into a Responsive Context for Development (RCD) and provided two cases that illustrated how this was achieved using location aware mobile devices. They specifically set out to design a mobile RCD that is able to respond supportively to, and that acts as a challenge for, learners in Higher Education. The first case was working with school pupils examining change in their local urban area from 1850 to the present day, whilst the second case took place in Yorkshire, where archaeology students explored Cistercian chapels and used 3D visualisations of wire-frame models on handheld devices.

Leilah Lyons (Computer Science & the Learning Sciences, University of Illinois at Chicago, USA) has investigated the use of mobile devices to support co-located, synchronous collaborative learning activities in formal learning environments (classrooms) and informal learning environments (science museums). On both cases, she worked with small groups of users who employed mobile devices as personalized interfaces to a simulation activity hosted on a nearby computer. She is collaborating with a zoo on her next project, where they aim to make real animal behaviour the phenomena of interest by placing GPS collars on free-roaming peafowl. Students will remotely track and study the movements of these birds over time in their classrooms. During field trips, they can examine hypotheses devised from afar (e.g., do the birds prefer areas with vegetation cover or open areas?) using GPS-equipped mobile devices to locate and document locations. Visitors will also be able to examine this long-term data, thus enabling location to act as a connection point between the two types of user and their learning activities.

Finally, Nicola Beddall-Hill from City University (London, UK) has been looking at mobile learning outside the university classroom in case-based learning activities on field trips. Her research investigates the influence that mobile devices have on learning processes and outcomes, and their influence on the use of the device in fieldwork settings. It compares the use of devices introduced for teaching and personal devices used during the learning activity by the group or individual. This project is not based on delivering an intervention *per se* but instead is a case study into current practices of TEL used on field trips.

Educational patterns in location-based and contextual mobile learning

Mobile learning technologies and support can be used in a variety of educational settings and domains. In the following section we will first identify some basic educational functionality connected to the interaction patterns described above. Furthermore, a key idea of contextual learning is to connect the real world with digital media, which is essential for the learning gain. The characteristics of a situation in the real world and the metadata of digital media in this sense are the key parameters, that are used to synchronise the augmented reality experience.

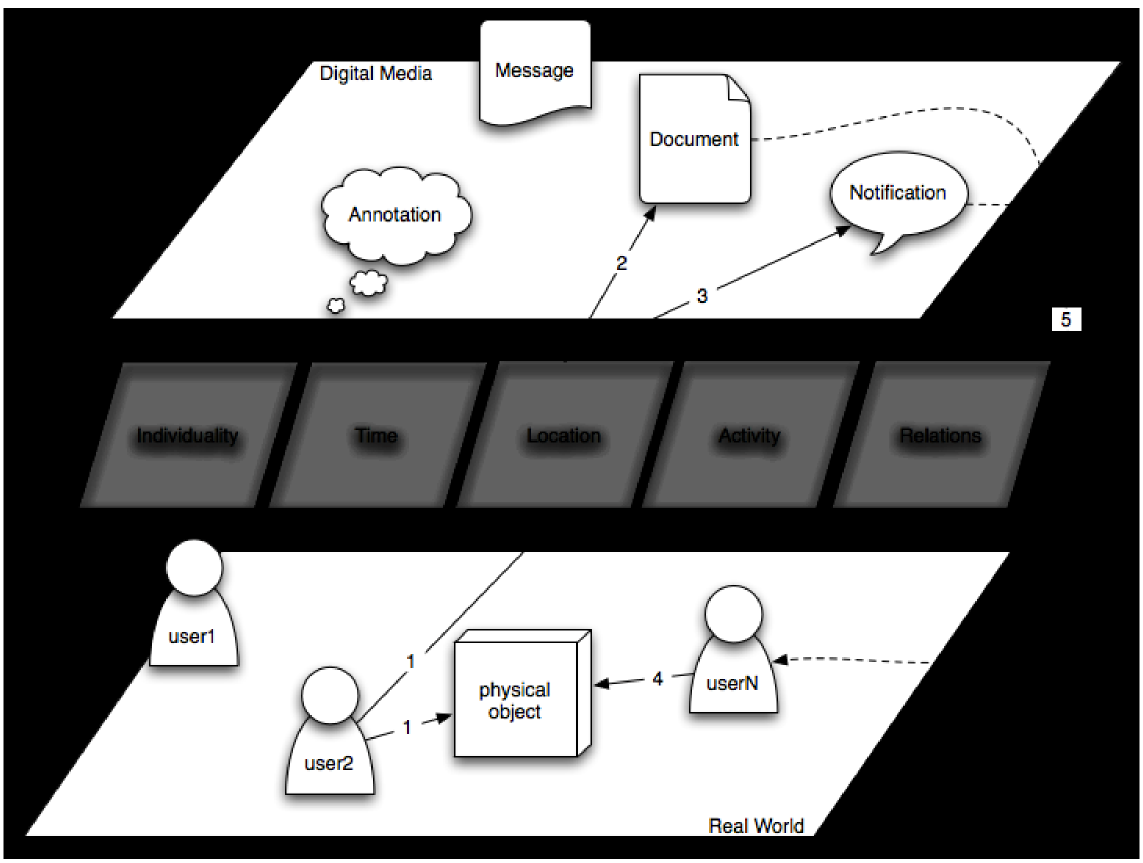

Figure 1: Connecting real world and digital media via context

The different interaction patterns enable different experiences that can give different perspectives, insights and forms of interaction for an augmented real world experience. As an example, Head-Up display interaction mostly enables users to get an enhanced vision of their current environment. The educational tool in this case basically filters information according to the current location and the direction a user is looking. The merge between user vision and tags in the enhanced vision basically visualise geo-located information or interaction facilities. In that sense ,a first cluster of educational patterns can be described as 'Geo-Location Layers'. All kinds of applications enable the perception and interaction with location related information, this basically happens in two ways: on the one hand with a Head-Up display, the augmentation of the video signal of the mobile device enables the direct linking of an augmentation layer and a view of the real world; on the other hand, a more map-oriented metaphor enables the relation of several layers onto maps which gives a more spatial relationship between the entities of the layers.

A second cluster of educational patterns is the "Tagged Environment". This subsumes approaches in which either computer readable tags are placed in the environment on specific locations or objects, or where these tags are used to identify interaction artefacts with which users can manipulate complex visualisations. With such a tag-based approach, different kinds of game play approaches can also be identified, that are used for learning or enabling other perspectives on learning content.

The most advanced and probably most technically challenging form of mobile AR is the 'X-Ray Vision' pattern, as it requires real time mapping of complex structures carried out on the mobile device.

Title	**Layers of Interest**
Description	The 'Layers of Interest' (LOI) pattern describes educational scenarios in which users consume information, while on the move. The information is delivered via the users' mobile device and can be manifold, ranging from location-based historical information to contextual language information. The location artefacts (e.g. buildings, landmarks, artwork) are stored in databases enriched with contextual metadata, such as location. Applications that support the pattern usually categorise the available information in 'layers' (e.g. architecture or history).
Educational Background	The educational focus of this pattern lies in the exploration of physical spaces. In both cases location related data is presented to a learner. Nevertheless via the selection of channels the learners can filter different views on their environment. The pattern basically can only filter information on the level of GPS and compass information, which typically can be used to either filter for physical objects of bigger size. The exploration of the environment also enables the visualisation of learning opportunities in the physical environment of the learner. Mobile learning makes it possible to support the learners in an authentic learning environment. The importance of an authentic context in learning is emphasised by several theories. For example, Dewey [41] and Wenger and Lave [11] state that knowledge needs to be presented in a realistic context that would normally involve its application. Moreover, the functional context approach described by Sticht [42] emphasised that assessment of learning requires a context/content specific measurement in an authentic work context. An authentic learning environment often has a complex and ill-structured nature that provides multiple perspectives on the theory learnt, and needs context-dependent, highly interconnected knowledge. Several aspects that are emphasised by cognitive flexibility theory [12] are as important for learning. Especially, the variety of stimuli and learning tasks available in an authentic context may result in a better generalisation of the knowledge constructed by learners [12][14]. Cognitive apprenticeship, as described by Collins *et al* [43], supports the learner in dealing with the complexity of an authentic environment by social interaction between a learner and an expert tutor. An important process in a cognitive apprenticeship is the reflection about action carried out by the expert in an authentic work environment [44][45]. In managing the complexity of an authentic environment, the learner can focus on certain cues and

	information in that rich environment which helps to reduce the information load and will lead to more effective learning.
Related Patterns	Head-up Learning Layers, Tricorder Layers

Title	**Head-Up Learning Layers**
Description	The pattern is deduced from the LOI pattern. As in most cases the sensors for relating information within mobile devices as GPS location, compass, and accelerometer the objects from a learning layer can be visualised in a certain direction, distance, and height from the viewers perspective holding the mobile device. This allows good results for giving estimations about the current environment but does not enable the viewers to develop a bird's eye perspective on the relationships between objects in the augmented view. On the other hand this kind of augmentation allows senseful learning support when ego-perspectives are necessary and helpful.
Educational Background	The educational background and potential of this pattern can be seen mostly in an explorative approach enabling the user to explore his/her current environment with different layers activated on a display. The pattern appears to be mostly appropriate for subjects where the relation between the entities in the layers is differing according to the viewers' direction or distance. Furthermore the merge of different layers that can be structured task specific or the mapping of digital media to locations could become the actual task for a learner. As an example for the last one the Locatory game was created. In the Locatory game the user has to do a mapping of a picture presented to him/her to the real world and drop the picture virtually on the real world object. This technology would also enable assessment methods and collection tasks related to real world objects. Examples can be found in domains as architecture, biology, geosciences.
Related Patterns	Layers of Interest

Title	**Tricorder Learning Layers**
Description	This pattern basically is a mash-up of contextualised information sources. In the pattern information layers are merged mostly with map information. The basic view is a map that is rendered according to the viewers' location, and viewing direction and overlaid with a learning layer. Tricorder can also work with head-up perspectives but focus more on the metadata about a certain entity (example could be the statics for air pollution in different directions of the viewers perspective).
Educational Background	This allows the learners to relate the layered information streams with their current location. It provides the learners with opportunities to learn relations between implicit of explicit characteristics of the current location and situation with digital data sources. As a difference to the head-up display approach in the tricorder pattern the relation between the real world view and the visualised objects is not the most important learning goal, the tricorder pattern enables more to visualise relations between different layers and the entities of these layers.

Title	**Tagged Environments**
Description	This pattern enables the integration of digital information via the integration of codes in the physical environment via real time or asynchronous scanning. In learning situations where the actual objects with which the users learn become of smaller size or are presented in an indoor scenario tags are often used to enable simple computer-based sensoring of the context and to trigger integration of augmented visualisations. The probably most prominent example of this pattern is the MagicBook, in which elements of a physical book can either be made alive of presented in augmented reality by scanning printed barcodes in the book.
Educational Background	Tagged environment link an educational function, interaction facility, or metadata about objects and the environment to a concrete location or object. The approach gives the learner the possibility to interact in tag-enriched environments with exploration, interaction, or augmented collaboration playfields.
Related Patterns	Tagged Artefacts, Tagged Locations, Tagged Interaction Objects, Tagged Playfields

Title	**Tagged Artefacts**
Description	The pattern is based on the MagicBook approach; basically it allows users to look at 3D models of learning content. A good example is learning about the solar system by manipulating the complete view of the solar system by moving the personal perspective. Or a Lego 3D becoming alive based on a tag on a packet.
Educational Background	The theory is that the traditional methods of learning spatially-related content by viewing 2D diagrams creates a sort of cognitive filter. This filter exists even when working with 3D objects on a computer screen because the manipulation of the objects in space is made through mouse clicks. I am investigating the possibility that the physical manipulation of the earth-sun virtual models in augmented reality will provide a more direct cognitive path toward understanding of content.

Title	**Tagged Locations**
Description	This pattern integrates codes in the physical environments as the visualisation of the information is highly related to a very specific location. Tags are used to enrich the objects within the physical environment. The artefacts are usually selected and enriched in an authoring environment and can then be accessed through mobile applications. Furthermore two types of tags can be distinguished, as they enable an active or passive access to the available information. To access information passively means to get the information presented in context (e.g. location), while the active access demand an interaction using physical tags (e.g. barcode). Using the mobile device the user can trigger an action by reading the tag.
Educational Background	A situated view on an object and on the relation between different tagged locations is supported. In this pattern the exact location of the tag is important as the overlay produces a unique merged view for the learner that combines properties of the real world objects and the digital media for augmentation.
Related Patterns	

Title	**Tagged Playfields** or Interaction Objects
Description	In this pattern users basically can use real world objects to manipulate augmented worlds, so by moving tagged objects user scan combine molecular structures or build new environments that are visualised in 3D. Furthermore this kind of technology is used in games where user scan interact with playfields via tags by viewing and interacting with virtual objects embedded in the real world.
Educational Background	This gives the learner an isometric perspective on the learning content as also is the basis for collaborative augmented reality approaches, in which learners have personalised views on playing fields augmented via tag recognition.

Summary

This deliverable for STELLAR Work Package 1 has included a comprehensive review into current research into location-based and contextual mobile learning. It has discussed the dimensions important in contextual learning and has presented detailed case studies of location-based research from the past decade. It has also showcased the work of the authors (both in the UK and in the Netherlands) and those who took part in the STELLAR Alpine Rendez-Vous 'Education in the Wild' workshop in December 2009, thus providing an excellent overview of research in this area being carried out across Europe and beyond, and the issues and challenges being addressed by academic colleagues.

We have also asked experts from the field of mobile and contextual learning to contribute to a concept-mapping study to identify the main issues and challenges that can be addressed by mobile learning. The results from this study are ongoing and will be included in a later version of this report.

Lastly, we are working on an identification of educational patterns, based on examples from the expert concept-mapping study, to develop an educational framework for contextual learning as a unifying approach for the field. This is already partly presented in this paper and the final version of the report will include this in more detail.

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Annex 1 Statement List

1. Limited access by some learners in remote locations.
2. Lack of support to young learners, which have the mobile technology.
3. Insufficient real life experience in the learning process.
4. Nomads who move from one location to the next while learning.
5. Lack of community building during learning.
6. Low motivation of learners who are mobile technology literate.
7. Not enough collaboration between learners.
8. Learning from any location.
9. Learning at anytime.
10. Learners not able to interact with experts from around the world.
11. Just in time information for immediate application.
12. Learners cannot learn in context.
13. Teachers not comfortable using mobile technology.
14. Lack of ICT skills for the 21st century.
15. Not enough self-directed learning activities while learning.
16. Ability to discover and experiment in own context.
17. Access to learning resources and learning opportunities without the restrictions of location, time and cumbersome equipment or facilities.
18. Provision of opportunities to contribute to the development/production of learning resources and course content without the restrictions of location, time and cumbersome equipment or facilities.
19. Provision of opportunities to collaborate, share and publish learning resources and course content without the restrictions of location, time and cumbersome equipment or facilities.

20. Actively participate in learning activities outside of formal educational settings and facilities.

21. Enhance teaching and learning within formal educational settings and facilities through handheld technologies.

22. Finding new teaching methodologies that are suitable for the challenges of, and embraces the opportunities of, the knowledge and information age.

23. Finding new learning strategies that are suitable for the challenges of, and embraces the opportunities of, the knowledge and information age.

24. Flexibility for the learner.

25. Mobility of the learner.

26. Cost-effectiveness for the learner.

27. Cost-effectiveness for the providers of teaching and learning.

28. Outside in, inside out problem, where cultural practices involving new digital media can be brought into formal learning institution, get enhanced inside the institution and in turn feed back into the digital world at large.

29. The design of augmented contexts for development problem to enable collaborative problem solving where learners generate their own 'temporal context for development'.

30. The provision of access to knowledge in the context in which it is applied.

31. Refreshing the image and practice of institutional e-learning.

32. Helping educational institutions understand the increasing & near-universal ownership, acceptance and use of mobile devices across society.

33. Taking education out of classroom settings into meaningful settings.

34. Helping educational institutions to offer learning aligned to the students' ownership, experience & use of technology.

35. Perceptions of technologically impoverished provision.

36. Make use of the affordable technologies that students have access to.

37. Design suitable activities for the mobile learners.

38. Assess learning experiences to be accountable for the stakeholders.

39. Interacting with your environment to achieve new knowledge from it.

40. Anything is a potential learning scenario.

41. Easing access to educational opportunities.

42. The perception that there is a lack of student engagement.
43. Students exhibit passivity, boredom, indifference, low attention spans, and fail to complete their studies.

44. Rigid assessment systems stifle creativity and innovation.

45. Inequality of access to computers, learning resources and teachers.

46. Pressured, busy, fragmented, mobile lives leaving little quality time for conventional, place-and-time-dependent education.

47. Blinkered, old-fashioned views about education stopping when working lives begin.

48. Traditionally ineffective instruction and low learner performance in some subjects.

49. Gaps (time lags) between traditionally scheduled learning sessions, limiting achievement, teamwork and collaboration.

50. Under-utilization of potentially rich learning resources in heritage sites, art collections and all sorts of other interesting places.

51. Enable learners in classroom settings to have equal access to rich resources and computational tools to support curriculum learning.

52. Orchestrate new forms of classroom pedagogy that require coordination of individual, small group and whole class activity.

53. Connect learning across contexts, including between formal and informal settings.

54. Maintaining continuity of learning across settings, such as between classrooms and museums on school field trips.

55. Enable enquiry-based learning in novel locations, through novel locations, and about novel locations.

56. Making use of space and environment as a backdrop for engaged spatial learning.

57. Making use of affordances of locations to support learning.
58. Using technology to probe or to enrich understanding of the natural environment, and annotating the environment for the benefit of visitors.
59. Access to information when and where it is required, through ‘just in time’ browsing of relevant information, and information push to support learning in context.
60. Enable learning through distributed conversation across contexts.
61. Accessibility of information in relevant everyday life and work situations.
62. Documenting real time experiences of learners.
63. Contextualization of e-learning.
64. Transfer of training.
65. Spontaneous collaboration in situated learning.
66. Harness the fact that every student in every university owns a sophisticated communications device.
67. Revolutionize mobile learning, as the iPhone has revolutionized mobile telephony.
68. Make mobile learning a revenue stream for telecommunication companies.
69. Dealing with small screens and difficult data input.
70. The worthwhileness of location-based and contextual mobile learning.
71. Difficulties to reuse the products.
72. Get students to use their mobile devices constantly also in education.
73. Learning in context.
74. Learning across contexts.
75. Self-directed learning.
76. Learning with narratives.
77. Mass-customized learning.

78. Including learners with disabilities.

79. Including learners from rural areas.

80. Developing third world countries' education.

81. Engagement of the learner.

82. Transformation of traditional education according to the needs of information society.