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Mobile Learning

Mike Sharples and Roy Pea

Since the dawn of humanity, people have learned outdoors while on the move. Now, mobile phones and tablet computers are enhancing this personal form of learning by connecting across time and space. In many developing countries, including most of Sub-Saharan Africa, there is no fixed line communication infrastructure, so a wireless mobile device provides the first opportunity to access the Internet or even to hold a telephone conversation. In every country, children and adults increasingly have mobile access to web resources.

The modern era of mobile learning devices may be traced back to the 1970s and a team led by Alan Kay at the Xerox Palo Alto Research Centre. They proposed a low-cost wireless handheld device named the *Dynabook*. Inspired by educational theories from Jerome Bruner and Seymour Papert, the Dynabook would support active involvement and interaction with dynamic simulations of physical systems, and allow learners to share their creative ideas. *Figure 1* shows an illustration from Kay's 1972 paper 'A Personal Computer for Children of All Ages' of two children engaged in a shared simulation game on wirelessly-linked Dynabooks, where winning involves understanding and controlling the thrust and motion of rockets in a planet's gravitational field (Kay, 1972).

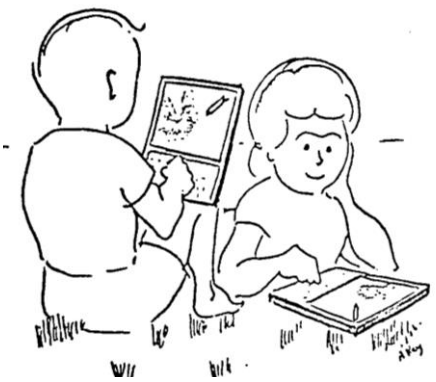


Figure 1. Illustration by Alan Kay of children learning outdoors on wirelessly connected tablet computers through shared simulation games (Kay, 1972)

In the 1970s, technology was not sufficiently advanced to construct a working Dynabook. But four decades later, technology has caught up, through the widespread availability of low-cost tablet computers and sophisticated mobile phones, all connected to the Internet. When well-designed educational software is installed, these networked handheld devices can provide interactive access to learning resources and support learning dialogues across widely differing settings and cultures,.

The earliest major mobile learning project was MOBIlearn, involving 24 partners from academia and industry across 10 countries (Bo, 2005). Its broad ambition was to develop, implement, and evaluate a learning system for work and leisure, based on theories of effective teaching and learning in mobile environments. The focus of the project was to develop and support learning outside classrooms, including learning in museums, studying for a work-related MBA, and learning to manage medical workplace emergencies. MOBIlearn developed a general-purpose software platform for mobile learning incorporating location-tracking indoors and outdoors, and delivery of multimedia content to a variety of mobiles. Trials were conducted on university campuses and in Florence's Uffizi Gallery.

In a final meeting of Mobilearn, researchers reflected on what they had learned as project partners. They concluded mobile learning should be re-conceived around *learner mobility* rather than technology—that learning interleaves with other everyday activities, complementing yet at times also conflicting with formal education. The project identified a need to provide structure and support for mobilised learners, the challenges involved in evaluating learning occurring outdoors, and ethical issues including people's rights to not have their learning activities continually monitored.

Mobile learning is now moving beyond research and pilot projects toward large-scale services. One recent initiative is English in Action (EIA): a nine-year project, since May 2008, to help 25 million people in Bangladesh improve their communicative English language skills. A partnership between the Bangladesh Government and the UK's Department for International development (DFID), it also involves The Open University and the British Broadcasting Corporation (BBC). The project is providing audio and visual learning materials on micro-SD cards for mobile phones, with portable rechargeable speakers, to support the professional development of teachers of English. Each video sequence on the mobile phones starts with a narrator explaining the teaching activity, followed by an example of its use in the classroom. After a pilot phase with 690 teachers, EIA conducted two large-scale quantitative studies. One lesson from each of 350 Primary teachers and 141 of the Secondary teachers in the project was observed and the results were compared to those found in a baseline study. The study found that teachers' competence in English language improved, they used English most of the time for classroom conversation, and they preferred the new communicative classroom activities to traditional English teaching through grammar lessons (Walsh, Shaheen, Power, Hedges, Katoon, & Mondol, 2012). The pilot study is being scaled up to 12,500 teachers.

Another part of English in Action, BBC Janala, provides daily three-minute audio lessons on mobile phones to adults wishing to improve their English language skills. Anyone can learn and practice English by calling a mobile short code, for the cost of 50 paisa (half a penny) a minute. In the first two years of the project nearly 24 million people (a quarter of the adult population in Bangladesh) accessed English in Action media (English in Action, 2013).

Seamless learning

As children and adults come to possess networked mobile devices, networked learning extends beyond classrooms and homes to become part of everyday life (Sharples, 2000), blurring the boundaries between formal and informal learning (Crowley et al., this volume).

School classrooms offer a limited range of sensory experiences and learning contexts. The world beyond classrooms is much richer and more diverse, but is not designed to foster maximum learning. Mobile devices provide us with opportunities to combine the distinct strengths of formal and informal learning environments (Bransford et al., 2006)—the direct instruction and space for reflection in classrooms, and the authentic, contextualized learning that can occur in the world outside schools, in homes, communities and nature.

Advocates of *seamless learning* (Chan et al., 2006; Kuh, 1996) propose that previously distinct experiences of learning (in-class and out-of-class; academic and non-academic; curricular and co-curricular; on-campus and off-campus) should be bound together to seem continuous. Such learning may be intentional, when a learning activity starts in a classroom and continues through discussion with colleagues or online at home. It can be accidental, when an interesting piece of information from a newspaper or TV programme sets off a learning journey leading to exploration, discussion or formal learning. Wong and Looi (2011; MSL5 as revised by Wong, 2012) proposed ten characteristics of "mobile-assisted seamless learning" (MSL):

(MSL1) Encompassing formal and informal learning;

(MSL2) Encompassing personalized and social learning;

(MSL3) Across time;

(MSL4) Across locations;

(MSL5) Ubiquitous access to learning resources (online data and information, teacher-created materials, student artifacts, student online interactions, etc.);

(MSL6) Encompassing physical and digital worlds;

(MSL7) Combined use of multiple device types (including "stable" technologies such as desktop computers, interactive whiteboards);

(MSL8) Seamless switching between multiple learning tasks (such as data collection, analysis, and communication);

(MSL9) Knowledge synthesis (a combination of prior and new knowledge, multiple levels of thinking skills, and multi-disciplinary learning);

(MSL10) Encompassing multiple pedagogical or learning activity models.

Wong & Looi, 2011; MSL5 as revised by Wong (2012)

So we can see how mobile learning merges into a fluid activity of learning pathways within and across locations, institutions, and social situations. The teacher has a central role, but as a learning orchestrator rather than an authority delivering information to learners. Within classrooms, wireless mobile devices can facilitate access to information while assisting teachers in managing transitions between individual, group and whole-class activity (e.g., Goldman, Pea, Maldonado, Martin, & White, 2004; Stroup, Ares & Hurford, 2005; White & Pea, 2011). Outside classrooms, mobile devices can continue to orchestrate and guide learning, offering toolkits to probe the natural environment, store information for retrieval and annotation, and supporting learning conversations.

Seamless mobile learning provides a powerful vision. There are at least four reasons to suggest such learning would be more effective than traditional classroom instruction. First, seamless learning is interwoven with other everyday activities, such as chatting, reading, shopping, or watching TV, and these activities become resources for learning. As Dewey (1897, 1938) proposed, learning emerges when a person strives to overcome a problem or breakdown in everyday activity, or recognises part of the continual flow of activity and conversation as worth remembering. Second, in seamless learning, the control and management of learning is distributed. In a classroom, the locus of control over learning traditionally remains firmly with the teacher, but for mobile learning it may diffuse across learners, guides, teachers, technologies and resources such as books, buildings, plants and animals. Third, seamless learning takes advantage of the fact that we are always *in a context*, situated in a location at a point in time surrounded by objects, persons and resources, and at the same time we *create context* through interactions with our surroundings, by holding conversations, making notes, and modifying adjacent objects. Fourth, with well-designed mobile applications, everyday natural interactions between people and their surroundings can be transformed into learning opportunities, by providing tools to interpret objects in the world, collect data, converse with people in other locations, and reflect on experience. For example, augmented reality overlays computer-generated graphics, video or audio onto a person's experience of the surrounding world.

Mobile learning in practice

Two primary motivations drive the increasing interest in mobile learning. The first is a desire to equip each student with a powerful individual device, as this could provide a customized and personalised learning experience, and we know that students learn more effectively when they build on their own current understanding and make learning choices (Gureckis & Markant, 2012; Schwartz & Arena, 2013). The second is an increasing recognition that in the 21st century, people must continue to learn throughout their lifetimes, as knowledge advances and technologies rapidly change (NRC, 2012).

Mobile devices and the 1-to-1 classroom

Colella (2000) reported a classroom project run by the MIT Media Lab to design and evaluate small wearable devices ('Tags') for children to engage in a computer simulation of a physical system, not by watching it unfold on a computer screen, but by acting out the simulation themselves orchestrated by computer Tags. Each Tag had a two-digit number display and five bicolour LED lights. The Tags could communicate automatically as children wearing them moved within range of one another. In one successful game, children acted as virus transmitters. At the start of the game, one child unknowingly carried a simulated virus. The children moved around the classroom as they wished and the virus started to spread, shown by LED lights flashing red when the Tag was 'sick'. Most of the Tags become infected, but not all of them, because some Tags were 'immune'. The simulation is governed by five pre-programmed rules—the children's task is to infer these rules of infection by repeatedly running the simulation. The rules (from Colella, 2000) are:

- The virus is latent (invisible) for approximately 3 minutes.
- Any person with a Tag with the virus, even if it is not visible, can infect another person's tag.
- The probability for infection when meeting an infected Tag is 100%.
- People with Tags numbered 1 or 2 in the ones position (1, 2, 11, 12, 21, etc.) [as shown on the number display] are immune to the virus.
- Immune Tags are not carriers of the disease.

A study of children playing the Virus Game in class revealed not only that it was highly engaging, but that children collectively enacted an inquiry learning process to uncover the game's rules. The teacher oversaw the activity, but did not guide students towards a correct answer. In one class Colella studied, children started by moving around the classroom without prior planning, reacting to events. They willingly adopted the role allocated by their personal Tags and 'died' when the lights flashed red. Then they re-started the simulation and in a series of repeated trials, over five sessions, they began to predict who might be the initial disease carrier ("Patient Zero") and why some children never died. In subsequent sessions they modified their behaviour—for example, deliberately not moving—to try and uncover the rules of the virus infection. The children Colella interviewed were able to explain part of the virus transmission rules, and some made analogies to the AIDS virus, exclaiming that they had "caught HIV". A later version of the game was implemented on handheld devices (*Figure 3*).

This early study provides a microcosm of mobile learning, demonstrating many of its opportunities and issues. Class time was devoted to the Virus Game for five days over a three-week period, so children repeatedly engaged in a game, reflected on and discussed outcomes, planned to vary the activity, and re-ran the game. For the Virus Game, the learning cycle of engagement and reflect was brought entirely within the teacher-managed classroom. Communication and collaboration were essential Virus Game elements, in the embodied interactions between children moving around the room passing on the infection, and in their reflective discussions and agreement on how to run the next game iteration. The potential for learning came from allowing each learner to experience an indeterminate situation and then to inquire into its underlying structure (Colella, 2000).

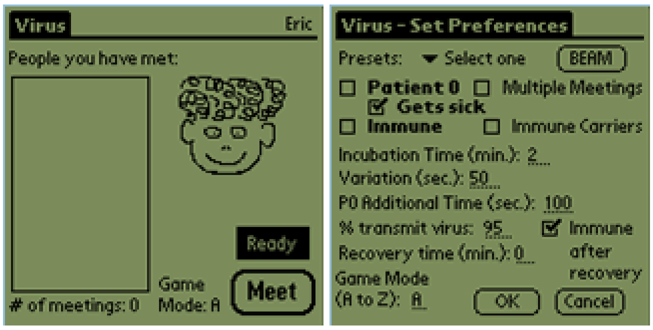


Figure 3. User and settings screens for the handheld version of the Virus Game

Personalised learning with mobile devices presents challenges for a teacher to convene and orchestrate activity. When learning is based on active inquiry, as in the Virus Game, then the teacher must guide the learners as they build shared understandings. If all the activity takes place within class, then the teacher may observe and guide its flow, but if children engage in learning activities with mobile devices at home or outdoors, then the teacher needs to conduct a semi-improvised lesson that integrates their findings into a productive outcome. Managing this process requires teacher professional development to refine these new pedagogical strategies.

Finally, there is the issue of what is actually learned and whether the technology assists or hinders that learning. Children had experiences of playing an active part of a virus simulation, but there is no evidence that the children gained a deep understanding of epidemiology or of scientific inquiry. Subsequent school-based mobile learning projects have explored these same themes: embodied engagement, personalisation and collaboration, orchestration, and teacher development. Roschelle and Pea (2002) identified opportunities for Wireless Internet Learning Devices (or WILDs) to support a new learning dynamics, where a teacher-provided question is shown on each child's device and each child's response is shown on a classroom whiteboard display. For example, the teacher could send a concept map of a topic to all devices, asking each child to indicate the concept or link that is most difficult to understand. All the responses are overlaid on the classroom screen, provoking a class discussion.

Nussbaum et al. (Nussbaum, Alvarez, McFarlane, Gomez, Claro, & Radovic, 2009) in *MCSCL* and Roschelle and colleagues with the *GroupScribbles* environment (Roschelle et al., 2011) established a joint investigation into handheld devices for classroom collaborative learning, building on the WILD design visions. In MCSCL, children work in groups of 3 to 4 and attempt to solve problems. The same problem is presented to all the students on their personal devices, requiring a closed response (for example, selecting the answer to a multiple choice question) or an open response (for example, writing a text paragraph or a graph). Each learner attempts to answer the question individually. Then when all are ready, they compare answers within their group. If all answers are correct (or for open responses, if they all agree), then they must all select a consensus answer to send to the teacher. If the answer is shown as wrong, or they disagree, then they must talk together till they reach a correct or agreed answer. The teacher then uses responses sent by each group as a focus for classroom discussion.

Zurita and Nussbaum (2004) compared MCSCL learning gains with an equivalent Collaborative Learning (CL) condition where students are given the same problems, in maths and language, and asked to follow the same process, but with pen and paper rather than handheld devices. They found significant gains for MCSCL. One aspect of MCSCL's success appears to result from handhelds performing the dual role of providing external representations and coordinating different types of conversation. Each learner has the opportunity to solve a problem, then to re-represent and discuss it within their group, and then to present it immediately for a teacher-managed discussion.

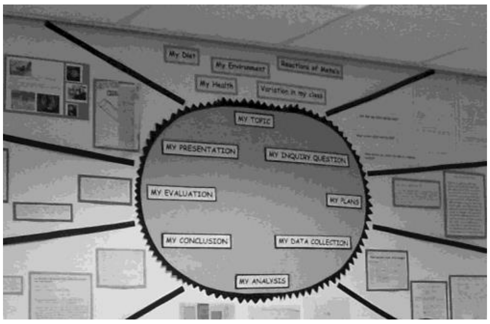
Mobile learning outside the classroom

A parallel stream of mobile learning projects outside the classroom has explored the value of 'being in the wild': having personal experience of a phenomenon or environment, such as a multimedia simulation, museum or field trip environment. Typically, such environments are engaging, rich and complex, raising the issue of how to get learners to attend to relevant aspects of the unfolding situation and uncover its essential features or implicit rules (Klopfer & Squire, 2008). In mobile learning during museum visits or field trips, the processes of reflection need to be managed, by designing technologies that encourage children to pause and think (Lonsdale, 2011), or by setting up a classroom-like environment associated with field locations (Facer, Joiner, Stanton, Reid, Hull, & Kirk, 2004), or by enabling children to collect appropriately detailed, contextualised information for analysis back in the classroom (Vavoula, Sharples, Rudman, Meek & Lonsdale, 2009).

The tension between allowing each child to experience the phenomenon and providing opportunities for collaborative sense-making and planning is explored in mobile learning projects including *WILD* (Roschelle & Pea, 2002; Roschelle, Patton & Tatar, 2006), *Collpad* (Nussbaum, Alvarez, McFarlane, Gomez, Claro & Radovic, 2009) and *Personal Inquiry* (Anastopoulou, Sharples, Ainsworth, Crook, O'Malley & Wright, 2012).

Mobile learning projects outside classrooms draw on a long educational tradition of informal, experiential and inquiry learning. What principally distinguishes mobile learning from this previous work is that the technology is a means not only of providing learning materials when and where they are needed, but also tools for scaffolding, orchestrating and connecting the learning across contexts.

The *Personal Inquiry* project helps young people aged 11-14 understand themselves and their world through scientific processes of active inquiry across formal and informal settings. The project developed an approach of ‘scripted inquiry’, where scripts are like dynamic lesson plans implemented on children’s personal devices for orchestrating learning. The *nQuire Software* runs on personal ‘netbook’ computers and smartphones, using their built-in sensors to provide a mobile scientific toolkit. The project developed a depiction of the personal inquiry learning process (Figure 5) as both a shared representation in class and an interactive guide on the nQuire screen.



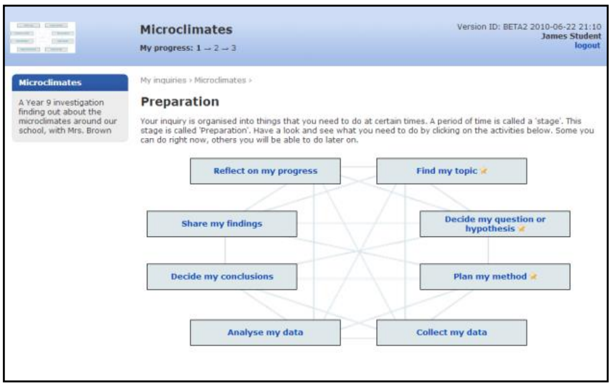


Figure 5. Representation of the personal inquiry process a) on the classroom wall and b) on the nQuire screen

Children typically start a teacher-managed science investigation in class, then continue it at home or outside, supported by nQuire; they then share, discuss, and present findings in class. The Personal Inquiry project conducted trials in two schools with topics engaging and relevant to young people’s lives —‘healthy eating’, ‘food decay & waste’, ‘micro-climates in school playground’, and ‘the effect of noise pollution on bird feeding’. Six school-based trials were conducted to evaluate this combination of technology and pedagogy. Results indicated positive effects on learning outcomes for the personal inquiry children compared with a control class. They also maintained enjoyment of science lessons. Participant interviews across trials revealed how children and their teachers increased understanding of inquiry learning (Anastopoulou et al., 2011).

What *Personal Inquiry* and similar projects, including LETS GO (Pea, Milrad, Maldonado, Vogel, Kurti, & Spikol, 2012) and SCY (de Jong et al., 2010), have shown it is possible to connect learning in and out of classrooms using mobile devices to orchestrate the learning, deliver contextually-relevant resources, and exploit mobile devices as inquiry toolkits. These efforts also raise deep challenges for extending this type of learning more widely within education systems. Each learner needs to be equipped with a personal Internet device usable at home, outdoors or in school. Children need to be supported in inquiry and collaboration as they move from instruction by the teacher to guidance and support by the software. For the teacher, challenges are to manage a classroom filled with distracting personal devices, and to orchestrate a lesson when the children return with the data they have collected outside. The children may arrive back with broken equipment, inconsistent or missing data, or unexpected findings. For example, in the Healthy Eating inquiry, children took photos of their meals each day, using nQuire to log each meal’s content and show a bar chart of its nutrition. In the classroom integration lesson, many children were initially reluctant to share images of their unhealthy meals. The teacher improvised a lesson on data anonymity, reassuring the children they would not be identified when the images were shown in class. They then carried out a new round of photo diary activity, collecting and sharing more complete data on their eating habits.

This type of lesson can be seen as a collective sense-making activity, with the teacher guiding the exposure of data collected outside and interpreting the findings in relation to the initial inquiry question. Sense-making is “a motivated, continuous effort to understand connections (which can be among people, places, and events) in order to anticipate their trajectories and act effectively” (Klein et al., 2006). It is an essential cognitive and social process for gaining awareness of a complex situation (De Jaegher & Di Paulo, 2007; also see NRC, 2009), understanding one’s place in society, and interpreting scientific findings. Mobile learning provides opportunities to connect sense-making outdoors and at home into classroom activities, relating emerging data to a shared inquiry question or hypothesis, and revising the question in the light of the emerging evidence.

A Theory of Mobile Learning

Several decades of learning sciences research have documented how conversation between learners contributes to learning (this volume: Miyake & Kirschner; Andriessen & Baker; Stahl et al.). A learning conversation may be with teachers, experts, or peers. One way that conversation contributes to learning is by enabling and requiring learners to externalize their developing understandings (Eisenberg & Pares, this volume), and this contributes to metacognitive awareness (Azevedo & Winne, this volume). To engage in a productive learning conversation, all parties need access to a shared external representation of the subject matter.

Even before the advent of computers, technologies were developed to externalize classroom understanding: slate tablets, student notebooks, blackboards, and interactive whiteboards allowed teachers to explain difficult concepts and students to express their thoughts. Shortly after computers were brought into schools, learning scientists began to develop software to structure learning conversations, typically called computer-supported collaborative learning (CSCL—Stahl et al., this volume). Many learning scientists have developed computer applications that support learners in externalizing knowledge, even in abstract and complex subject matter such as complex systems (Wilensky & Jacobson, this volume).

To optimize learning, teachers must manage these conversations so that they remain aligned with the curriculum and progress towards desired learning outcomes. Learning scientists use the concept of ‘orchestration’ to describe a teacher’s management of a classroom in which each child has access to a computational device (Dillenbourg & Jermann, 2007; Dillenbourg, Järvelä, & Fischer, 2009; Roschelle & Pea, 2002). In orchestration, the teacher creates a ‘script’ (like a dynamic lesson plan) that runs on every learner’s device and assists the teacher in allocating resources, assigning learners to groups, presenting materials, setting constraints, monitoring progress, enabling communication and shared activity, and integrating outcomes (Collins, Mulholland, & Gaved, 2012). In the ManyScripts software (Dillenbourg & Jermann, 2010), teachers can choose and edit scripts so that they guide lesson flow. One such script is *ArgueGraph*, where a teacher designs a multiple-choice question, with each student selecting an answer. The spread of answers is displayed for all to see and the teacher uses the range of answers to guide a classroom discussion.

With mobile learning, these conversations can be taken outside the classroom. They may be conducted outdoors, or at a distance between people on the move. The common ground is continually shifting as people move in and out of communication and change technologies and contexts.

Context and learning

Sociocultural and situated perspectives have been influential in the learning sciences (see Greeno & Engestrom, this volume). In the sociocultural perspective, all learning is thought to be unavoidably embedded in a physical and social context, and sociocultural research attempts to identify how different contexts can both enrich and constrain learning. The sociocultural perspective is particularly important as we study mobile learning, because with these wireless handheld devices, learning can occur anywhere, in or out of class and with or without a teacher. Consider a group of friends visiting an art gallery and standing in front of a painting. Each person has arrived at a current understanding of the painting from the path they have made through the gallery – taking in the ambience, stopping at other paintings, reading the guidebook – and also from each person's lifetime of creating and interpreting works of art, starting with childhood drawings. Standing together by the painting, they construct a learning 'micro-site' by sharing and discussing their knowledge of art while viewing the painting, resourced by guide books and descriptive labels. To understand mobile learning, we need to examine how people adaptively engage with their surroundings to create impromptu micro-sites of learning—and how they carry that learning from one setting to another (Pea, 1992, 1993, 1994).

Augmentation and ubiquitous learning

Today's mobile technologies support ubiquitous learning—learning anywhere, any time. Smart-phones and tablet computers are powerful computers, capable of guiding learning activities. They are also scientific toolkits, with embedded cameras, voice recorders, increasingly many sensors, and multimedia communications. Further, there are now technologies available that can support mobile learning even when students do not personally carry a mobile device. For example, a building can be augmented with sensors that detect where people are, and with communicators that provide occupants with information about energy usage. With the GPS capabilities of today's wireless devices, it is possible to create location-specific messages—for example, "virtual tourist trails" as visitors walk around a city. Thus technology is used to *augment* everyday experience, such that everyday objects and locations become "learning-enabled" (Spohrer, 1999).

Mobile devices, combined with augmented environments, potentially allow learners to decide where and when to learn. Rather than sign up for a class and go to a school to learn something, they would instead continue with their everyday activities, retrieving knowledge and learning only when it becomes useful.

The site of an historic battle, the underlying rock formations in a mountain landscape, or the daily energy consumption of a building's rooms cannot be readily seen from visual inspection or data probing. This is why augmenting reality is potentially so powerful for learning. As an example, the fabric of an engineering building at Marquette University in Wisconsin, USA has been instrumented to enable students to gain knowledge about building design and power generation by measuring wind speeds, structural strains, and foundation pressure on the building (Claeys, 2009). Rogers et al. (2004) designed forms of digital augmentation and processes by which they could be accessed as part of an outdoor learning experience ('Ambient Wood'), to encourage 6th grade students to conduct contextualized scientific enquiry and reflect on their interactions. Ogata and colleagues (Li, Zheng, Ogata, & Yano, 2005; Ogata, Miyata, & Yano, 2010; Ogata & Yano, 2004) have developed ubiquitous learning environments where support for learning is embedded into sensor-augmented 'smart objects,' such as furniture and utensils that can speak their names in a foreign language, or describe their functions. In their *Out There In Here* project (Coughlan, Adams, Rogers & Davies, 2011) students on field trips were connected via voice and video with other students in a basecamp room. The two groups of students formed a mutually-augmenting learning system, where the students in the basecamp room proposed questions and provided reference information, while students in the field collected data to answer the questions and shared the experience of 'being there'.

Disruptive activity

Children have always sought to disrupt the routine of the classroom by provoking the teacher or engaging in surreptitious activities. But internet-connected mobile devices and smart-phones take this to a new level, enabling children to converse with one another and with the outside world by 'backchanelling' through social media, breaking the classroom's hermetic seal and challenging the teacher's ability to successfully orchestrate learning (Sharples, 2002).

The early reaction of most schools and teacher organisations has been to *ban* mobile devices in class. However, there has been growing recognition of the need to connect the two spheres of institutional and informal learning (Bevan, Bell, Stevens & Razfar, 2013), and as we point out above, mobile devices can do that very effectively. Outside school, children use their mobile devices to create social networks, to constantly converse, and they develop skills in information sharing and online research—and these skills, although developed for personal and social reasons, are valued in the knowledge economy. Although these activities may be severely restricted in school, we believe they should be recognised as complementing rather than conflicting with formal education.

Bringing these themes together, we come to see mobile learning as "processes of coming to know through conversations and explorations across multiple contexts amongst people and personal interactive technologies" (adapted from Sharples, Taylor & Vavoula, 2007). This emphasises cognitive and social processes for individuals and groups to gain knowledge and reach shared understanding, by conversing with each other and exploring their surroundings, across locations and over time, enabled by a range of fixed and portable technologies.

Future trends and challenges

Over the past decade, the field of mobile learning has expanded from pilot research projects to large-scale deployment of technologies and services. The ubiquity of smartphones and tablets means that internet access on the move has, for many people, become daily life, as technology becomes culture. E-books are already replacing paper books; mobile internet access is replacing desktop browsing, with a third of all web traffic now being mobile (ComScore, 2013). A survey of internet access by the UK Office for National Statistics (Office for National Statistics, 2013) shows that 51% of adults used a mobile phone to access the Internet, rising to 80% for people in the age range 16 to 34. In this age group over 60% used their phone or other mobile device for social networking and over 15% for reading e-books. By contrast, less than 10% of people aged over 55 in the UK use mobile devices for social networking or reading.

As people go through life constantly connected by mobile devices, their patterns of learning will change. Rather than acting as direct substitutes for books and informational videos, mobile devices are becoming tools for managing a lifetime of education and learning. Social networks provide a peer group of informal learning contacts. Tools such as Evernote, Dropbox and Google Docs offer support for seamless learning across devices and contexts; emerging MOOCs (Massively Open Online Courses) provide deep dives into the best courses from leading universities. New technologies for augmented reality and personal information capture will enable annotation of locations and sharing of experience.

Two examples of such innovation are contextual language learning and citizen science. In contextual language learning, people learning a foreign language use an application running on their own mobile phones to find words and phrases relevant to their location (Sweeney, Pemberton, & Sharples, 2011). These vocabulary lists have been provided by other language learners. For example, at a local restaurant a previous language learner may have provided a definition of its speciality 'banoffee pie' and taken a photograph of the dessert. Then, when other people visit the restaurant they can see this along with other definitions and photographs, relevant to that specific location, provided by other language learners.

The general approach of 'crowdsourced' mobile learning, where many thousands of people contribute and share location-specific information, is also being applied to citizen science. The mobile iSpot application (Woods & Scanlon, 2012) enables people to upload and share location-specific observations of wildlife and nature and to see what observations have been made nearby. The iSpot website has over 18,000 registered users who take photographs and make identifications of plants and animals. Each sighting can be seen by other users who may verify the identification. A system of reputation management promotes those who provide regular and accurate identifications, awarding them virtual 'badges' and also giving more weight to their verifications.

Shared contextual learning activities such as these will blend into the fabric of daily life. E-books are allowing readers to engage in social reading, sharing margin notes and annotations. Wearable devices, like glasses and badges, will allow location-specific experiences to be captured, shared and recalled. Buildings and street displays will provide information about their structure, energy use, and history. People will be able to leave 'virtual graffiti' at locations to record their impressions and stories.

A long-term Intel labs project explores *Context Awareness Activity Recognition*. Sensors already used on consumer mobile devices for 'hard' sensing (detecting location, relative motion with accelerometers, and ambient light and sound) are combined with 'soft' sensing (such as device activity, social networking actions, calendar data) to produce aggregated data streams that can be interpreted to predict what an individual is doing. Intel proposes that such activity recognition may be used to guide, instruct, encourage, inform, and otherwise support a user's activities in a personalized way (Intel, 2013). Intel observes how activity recognition may be combined with elements such as gesture recognition, social proximity, and emotional classifiers (Healey, Nachman, Subramamian, Shahabdeen & Morris, 2010) to develop a wide range of highly personalized applications.

This emerging future of continual monitoring of ambient activity raises deep issues of ethics and education. Some of these have been identified as part of the 'information revolution', including problems of information overload, needs to escape from relentless connectivity, and the skills required to filter and discriminate valuable knowledge from background data noise. As information becomes contextualised, these issues will not be confined to 'online activity'. More activity will be taken online, so that all locations become associated with a buzzing profusion of data competing for attention. Each person will face the challenge of using mobile tools to create a coherent life story that connects times, places and social groupings, to support personally-meaningful projects and filter out unwanted distractions. Formal education may offer a sanctuary, freed from context-specific intrusions, and also an opportunity to plan and reflect on mobilised learning projects. For this to occur, teachers will need to adopt a transformed role: preparing children for a lifetime of contextualised meaning-making, helping them tap funds of knowledge and experience gained from learning outside school, and fostering learning with mobile devices.

One ethical problem is that if learning is no longer seen as confined to the classroom or lecture hall, but is embedded into everyday lives, then what rights or responsibilities do schools and colleges have to guide such education across formal and informal environments? Most children are already required to perform homework. Should other online activities outside school be managed, monitored and assessed? Should children be given inquiry science tasks to record pictures of their daily meals for a 'healthy eating' project, or asked to monitor their heart-rate for a project on fitness and exercise? These activities are all technically feasible, but what should be the ethical boundaries?

A related issue concerns the rights of young people to own and control their data, and to have online spaces where they can capture and share ideas, free from adult monitoring and interference. Parental fear of internet predators and inappropriate behaviour has resulted in the home online activity of some children being continually monitored. As online activity extends outside, young people may inhabit a world without privacy, where every activity is checked. The converse is true for teachers – their classroom activities may be open to continual scrutiny by children with camera phones. A productive and ethical balance needs to be struck between seamless connectivity and guarded privacy and reflection. A new frontier beckons in mobile learning as it merges with life itself.

Conclusion

From a technology perspective, mobile learning is the provision of educational content and services to people on the move, relevant to their location, across multiple devices including smartphones and tablet computers and even wall-size displays. To learning scientists, the emphasis and the questions concern context and continuity of learning: how can our learning opportunities be best shaped in relation to location and time?

Mobile learning takes for granted that learners are continually on the move. We learn across space, taking ideas and learning resources gained in one location and applying them in another, with multiple purposes, multiple facets of identity. We learn across time, by revisiting knowledge that was gained earlier in a different context. We move from topic to topic, managing a range of personal learning projects, rather than following a single curriculum. We also move in and out of engagement with technology, for example as we enter and leave phone coverage (Vavoula & Sharples, 2002).

An emphasis on mobility is important for understanding and supporting learning, for many reasons. As parents and teachers, we need to equip our children with skills and strategies not only for learning specific topics, but also for managing learning projects across locations and adapting learning to physical and social contexts. Teachers will need to support children bringing not only mobile devices but also their own personal learning purposes, resources and networks into classrooms. *Context* is a central and evolving theoretical construct for mobile learning. People learn within multiple contexts; by moving through and comparing contexts; and by creating contexts from interacting with locations, artefacts, resources, and other people.

Since most previous educational research has been conducted in school settings, we know too little about how people learn outside classrooms: how they engage with their surroundings to create micro-sites of learning and carry learning from one setting to another. The science of mobile learning must examine mobility not only of individuals, but groups and societies. We are only beginning to understand how to design cities with buildings, public spaces and services that enable not only commerce and entertainment but also technology-enhanced meaning-making: for example, enabling immigrants to learn about language and culture through a combination of interactive public displays and personal context-aware applications. How people learn through movement is a central concern, whether in sport and dance, or by moving about a conceptually rich space such as a museum or heritage centre.

New technologies can offer personalised toolsets for mobile learning, combining location-aware sensors with facilities for accessing, communicating and sharing knowledge on the move. People in a real setting, such as a heritage site, can share situated knowledge with people online moving around a virtual simulation of that location. Citizen scientists may use mobile phones and tablets to perform experiments, to observe and share questions and information about nature. Mobile services allow people to leave 'virtual graffiti', hear context-specific stories, and engage in simultaneous shared experiences across multiple locations. These offer new ways of learning, but also raise deep ethical issues of privacy, ownership, and space to reflect in an 'always on' society. Learning happens through a cyclical process of engaged flow of experience, interspersed with opportunities for reflective understanding and knowledge sharing. As learning scientists we need to understand how to spark and maintain this learning engine for people, groups and societies, ever on the move.

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