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A Mobile Learning Overview by Timeline and Mind Map

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ABSTRACT

Mobile learning has been a research topic for some 20 years. Over that time it has encompassed a wide range of concepts, theories, designs, experiments and evaluations. With increasing interest in mobile learning from researchers and practitioners, an accessible overview of this area of research that encapsulates its many facets and features can provide a useful snapshot of the field to interested parties. This article provides a summary of the field of mobile learning, applying the main analysis categories of research, technology, content, learning and learner. The author presents these categories and subcategories in the form of a mind map, which outlines the details of the major themes in mobile learning. In addition, the author contextualises the key developments in mobile learning in a timeline. The intent of this article is that it may serve as an introduction to the research field of mobile learning, enabling researchers to quickly familiarise themselves with the type of work that has been done in the past, and the potential areas of investigation that might prove fruitful in the future.

Keywords: Literature Review, Mind Map, Mobile Learning, Timeline

INTRODUCTION

Mobile learning is an increasingly popular approach to learning with technology, particularly with the increase in BYOD (Bring Your Own Device) approaches to classroom learning, where students are using their own mobile devices to learn. With this increasing interest in the subject, it may be a useful aid to new researchers, or other interested readers, to provide an accessible overview of mobile learning that encompasses its many facets and features. Although there have been many reviews of the mobile learning literature, these have tended to focus mostly on the nature of the work from a research perspective. Further, they have focused on a specific subset of the overall literature. For example Wingkvist & Ericsson (2011) surveyed the papers published in the Mobile and Contextual Learning (mLearn) conference series, but classified them according to only two dimensions: research method and research purpose. Pollara & Broussard (2011) provided a review focused specifically on student learning outcomes and processes. Sattler et al (2010) focused on the benefits (particularly to constructivist learning) and challenges (buy-in, interface issues, cost and infrastructure.) Orr (2010) focused on pedagogy and constraints. Some review articles have specifically confined themselves to a particular type of mobile learning, for example mobile language learning (Viberg &

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Grönlund, 2013.) It is, of course, in the nature of a comprehensive literature review that it will sacrifice breadth in favour of depth, within a chosen area of investigation. The intention of this article is to sacrifice depth in favour of breadth, in order to provide a full-landscape view of the field of mobile learning, which has so far been lacking from the literature.

THE CONCERNS OF MOBILE LEARNING RESEARCH

A number of authors have attempted to break down the field of mobile learning research into various specific concerns. The ways in which this has been done has, of course, varied depending on the focus of interest of these authors. From a general perspective, for example, Traxler (2009) defined a number of mobile learning categories: technology-driven, portable, connected classroom, informal, personalized, situated, performance support and in the development context. He also outlined some aspects of affordances; infrastructure, sparsity, policy agenda and blended learning modes. Laurillard (2007) provided a slightly different interpretation, pointing to aspects of mobile learning's uniqueness as a learning mode by referencing learner generated contexts, digital objects co-located with the learner, the three 'mobilities' in m-learning (learners, technology objects, and information) and motivation through ownership and agency. While these categories are all relevant and helpful, this article attempts to develop a new overview, based on a broad analysis of the literature up to and including 2013, and provide visualisations of the main themes, concepts and concerns of mobile learning.

ANALYSIS METHODOLOGY

The methodology used in this article was based on seeking comprehensive coverage of mobile learning research as represented primarily by journal articles and book chapters, and presenting visualisations of our findings (in the form of a timeline and a mind map.) Our main sources were journal articles on the topic of mobile learning revealed in a search of the Web of Science (400 articles), all articles published in the International Journal of Mobile and Blended Learning (94 articles), chapters in mobile learning books (~50), and additional articles found in a search of Google Scholar that covered concepts not previously identified, and included additional types of publication such as conference papers (~50). Each paper was analysed in terms of its own statements of its key features and contribution, based mainly on the abstracts and conclusions of the papers, and visualisations of the data were developed incrementally as new concepts were added, revised and rearranged. In seeking a saturated sample, these data were accumulated until the additional concepts being gleaned from the literature were either (a) already included in the data or (b) were only providing further examples that were indicative rather than exhaustive. For example, one of our themes related to the subject content of mobile learning systems. Since the number of subjects became increasingly large, the final visualisation only includes a small subset of the most popular subjects covered. The papers cited in the commentary provide indicative examples of each of the main concepts of the mind map, though in many cases there were many other papers that could equally have represented the chosen concepts, and it is not claimed that each of these examples is the 'best' paper that could have represented each individual concept. Further, due to limitations on space, it has not been possible to provide commentary and references for every single concept in the mind map, so the article focuses instead on what is hoped to be a representative sample.

Data Presentation

This article presents its landscape view of the field of mobile learning in the form of a timeline (mapping in time) and a mind map (mapping in space). Timelines are an important tool in the visualisation of temporal data, for example they have proved particularly useful in the visualisa-

tion of time-sensitive medical data (e.g. Bui, Aberle & Kangarloo, 2007). In this article, the value of temporal visualisation is to give greater clarity to what we have identified as key phases in the evolution of mobile learning research.

Whilst timelines are well established as having value in several research domains, the use of mind maps is perhaps more controversial. Although this approach to visualization is relatively subjective, it is a qualitative approach that allowed us to find creative associations between ideas, as opposed to some other approaches that simply present quantitative data (Davies, 2011). It enabled the researchers to work creatively and interactively to integrate large volumes of individually captured data. Although the current work does not address this aspect, it also potentially supports additional services such as certain types of information search (Beel & Gipp, 2010). Through an iterative process of refinement, we have applied the main analysis categories of research, content, technology, learning and learner, with a range of subcategories and representative exemplars. There is a large number of Mind Map creation software tools available, but the mind map presented here was created using XMind (http://www.xmind.net/).

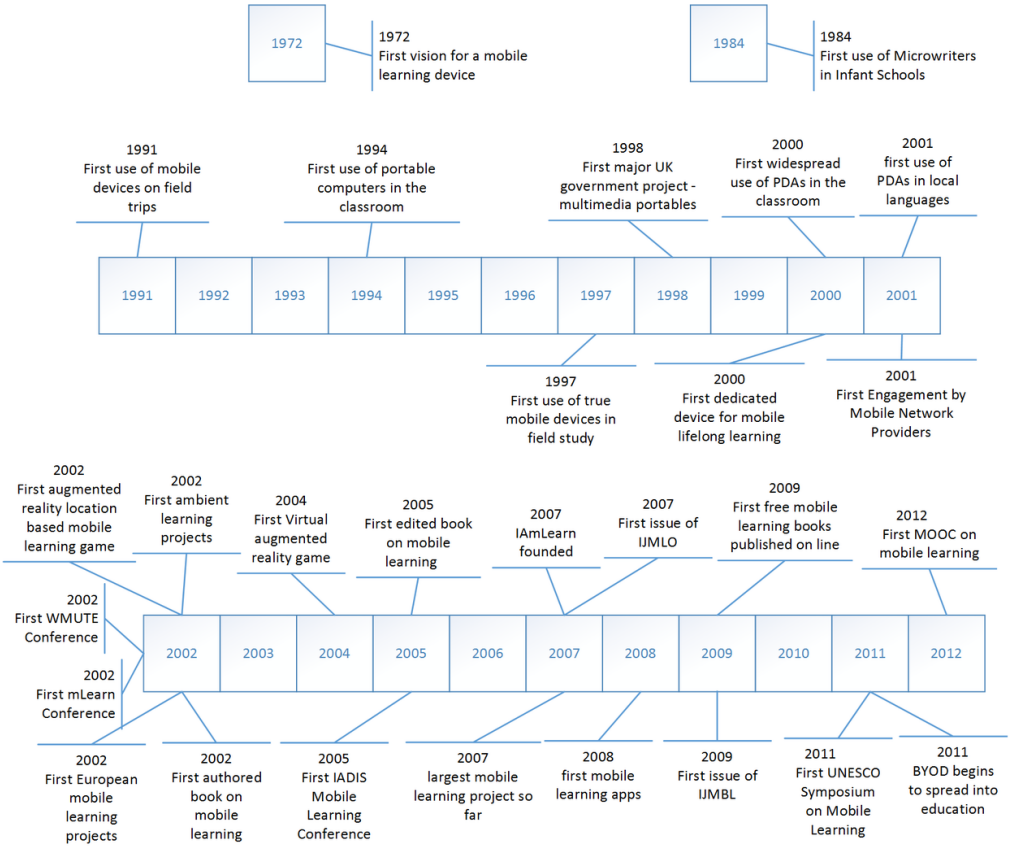
A MOBILE LEARNING TIMELINE

The mobile learning timeline (Figure 1) describes the evolution of mobile learning through a series of significant 'firsts'. The events on the timeline are of various kinds; notable research projects, the establishment of relevant journals and conference series, and some technology related innovations. In each case, an attempt has been made to identify the first occurrence of each type of mobile learning project, forum or application. This has two main purposes. First, it allows the reader to see the roots of mobile learning research, and to appreciate its history. Second, it reveals some important themes in the field that are explored in more detail in the mind map described later in this article. The timeline was partially crowdsourced by seeking contributions and debate among members of the International Association for Mobile Learning via their shared mailing list.

The first two items on the timeline are separated by several years from the main body of activity. The first of these is Alan Kay's visionary Dynabook, a vision for future mobile learning, which laid out many of the affordances for a mobile learning device that we now take for granted (Kay, 1972.) However, it was many years before anything like Kay's vision could be realised in a practical way. The first attempt to use a small device for learning seems to be the use of Microwriters in Infant Schools (High & Fox, 1984). Of course these simple word processing devices were very primitive compared to the concept of the Dynabook, and classifying them as mobile learning might be stretching a point. Nevertheless they were small semi-portable devices used to encourage autonomous and collaborative learning, so that within the technical limitations of the devices, this project was pioneering in some of the concepts that were to prove central to mobile learning.

The first attempt to take mobile learning out of the classroom, to make it truly mobile, appears to have been the Apple Classrooms of Tomorrow (ACOT) project in 1991, including the first use of mobile devices for field trips (Grant,1993), which has since become a core context for mobile learning. 1993 saw the Pupils' Learning and Access to Information Technology (PLAIT) project, which was probably the first project to use truly portable (though not really mobile) computers in the classroom (Gardner et al., 1994.) If nothing else, this project first raised the seemingly endless debates about how mobile learning might or might not impact on learning performance and learner attitude. While early field-based projects used devices that might be better described as portable rather than mobile, the first project to use truly mobile devices for learning in the field was probably the Cornell Plantations projects in 1997, which utilised the (then new) Windows mobile devices (Rieger & Gay, 1997.) At around the same time, the indoor equivalent of the field trip, the museum or gal-

Figure 1. A Timeline of mobile learning research



lery tour, was also a focus of innovative mobile projects, including Hyperinteraction within Physical spaces (Oppermann & Specht, 1998.)

While previous projects has been either small scale or driven by vendors, the first large scale government funded project was the 1998 Becta Project in the UK, Multimedia Portables for Teachers. Although this focused more on the portable than the mobile, it was significant in its emphasis on educators rather than learners, and on the use of multimedia and internet connectivity to support teaching and learning (Harrison et al, 1998.)

The first attempt to truly address Kay's vision of a mobile learning device was probably the HandLeR Project in 2000, which sought to design and build a mobile device that would directly support mobile learning (Sharples, 2000.) Around the same time, Palm were distributing the Palm Education Pioneer grants, to provide handheld computers for teachers and their students in K-12 classrooms. This may be seen as the first project designed to see large scale use of mobile devices by children for learning within the classroom. Perhaps less high profile, but also significant, the Enlace project provided the first use of Personal Digital Assistants for mobile learning in languages other than English (Rodríguez et al, 2001)

While manufacturers of mobile devices (Apple, Microsoft, Palm) had been active in promoting and supporting mobile learning initiatives, mobile network providers finally became formally involved in 2001, with the inaugural meeting of the European m-learning Forum (PJB Associates, 2001.) This signalled

the increasing move away from standalone mobile learning tools deployed on disconnected PDAs to connected tools, utilising the content and collaboration opportunities of wireless mobile devices.

2002 was a very significant year in the development of mobile learning. As technology developed, more ambitious forms of mobile learning became possible with ambient, pervasive and ubiquitous technologies. Perhaps the pioneers of this type of mobile learning were the related Hunting of the Snark and Ambient Wood projects, explorations in contextual learning through ambient devices that pushed the boundaries of mobile learning in outdoor environments (Price et al., 2003, Harris et al, 2004). In a similar vein, the first augmented reality location based mobile learning game, Environmental detectives, was developed (Klopfer, Squire & Jenkins, 2002.)

The first authored book on mobile learning appeared in 2002, and interestingly was based not on classroom learning but on work-based learning, reflecting a quick uptake in the United States of mobile technology by employers who saw the potential for mobile learning in a work-based training context (Gayeski, 2002). 2002 also saw the beginning of the first major mobile learning projects to be supported by European funding. The M-Learning Project was funded by the European Fifth Framework programme to help disaffected learners aged 16 to 24, while the more ambitious Mobilearn Project was a worldwide European-led project exploring context-sensitive approaches to informal, problem-based and workplace learning. Further major events in 2002 were the first meetings of two conference series that have continued to act as significant forums for the research community. The First IEEE International Workshop on Wireless and Mobile Technologies in Education (WMTE) took place at Växjö University in Sweden, while the first World Conference on Mobile and Contextual Learning (mLearn) was held at the University of Birmingham, UK, though it was initially called the European Workshop on Mobile and Contextual Learning. mLearn is the longest continuously running international conference series on mobile learning. A further conference 'first' took place in 2005, with the IADIS Mobile Learning conference series being inaugurated in Malta. This conference series differed from its predecessors in that it remains focused on European venues.

2005 also saw the publication of the first edited book on mobile learning (Kukulska-Hulme & Traxler, 2005.) The Advanced Mobile and Ubiquitous Learning Environments for Teachers and Students (AMULETS) project in 2006 might also be seen as innovative in its blending of mobile device use in the field with integral classroom activities, bringing together the two contexts of mobile learning (in the classroom or in the field) that had been previously explored separately. Another evolutionary step from 2006 was Futurelab's Savannah project, which was the first mobile learning application that overlaid imaginary (rather than informational) virtual content onto real world contexts (Facer et al. 2004).

2007 saw the beginning of the large scale MoLeNET (Mobile Learning Network) Project in the UK, which claimed to be the world's largest and most diverse implementation of mobile learning to date, including 50,000 learners and 4,000 staff. The increasing maturity of mobile learning as a research field began to lead to more formal outlets for publication and collaboration. The first issue of the International Journal of Mobile Learning and Organisation, the first journal to include mobile learning in its title, was published in 2007. This was followed in 2009 by the first issue of the International Journal of Mobile and Blended Learning. The International Association for Mobile Learning (IAMLearn) was established in 2007, while in 2009 the first free mobile learning books were published on line (Ally, 2009; Herrington et al., 2009.) Meanwhile, technology development continued apace. In 2008 the first mobile learning apps began to appear in the App stores for both Apple and Android devices, enabling mobile learning apps to be distributed for both platforms.

Another significant first took place in 2011, with the first UNESCO Symposium on Mobile Learning, acknowledging that mobile learning was by now of global interest, and a potentially important tool for educational delivery in developing nations. The following year, with increasing interest in the potential of massive open online courses (MOOCs), the first MOOC on mobile learning (MobiMOOC) was delivered. Around the same time, a sea-change began to occur in the way that mobile learning was deployed in schools and higher education institutions, with the increasing uptake of bring your own device (BYOD) policies (Norris & Soloway, 2011.) This change suddenly brought mobile learning into the mainstream, forcing mobile learning researchers to adapt to the new world of research challenges and opportunities brought by mass adoption of mobile learning.

It is notable that the timeline reveals three distinct phases in mobile learning evolution. Initially, innovation is driven by individual researchers or small groups, perhaps supported by technology vendors such as Palm and Apple, exploring new concepts in teaching and learning by being early adopters of new technology. Later, we see a series of large scale projects, sponsored not by commercial enterprises but by quasi-governmental organisations such as the European Union. More recently, we see new channels of dissemination and collaboration; journals, conferences, MOOCs etc. Underlying these developments we see the evolution of mobile technology from early portable devices, through PDAs, to contemporary touch screen smart devices, owned by learners. Given this context, it may be useful to the researcher to consider what the next phase of mobile learning research might be, and how the research community might contribute to future developments.

A MIND MAP OF MOBILE LEARNING

In creating our mind map, the main areas we have identified are: Research, Technology, Content, Learning and Learner (Figure 2). These concepts 'bubbled up' through the process of interactively developing the mind map, so were not starting points in our analysis, rather they were the final result of generalising concepts from the specific to the generic. In the remainder of this article we have attempted to summarise the key concerns of each area, presenting the relevant subtree of the mind map, with some indicative examples where appropriate. For example under 'Content', one of our subconcepts is 'Subject Specific (content)'. Within this branch of the mind map we include a number of popular subjects that have been addressed by mobile learning, but this is by no means an exhaustive list. Similarly under the 'Learning' concept, in the 'Specific Context' subconcept, we include some popular contexts for mobile learning. Again, these are only intended to be indicative. A similar philosophy applies to most of the branches of the mind map.

RESEARCH

Figure 3 shows the subtree from the mind map that explores the overarching theme of 'Research'. Mobile learning research has fallen into a number of categories. Some papers have focused on theory, with activity theory being one of the most popular theories applied to mobile learning (Uden, 2007). However there are many other theories that have been found relevant, including psychological theory (Brown & Campione, 1996), in particular behavioural psychology, flow experience (Csíkszentmihályi, 1996; Park, Parsons & Ryu, 2010) social constructivism (Cochrane & Bateman, 2010) and constructionism (Patten et al., 2006). Learning theories that stress context, a particularly important feature of mobile learning, include situated cognition (Brown, Collins & Duguid, 1989) and distributed cognition (Hutchins, 1995). Siemens (2004) also stresses the importance of context in applying connectivism to mobile learning. There have also been efforts directed at creating an overarching theory for mobile learning research (Sharples, Taylor & Vavoula, 2007). Theories that apply specifically to practi-

Figure 2. A mind map of mobile learning categories

cal aspects of education are clearly important in mobile learning, for example experiential learning (e.g. Facer et al., 2004)

A large number of methods have been used in mobile learning research. A popular strand of research is the review paper, several of which have been mentioned in the introduction. However most research addresses new areas of investigation, many of which involve human subjects, since the main purpose of mobile learning research is to measure its effects on how people learn.

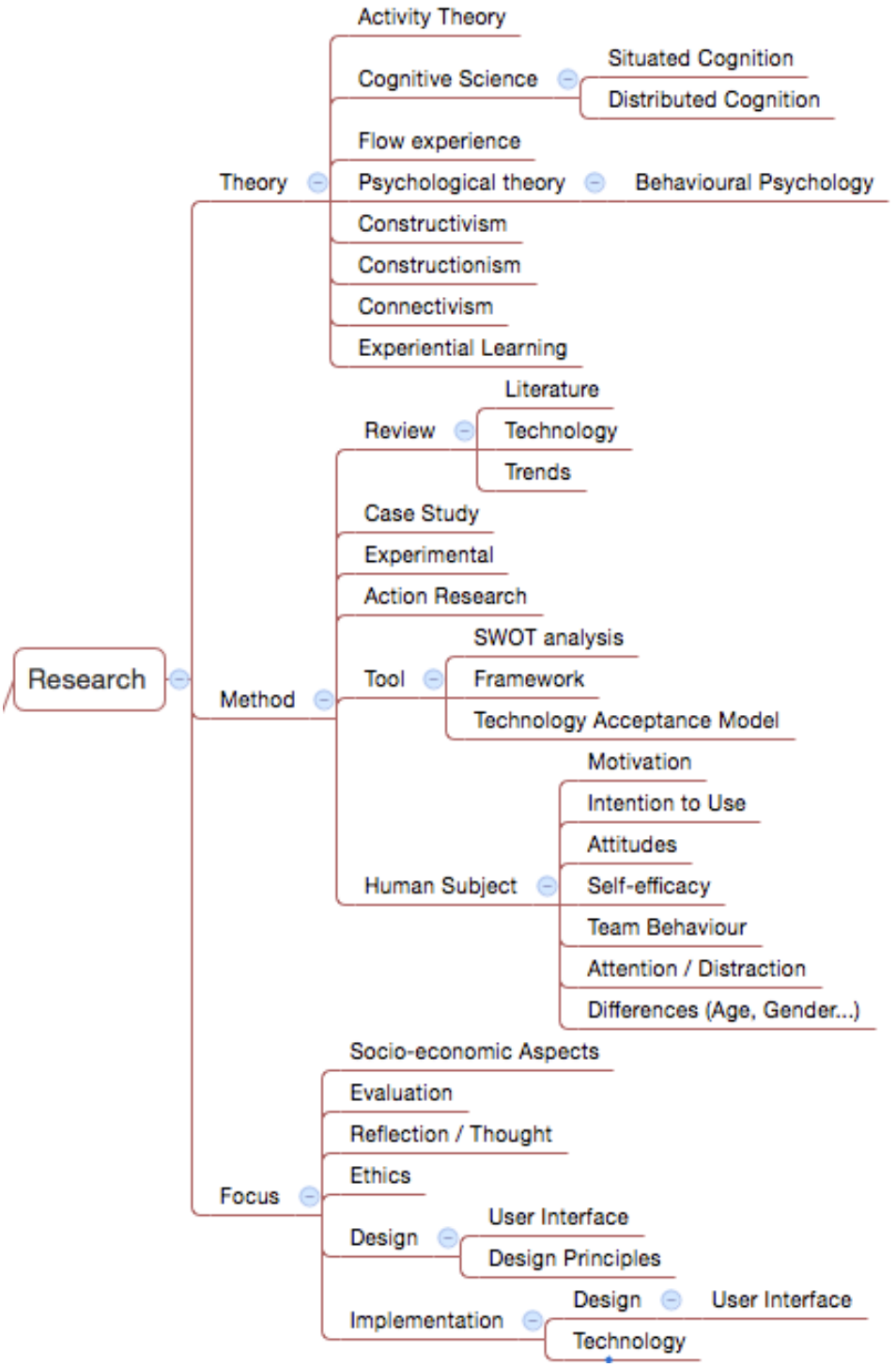
The focus of research may range from general thought pieces on the philosophy of mobile learning to specific implementations of hardware or software tools. All research needs some form of evaluation, and a number of authors have tried to address how mobile learning interventions should be evaluated, including Traxler & Kukulska-Hulme (2005), Motiwalla (2007) and Vavoula & Sharples (2009).

Research into design has been approached both from the general perspective of design guidelines and frameworks (Parsons, Ryu & Cranshaw, 2007), in specific areas of design concern such as the user interface (Carmen et al., 2012) and also looking at the design (and implementation) of individual mobile learning applications (Sharples, Corlett & Westmancott, 2002.) While not all research into design formally uses design based research as a methodology, there are a number of examples that do (e.g. Ahmed, & Parsons, 2013).

TECHNOLOGY

Figure 4 shows the subtree from the Mind Map that explores the overarching theme of 'Technology'. This theme is divided into technology platform concerns (devices and communications) as well as potential ways of using these technologies (web-based applications and system affordances). One aspect of mobile learning that is difficult to ignore is the device, since the rate of change of these technologies is such that it constantly drives new research opportunities. While the device itself is not the subject of the research, specific devices inevitably get used in empirical research projects. Thus mobile learning has, over the years, used many different types of technology, for example iPods, MP3 Players, Personal Digital Assistants, USB Drives, E-Readers, Smart Phones, UMPCs, Laptops and Tablet PCs (Corbeil, 2007). In some cases, specific mobile technologies have been chosen because they are particularly useful in a given context. A good example of this is the E-Reader, which can provide large volumes of material when offline. For example Havelka (2011) described

Figure 3. The 'Research' branch of the Mind Map



the use of E-Readers with nursing faculty and students, because these users require instant access to large amounts of reference material that would be inefficient to download on demand. E-Readers have also been used in a prison context to support mobile learning where internet access is forbidden (Murphy, Bedford, & Farley, 2014). While many studies focus on particular technology, others compare different technologies, for example Martin & Ertzberger (2013) compare iPods, iPads and traditional computer based instruction.

Along with the devices themselves, technologies for communications have also evolved considerably, changing the focus of research. Many early mobile learning systems relied on SMS text messaging (Bollen et al. 2004), and indeed this simple technology still has a role to play in mobile learning systems in parts of the world where mobile device ownership is predominantly focused on low-end devices rather than smart phones or tablets (e.g. Cavus & Ibrahim, 2008.) Similarly, with the rise of personal digital audio devices, podcasting became very popular (Read, 2005), followed by vodcasting, as more devices became capable of playing video (Edwards, Jones, & Murphy, 2007.) Not all of this work was confined to one way broadcasting. Some mobile learning using small video capable devices enables the learners to develop and share their own content (Wilson, Andrews, & Dale, 2009.) Thus when we refer to communication, we are concerned not only with the technologies that support it, but the modes of communication that leverage this infrastructure, such as audience response systems and learning management systems.

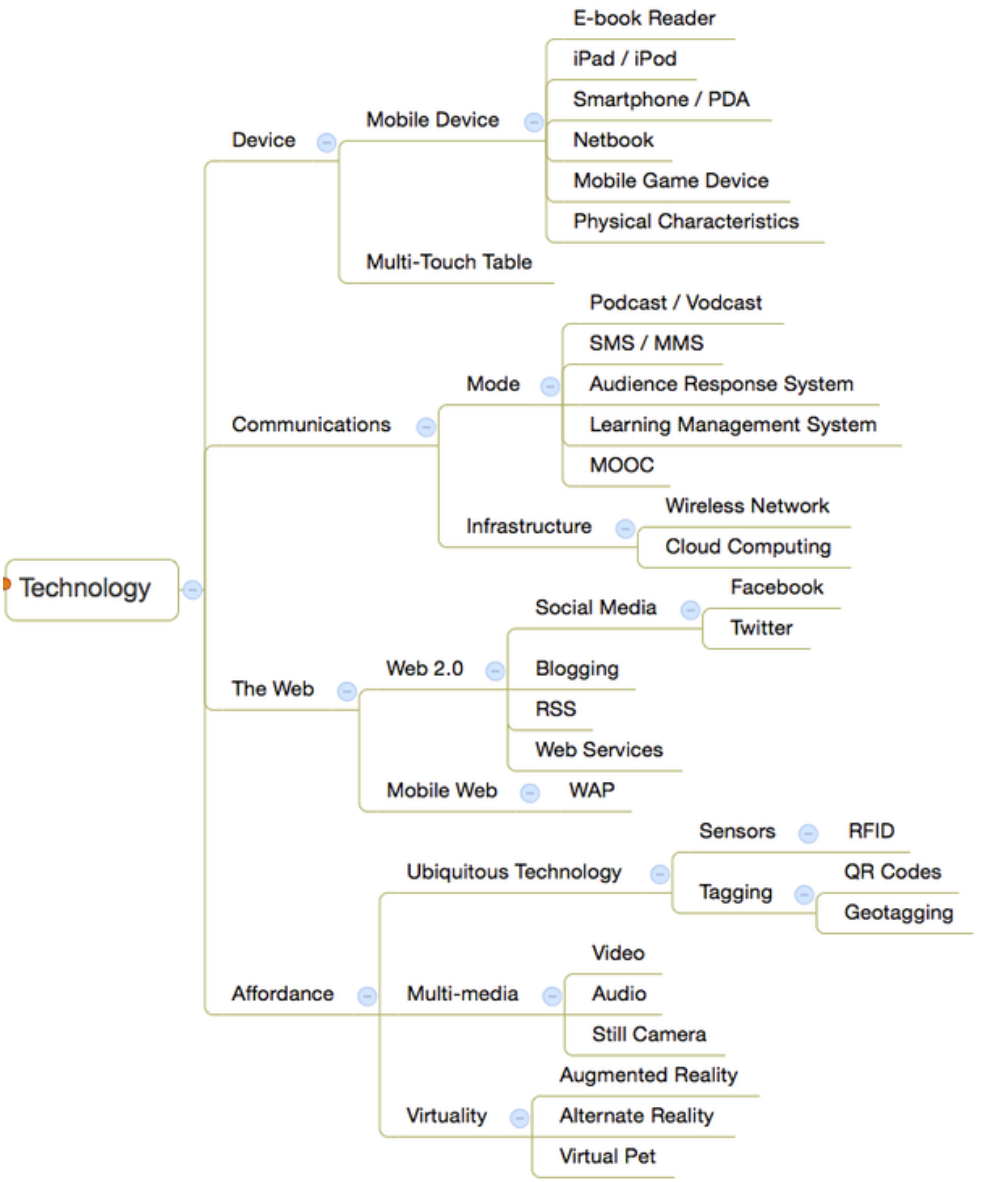
A consequence of increasing access to communications technology has been the increasing use of web based tools. Indeed, in the first decade of the 21st century, the concepts of content creation and sharing became increasingly prevalent as Web 2.0 tools became commonly used as a means of supporting mobile learning where both teachers and learners could create and share content, using various features of Web 2.0 technologies such as blogging (Pierroux, Krange & Sem, 2011) and social networking (Pimmer et al, 2012.) The affordances of these Web 2.0 tools enabled educators to support constructivist learning in their courses (Cochrane & Bateman, 2010.) As the technology continues to evolve, mobile learning researchers embrace these changes, for example the rapid adoption of tablet computers (Melhuish & Falloon, 2010) and cloud computing (Verma, Dubey & Rizvi, 2012.)

Technological advances have increased the affordances of mobile learning. These range from the straightforward concepts of multimedia, to more complex types of affordances such as ubiquitous technologies and virtuality. There are a number of examples of work where some kind of virtuality is introduced into the mobile learning process. This includes augmented reality (Price & Rogers, 2004), mixed reality, where real and virtual worlds are combined in real time (Doswell & Harmeyer, 2007) and alternate reality. Alternate reality activities are a combination of searching for information and sharing information, but have no predefined narrative. Open ended alternate reality is uncommon in learning activities, as they tend to be more structured. However there are some interesting hybrids of mixed and alternate reality, where the investigation is loosely structured. Kocher, Rusnak & Eklund (2010) emphasise a ludic (playful) approach focused on storymaking, which embodies ambiguous properties giving implicit direction for participants to collaborate with each other and understand what they can or should do. A broader and longer running alternate reality game that included elements of mobile device creativity is described by Keegan (2011). Other more structured examples include 'Invisible Buildings' (Winter & Pemberton, 2011) and 'Savannah' (Facer et al., 2004.) Virtuality also extends to virtual pets (Hildmann, Uhlemann & Livingstone, 2008.)

CONTENT

Figure 5 shows the subtree from the Mind Map that explores the overarching theme of 'Con-

Figure 4. The 'Technology' branch of the Mind Map



tent'. Content in mobile learning systems is usually targeted to a specific curriculum subject, and for the purposes of the Mind Map these have been grouped according to the Library of Congress classification (Library of Congress, 2014). Sciences are well addressed in mobile learning, for example mathematics has frequently been the target of mobile learning systems, as it can take advantage of various affordances of mobile devices such as calculators and sensors, and many mathematics learning systems are based on the ability to take the device outside the classroom and apply mathematical problem solving to real world contexts (Tangney et al.,

2010.) Other major science classifications addressed by mobile learning include chemistry (Dekhane & Tsoi, 2012) and biology (Liu et al., 2009). Subjects from science subclasses have included nuclear power (Chang, Wu & Hsu, 2013) while subclasses from the social sciences have included awareness of traffic violations (Lan & Huang, 2012.) Further main classifications that are well represented in the mobile learning literature are world history (e.g. Wake & Baggetun, 2009) geography (Chang et al., 2012), and language and literacy, where mobile learning has proved particularly popular for learning languages, especially English. For example Cavus & Ibrahim (2009) used SMS for those learning English as a foreign language.

Mobile learning systems targeted at the professional learner will have content oriented towards skills, such as medical (Edwards et al. 2007; Havelka, 2011) or teaching skills (Seppälä & Alamäki, 2003). Not all content is specific to a curriculum subject or professional skill. For example Chiauzzi et al (2008) focus on the personal development topic of stress management. More generic types of content covered in mobile learning include learning schedules and cross cultural communication.

LEARNING

Figure 6 shows the subtree from the Mind Map that explores the overarching theme of 'Learning'. The learning category has been subdivided into style and context, with context further subdivided.

There are many learning styles, for example game-based learning which has been suggested holds the attention of young learners and motivates them (Kumar et al, 2010). The concept of scaffolding (from Bruner) is intended to support the initial stages of a learning process, and can be embedded in the design of mobile learning tools (Chen, 2003). Many authors distinguish between formal and informal modes of learning (e.g. Santos & Ali, 2012). Some learning styles are targeted at the individual, some at the group. Individual mobile learning addresses issues such as self-regulated learning (Sha et al., 2012), while other approaches emphasise collaboration and group work (Bowman, 1998), and the supporting of learner communities.

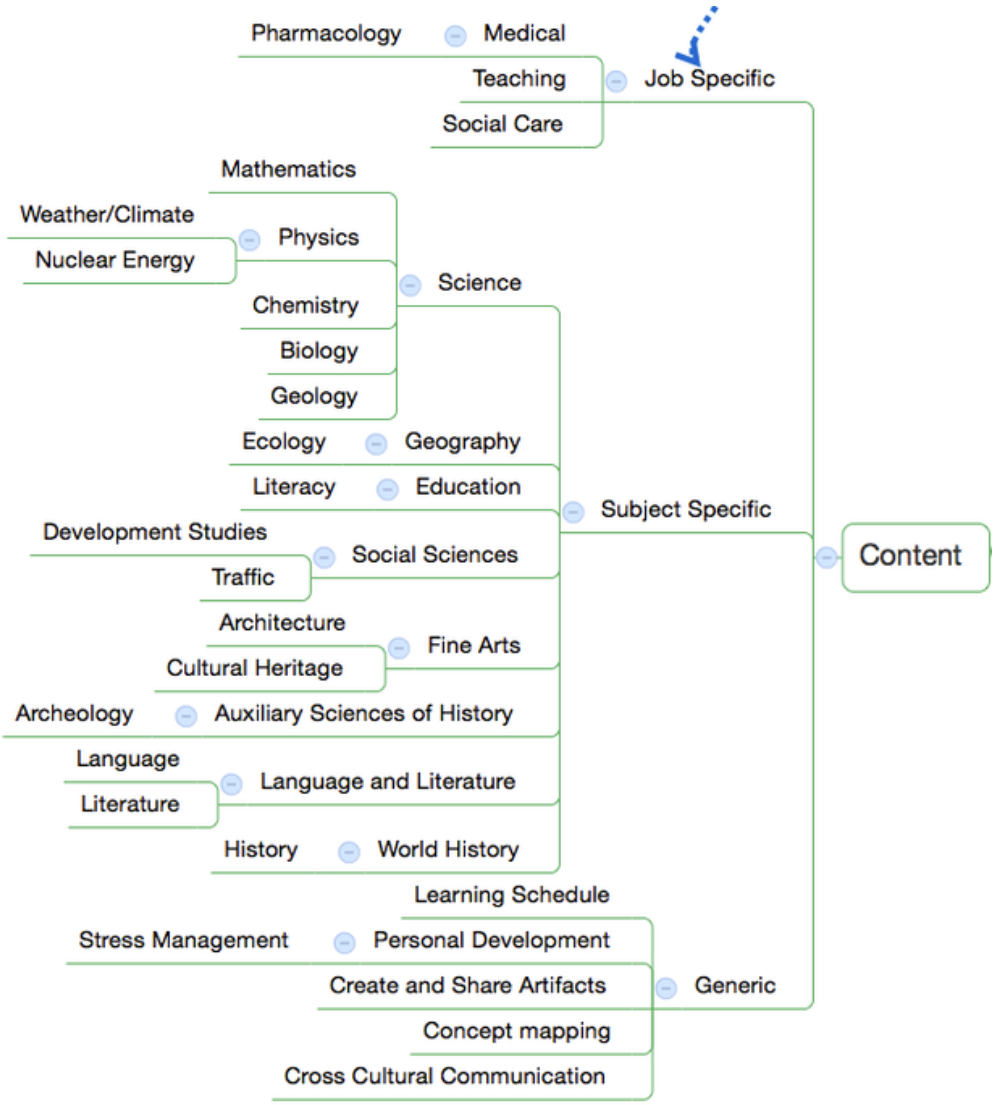
Within the context category, we make a distinction between general types of context and specific learning locations. For example, the classroom is one type of context, which relates to the general concept of using mobile devices inside the classroom; the actual location of the classroom is not relevant. In contrast, the specific physical location (which may range from a local to a national context) is an important feature of many mobile learning experiences. A further task context is one in which a particular work-based task is to be performed. This is categorised as a separate context, since it may be relevant to both generic and specific situations.

Though we have separated out styles and contexts they may of course overlap. For example Hung (2002) draws connections between situated cognition and problem-based learning (PBL) with educational technologies, and Uden (2007) discusses the relationship between collaborative learning using mobile technologies and the concepts of distributed cognition.

For learning in specific context, mobile devices naturally extend their learning support to outdoor learning environments. One of the most effective ways to teach subjects such as geography and heritage is through situated field study (Ahmad & Pinkward, 2012; Nordmark & Milrad, 2012). Where learning is situated in this way, location awareness is often a key component, whether indoor or outdoor (Brown et al, 2010.) Cook's (2010) concept of the augmented context for development in mobile learning applications integrates Vygotsky's zone of proximal development into location based learning activities.

Although our mind map includes a separate 'Technology' category, we also include a 'Technology Context' here, because specific types of technology environment can shape particular types of learning. A simple example is 'anywhere, anytime' learning, which depends on seamless technology infrastructure. A number of articles that explore more specialised

Figure 5. The 'Content' branch of the Mind Map



technological contexts refer to terms such as ubiquitous, pervasive and ambient learning. These terms can be difficult to pin down, and in some cases may be used interchangeably. For the purposes of our analysis, we defined the terms as follows:

1. **Ubiquitous Learning:** learning that takes advantage of ubiquitous technologies, with technology integrated into the objects and activities of learning (Ogata et al, 2010).
2. **Pervasive Learning:** Where the technology penetrates or affects everything in the learning process. Thus it may be seen to be perhaps more specifically mobile than ubiquitous technology. For example it may involve bringing a mobile learning game into a particular environment (Laine, et al 2010). A consequence of this is that per-

vasive learning is also likely to be aware of its context (Syvänen et al, 2005).

3. **Ambient Learning:** Where the learning technologies are in the surrounding environment, For example the learning context might include sensors, tags, geotagging, interactive bar codes etc. (Price & Rogers, 2004).

LEARNER

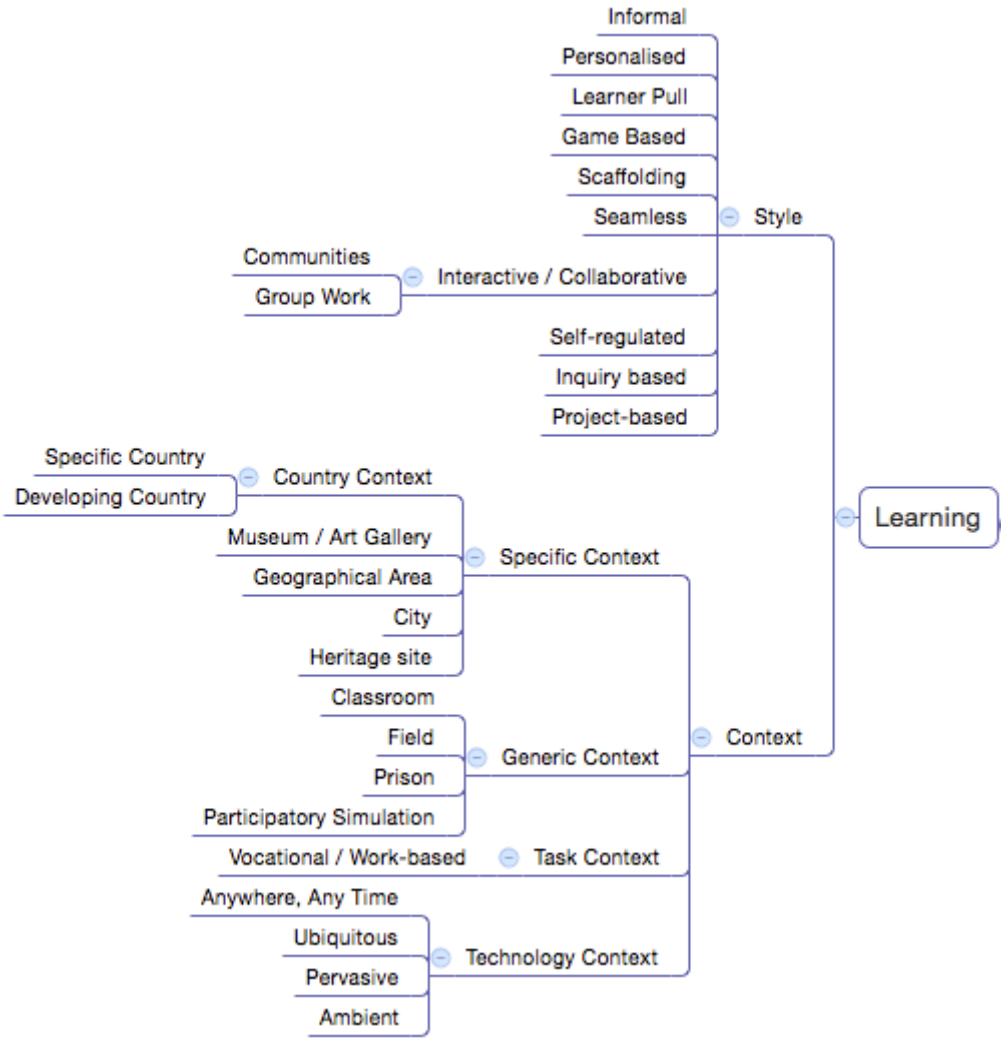
Figure 7 shows the subtree from the Mind Map that explores the overarching theme of the 'Learner'. Mobile learning solutions cannot be considered independently of the learner group for which they are intended. The learner category is mainly concerned with particular groups of individuals whose physical or social constraints lead to specific goals and needs. Groups of learners might be categorised in number of ways, for example by age, nationality, language or role, among many other possible categories. Age is an important learner category, because content and learning style need to be age appropriate. This does not just mean differentiating between the stages of institutionalised schooling, such as higher education (Alexander, 2004) or school, but may also involve other age groups outside of formal institutions, such as the elderly (Lam & Chung, 2009). Neither is the learner necessarily being targeted in the mainstream of education provision, since they may be challenged in some way, for example they may be marginalised (Unterfrauner & Marschalek, 2009). The nationality and/or language of the learner can also be a major factor, since some mobile learning applications are designed for a particular country or wider geographical context, often focusing on issues in developing countries, such as in Africa (Traxler & Leach, 2006; Lwoga, 2012), or India (Kumar et al., 2010), while others are specifically about teaching foreign languages (Viberg & Grönlund, 2013). Another important learner type is that of the professional learner, whose mobile learning needs may often be focused on learning support in context, or specific professional training. Common categories of professionals targeted by mobile learning systems include teachers (Seppälä & Alamäki, 2003), medical workers (Edwards, Jones & Murphy, 2007; Havelka, 2011; Pimmer et al. 2013) and those in the military (Metcalf & De Marco, 2006), or even a combination of military and medical (Han, Harkke, Collan & Tétard, 2006). Further categories of learner include prisoners (Murphy, Bedford & Farley, 2014) and the disabled (Rainger, 2005, Brown et al., 2011).

CONCLUSION

This article has approached the field of mobile learning research from a perspective of creative visualisation. A timeline has revealed notable stages in the evolution of research, from pioneering concepts and activities, through large scale national and international projects, to maturing forms of dissemination, with an underpinning process of technological change. The mind map has shown the breadth of research, its core themes, and some indicative work. This shows how mobile learning research is sometimes of the moment (many of the technologies used in past research are now obsolete) or very specialised (e.g. teaching a very specific topic) but may also address long term issues of teaching and learning theory and practice.

What conclusions might we draw from this analysis? From the timeline we can see that mobile learning as a research field has evolved through a series of stages, in which researchers have often provided the vision for the future that has later been met by the technology. Eventually, Alan Kay's vision for the Dynabook could be implemented in hardware and software. Pioneering researchers brought new devices into the classroom, and ultimately the learners began to bring their own devices. From these cycles we can see that the main role of the researcher is to create visions for the future. These visions may not be very practical in the short term, but give direction and impetus to others who can bring these ideas into mainstream learning. The message from the timeline for current researchers is

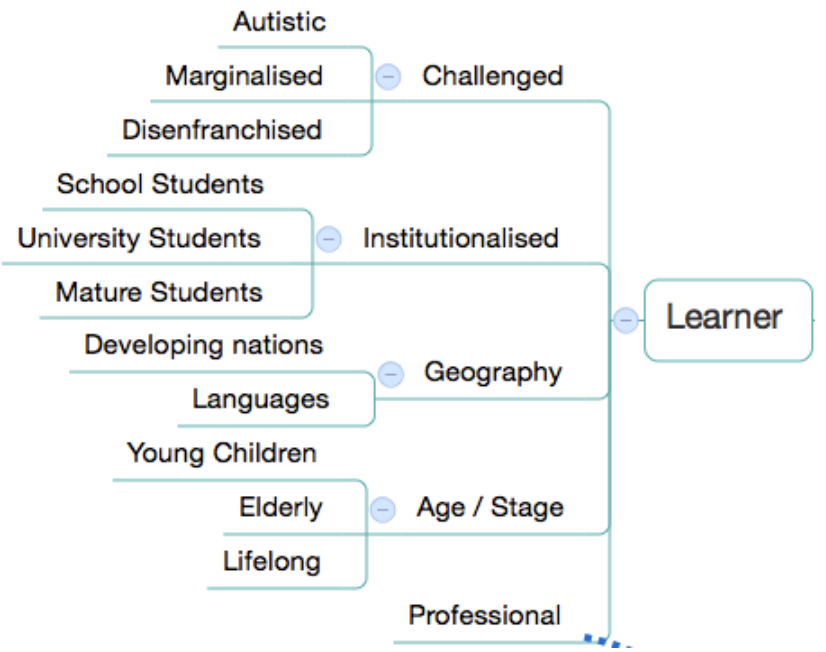
Figure 6. The 'Learning' branch of the Mind Map



to cast their eye beyond current technology and practice and imagine the potential opportunities for the mobile learning that are not yet even possible or practical.

From the mind map we can see that the field of mobile learning is very broad and researchers have already explored a multitude of theories, applications, topics and tools. Nevertheless there are great future opportunities. New technologies arrive all the time, enabling us to explore new ways to learn with these tools. There are many mobile learning applications that have addressed the core categories of the Library of Congress classifications, yet there are many sub-classifications that have yet to gain the benefit of innovative, specialised mobile learning applications. Many theories have been applied to mobile learning, yet there still seem to be ample opportunities for researchers to reinterpret existing theory in this research context, and to evolve new theory as the field matures and evolves. Perhaps the lesson that we might draw from the mind map is that, whilst some aspects of mobile learning have

Figure 7. The 'Learner' branch of the Mind Map



been exhaustively covered, there are always new branches that can be added to this tree of concepts.

There are of course a number of limitations to this work. While the literature coverage is broad it is by no means exhaustive. The categorisation is also largely subjective and is not quantitative. It would be interesting to see how this creative mind mapping technique might reveal very different interpretations of similar source material, if used by other researchers. More objective, qualitative analyses, perhaps measuring impact, would also be of value.

Despite its limitations, it is hoped that this article will be useful to new researchers seeking to understand the background to the research field, and find areas of research that are of interest to them. It may also act as a guide to aspects of mobile learning that have not yet been reported in detail in the literature. For existing mobile learning researchers, perhaps this contribution will help them to contextualise their own work within a broader vision of mobile learning, and thus give them inspiration for extending their future work into new areas.

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