Researching mobile learning: Overview

September 2006 to September 2008

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Summary

This report is a summary overview to highlight the key findings of a two-year development and research project focused on the impact of one-to-one personal ownership of mobile devices. The research was carried out in partnership with primary and secondary schools in two local authorities, which have taken part in projects that supplied handheld devices to each pupil in a year group.

This overview draws on reports from the three phases of the project:

- September 2006 – May 2007: McFarlane *et al*. (2007) *Mobile learning: Research findings, July 2007*
- April – December 2007: McFarlane *et al*. (2008) *Researching mobile learning – Interim report to Becta, April – December 2007*
- January – September 2008: McFarlane and Triggs (2009) *Researching mobile learning: January to September 2008*

You can find all Mobile 1:1 reports on the Becta website.

The key findings are set out in the following section. A more detailed account of the research findings can be found in 'Findings related to the research questions' and 'Teachers and learners as users'. ' Why 1:1 mobile devices?' contains a discussion of the value of mobile devices in learning and teaching.

This report will be of interest to those engaged in the provision of ICT for learning, particularly policy makers at all levels and school leaders.

Key findings

Overall

The research captured a range of device use that is effective, innovative and supports teachers and learners. Learners associated the use of handheld devices with learning in school and out of school. Moreover, they saw the devices as supportive of effective learning, even where their own levels of use were low; this perception persisted over time, so is not simply an effect of novelty. As with any technology-based innovation, it takes time to establish effective use of mobile devices in a classroom. In two years, teachers and schools have travelled a long way. Clusters of active use clearly show the potential for these devices. The practice is developing, but there are many aspects of device use to be further developed and embedded. The research also identified barriers to full exploitation.

The evidence suggests that a large proportion of learners gained learning value from use of the device. However, it is important to understand the processes by which the potential of the devices to deliver learning value are realised. The research indicates that teachers' practice and learners' skills and competences are significant factors. The extent to which teachers incorporate the use of devices for learning (even if that

use does not exploit the full potential of the device) has an effect (for most users) on how much they use the device for learning, on the development of skill and competences in device use and in learning, and on the attitude of learners and their families to the device.

In connection with implementation, the research confirmed some classic findings: the technology must be reliable, robust and flexible; and all users, teachers and learners, must be competent with the device.

Specific to this project, we found that initial teacher professional development must include the basic operation of the device on its own and with a network, and offer clear examples of effective use within the classroom. The positive impact of device use is limited if teachers have had limited professional development in pedagogy and the incorporation of devices in learning. One or two examples of powerful applications were enough to seed uptake, but this use needed to be monitored, nourished and sustained. (The use of video from classrooms, especially of teachers in the same school or area, can be useful for demonstration and as a basis for discussion.) Regular in-class support for professional development of lead teachers, from people with technical and pedagogical expertise, resulted in teacher-led innovations and developments in productive device use. A number of teachers in the study emerged as natural innovators and have been champions for uptake. They all, however, have many other in-school responsibilities and found that there was little or no time to reflect on or share their practice.

Developing effective learning practice with the device takes time. This is true for both teachers and learners, but especially for teachers. The teacher's role in developing, explicating, modelling, requiring and supporting effective learning practice with students is crucial. Even when a technology-based innovation is established in the classroom, it takes even more time for this to spread within a school. Schools have found it difficult to facilitate professional development and effective dissemination. Time is a scarce commodity in schools, and that assigned for an innovative teacher to share practice with other class teachers or, in secondary schools, with colleagues in their own or other departments or faculties is too little to encourage their engagement. In addition, enthusiastic and experienced teacher 'champions' need time to reflect and develop their ideas about the contribution the device makes or could make to teaching and learning in their subject domain or age group; this is especially important in considering generic and subject-specific uses of the device. Allocating teachers time to think, and facilitating contact with other teachers working with handheld devices, in-school and in a wider network, would encourage the 'viral' effect and be beneficial in sustaining development.

Parallel with documenting a wide range of productive uses of the device in teaching, the research identified a number of barriers to device use becoming universal, embedded or habitual:

- The current assessment regime and schools' concerns about league tables constitute a major barrier. As key assessment points approached (in Years 6 and 11), even teachers who were enthusiastic about handheld devices and had developed innovative and productive uses for them felt they could not take the risk of not returning to tried and tested ways of achieving expected levels of attainment at Key Stage 2 and expected grades at GCSE. Many teachers argue that device use in class does not contribute to ensuring learners' success in SATs and GCSE. (Devices at this stage were widely used only for out-of-school revision.)
- The at-times unreliability of devices and problems with wireless connectivity, which mean that connectivity is unpredictable, constitute a second barrier. For teachers, technical issues around the reliability of devices and connectivity are the main deterrent to incorporating devices in learning. Also, when teachers cannot rely on all students in a lesson having a working device, they make using the device optional, so that learners without a device (it may be broken, left at home or with a flat battery) can still take part. This pragmatic response, as well as being time-consuming in relation to planning, results in a hybrid pedagogy which does not make full use of the device's potential to support learning.
- Teachers think that the more open-ended, learner-centred approaches and increased learner autonomy that device use affords require more time than is available.

Actual achievements in Key Stage 2 tests cannot be mapped to use of devices. Some high-level users achieved beyond their predicted grades; others did not. Similarly, some low-level users exceeded their predicted grades and others did not. However, current assessment data (including level achieved) are unlikely to capture fully the skills and more subtle learning that takes place with devices. Learning-related gains from device use may focus more on longer term orientation towards learning, and on skills for learning, rather than on shorter term key stage outcomes. (For a more detailed discussion, see the section 'What impact on attainment and other defined learning outcomes can be linked to this intervention?'.)

Findings related to teacher practice

There is little evidence that device use is fully incorporated in assessment for learning. Although assessment is a feature of technology use generally, it becomes more salient with personally owned mobile devices because of the increase in the amount of digitally produced work. The research provides isolated examples of innovative and effective formative assessment using digital means. However, there is limited evidence of formative assessment of digital work. In general, feedback remained predominately on paper and given for work produced on paper. In addition,

because high-stakes assessments rely on handwriting skills, teachers and some learners tended to concentrate on paper-based work, especially as assessment points approached. Digitally produced work generally had low status, and any feedback on it was given orally or on paper. Assessment is an area for professional development in teachers.

Our research so far suggests that the learning value of the devices (apart from in increasing motivation) is associated with the opportunities they provide for iteration and transformation. Because work is all in one place and easily accessible, learners say they voluntarily go over what they have done in school; when teachers build on this, it has learning value. However, because of perceived pressure on time and the low status of digitally based learning activities, they can be unfinished. Programs offering drill and practice in a game format, teacher-produced revision packages, guides and criteria statements have all been mentioned by learners as valuable in relation to tests and examinations.

Teachers have exploited the one-to-one aspect of device ownership more than device mobility out of the classroom. The optimum use of the device as a tool which can productively interact with other technologies has also been neglected. The device is most frequently seen as a stand-in for a computer. This is mainly because, in both primary and secondary phases, learners rarely move out of the classroom, learning content and processes are tightly defined by schemes of work and/or strategies, and time allocation is not flexible.

Findings related to learners' attitudes, skills and competences

Patterns of use of devices by students varied, with some learners enthusiastic and frequent users, in and out of school, for learning and other personal purposes. Other students in the same school used their devices very little. Level of use was not associated with overall attainment level, but use of devices in and out of school was related to levels of teacher-guided use in class.

Features associated with the device and valued by students to support learning include that it:

- facilitates individual, co-operative and interactive work in class
- enables the sharing ideas and responses and the building of knowledge
- increases participation in whole-class settings
- enables learners to revisit areas for consolidation and reflection out of the classroom – this, learners say, helps to increase understanding
- provides opportunities for autonomy and independence
- provides work and resources all in one place and to hand
- gives the ability to transfer work between digital devices
- alleviates pressure on the computer rooms and makes learning more flexible.

Where learners show low levels of use of the device, this may indicate low motivation, but in this study it was also strongly associated with a lack of knowledge of how to use the device. The idea that, once they have the device 24/7, young people will quickly learn to use it and exploit its full potential, is not supported by the evidence. The data gathered over two years show that only small numbers of learners spontaneously begin to use devices for any purpose – in or out of school. The attitudes to the device, and patterns of use in homes and in peer groups, combined with the availability of support for gaining expertise in both these contexts, constitute a key variable in the development of use. Learners for whom a supportive context for developing expertise is not available, and who are not proactive in seeking help, are much less likely to be effective users. There is a need to identify these learners early and provide support to make sure they know how to operate the device competently.

A frequent approach by teachers to incorporating devices in learning is to give learners a choice of whether or not to use a device for a task. This is not beneficial where learners' repertoires of skills and competences are limited. Where learners are skilled and competent, choice may be valuable in relation to personal preferences for independent learning.

The positive impact of device use is limited where learners have devices but teachers do not. Related to this, in the secondary phase, the responses of teachers (with and without devices) to autonomous use of devices by learners in lessons are varied. Whether use is encouraged or forbidden has an impact on levels of skill and use, and on attitudes.

Increased learner autonomy requires a more sustained and explicit focus by teachers on effective device use and developing skills in locating and evaluating information, critical thinking and reflecting on learning. The range and extent of device use for learning is affected by teachers' practice. Many apparently skilled students make use of only a limited amount of the potential of the device for learning. Some programs and applications are reported as being rarely or never used. Very few learners have developed effective systems for saving, naming, storing, organising and retrieving what is on their device, and there is little direct teaching of this. 'Looking things up on the internet' was the most frequently reported activity by students. Students viewed positively being able to search on the internet, but our observations suggest that there is little direct teaching in context of the skills required to effectively search for and evaluate information.

Findings related to homes and families

In general, across all schools, there was a high level of support for the projects from parents and carers. At all levels, even Key Stage 4, pupils reported that they are more likely to show school work to family members when it is on the device. Families feel they know more about what is happening in school when they see work regularly and not only at parents' evenings. In the few homes without internet access, the

positive impact of devices with 3G has been considerable. Having access to the internet via a device also takes the pressure off in the competition for computer access at home.

Looking ahead

Within the short span of the research, the whole technological landscape has been rapidly developing; this shows no sign of stopping. We have seen changes in the devices and device specifications used by teachers and learners in the study. The pattern of constant change in the industry presents challenges to local authorities and schools aiming for consistent and sustainable development of mobile learning.

Within the education system, developments and reforms are prompting change: the spread of learning platforms/VLEs, the introduction of Diploma courses and the greater integration of subjects in learning are likely to have an effect on how teachers teach and learners learn. Mobile devices could find a place in this future. The lessons learnt in these early pioneering projects of one-to-one mobile learning will remain valid and should inform personal use of technology for learning going forward.

Why one-to-one mobile devices?

Whatever model of teaching and learning was in use, it was clear that teachers' and learners' responses to the device itself shaped their attitudes to learning with it. The study identified the following benefits of device use:

- The small size of the device and the potential for personalisation that ownership made possible meant that many learners developed a strong and intimate relationship with this learning tool.
- In addition to its mobility, having everything (completed work, resources, and tools such as cameras, software and applications) in one place was frequently cited as a positive aspect by learners and teachers. Teachers thought the devices enabled them to be more flexible in their planning and more fluid in their teaching, able to seize learning opportunities more easily. The device enabled learners, for example in a science investigation, to take photographs or videos, log data on a spreadsheet, have access to the internet, and make notes. In performing arts, PE or modern foreign languages (MFL) lessons, the video and audio recorders were used to capture performance for examination and improvement. Although all these activities are possible with a digital camera and laptop, the fact that they could be achieved with learners' devices meant that teachers were more likely to use a more learner-centred approach. Teachers were glad not to have to book equipment or computer access, or be constrained by having to timetable lessons in the computer room. Learners also looked more often at things on their devices than at work they had done on paper.

- During the period of this study, none of the schools had access to a learning platform. However, all had internal systems (most frequently referred to as a 'shared drive') so that learners were able to download materials placed there by their teachers. Beaming and Bluetooth were also used to download materials. The materials were used in class and also for revision. As with other work done on the device, these materials were reported as being frequently consulted by many students. There was some evidence of material being uploaded by students to the shared drive for storage. Students also uploaded (or beamed or used Bluetooth to transfer) material for teachers to see; there was very little evidence of digital feedback to students.
- Devices also made possible whole-class interactions between the devices and the whiteboard. This increased learner participation in lessons and also helped teachers monitor development of understanding and spot misconceptions.
- In two of the primary schools where the computer room was located next to the Year 6 classrooms, there was some evidence of interaction between mobile devices and desktops. However, this interaction was not seen to involve the creation by students of multimedia products (such as e-books). Lack of time was the reason given for this. There were isolated cases where the teacher created a class e-book from resources collected by students on their devices. This e-book was then placed on the students' devices and was much prized by students, being kept carefully and shown over a year later.

With the price of laptop computers or equivalent devices falling, and learning platforms that are accessible beyond school becoming widespread, there is inevitably a question of whether a device that can be carried in the pocket and held in the hand will be important. Although the ability of learners to access the internet individually in lessons (without having to go to a computer suite or book a set of laptops) is used, often the activity could have been carried out on a laptop. Equally, homework could be done on a desktop or laptop (and frequently is). When learning platforms provide every student with a space for storing work and materials, the use of a handheld device to transfer work between home and school (a key utility in this project) will be redundant. Families may also be able to get easy access to students' work on a learning platform – access to work is one of the advantages of handheld devices that is valued by some students and their parents.

However, with handheld devices, the battery lasts all day, and the devices are always there and instantly on. Learners can carry everything with them: the data stored on the device includes work in progress and a mix of personal and public content. The device belongs to the learner and is with them 24/7. We have already seen its potential for personalising the learning process.

With the current curriculum and assessment regime, we have as yet seen relatively little planned use for learning in school but outside the classroom. Notable exceptions that indicate potential were: in one primary school, a visit to the school garden and pond to make notes and photograph and record sound as a basis for writing poetry; in another primary school, using the video facility in the playground to create an 'outside broadcast' item for a news programme. In the secondary phase, Year 10 students toured the school, using notes and photographs to create a health and safety report. Away from school, the mobility of the device has been well exploited on primary school camp and in secondary work experience modules.

The opening up of the curriculum to learning based on greater integration between subjects, the removal of nationally reported assessment for 14-year-olds at the end of Key Stage 3, the development of Diploma courses, the focus on personalisation: all of these recent moves could be well served by one-to-one mobile device ownership. In addition, the roll out of VLEs and learning platforms in schools may mean a school-wide endorsement of digital work, which could encourage innovations in effective assessment for learning, and make tracking out-of-school learning more possible.

Within the short span of the research, we have seen changes in device choices and specifications. Indeed, the whole technological landscape has rapidly changed and developed. Nonetheless, the lessons learned in these early pioneering projects of one-to-one mobile learning will remain valid and should inform personal ICT use for learning going forward.

Background

The research was located within two ambitious initiatives: Learning2Go, a local authority initiative in Wolverhampton, and Hand-e-learning, a city learning centre initiative in Bristol. These projects have enabled all pupils in a year group and their teachers to each have a mobile device. The teams of professionals at the local authority education support service in Wolverhampton and at CLC3, a learning centre in Bristol, have been essential to the projects, providing vision, leadership, professional development, advice and technical support.

Three primary schools and two secondary schools were involved in the research. In all cases, the head teachers showed significant commitment to the vision of embedded use of technology in the school through the use of personal mobile devices.

In the primary schools, pupils in Year 5 in 2006–07 were followed into and through Year 6. In the secondary schools, pupils in Year 10 at the start of the research were followed into Year 11. In addition, in 2007–08, two additional year groups were added. In one secondary school, mobile devices were introduced in Year 7, and in the other in Year 10. This increase in the sample was the result of a re-launch of the secondary project with a new model of device.

In all cases reported here, the devices were funded by parental contributions linked to grants from the e-Learning Foundation. The learners had full-time ownership of the devices, including at weekends and during holidays.

Mobile devices in the context of this research are portable, mobile technologies which can be held in the hand and used in any location or context. A range of devices can be included within this definition. In this project, the device that was initially provided to teachers and pupils was a PDA (personal digital assistant) or a customised PDA known as an EDA (educational digital assistant). Each of these devices was equipped with a mobile version of an operating system found on PCs, Wi-Fi capability, the ability to read SD memory cards, and an integral camera. The lead agencies in each location selected additional applications and content to be installed or made available to the particular user group via an SD memory card. The battery life of each device was one working day, and the devices activated instantly when switched on. Devices were wireless enabled, and all schools involved had wireless access.

The device chosen for the re-launched secondary project was a mini clamshell-style device with a larger screen and in-built keyboard. Like its predecessor, it had a camera but came with a higher specification system, which meant that data was not lost if the batteries lost power; it also had increased storage and 3G connectivity. The city learning centre entered into a contract with a major service provider for data services and loaded onto each device a profile designed to suit the learning needs of the users.

The research

The design of the research project was developmental in that data were progressively analysed and findings fed back regularly to teachers and headteachers for their validation and comment. The researchers' role, initially, was to record and provide a mirror. As the project progressed, teachers, as co-researchers, were invited to make a contribution to the analysis of data and the creation of knowledge. The findings were shared with and validated by all involved, and the research fed into developments in implementation and practice.

For more detail on the research design and methods, the schools and the sample of learners, see the appendix to the full report, *Researching mobile learning: January to September 2008*.

Research questions

Becta commissioned the research project to address the following questions:

- What pedagogic models best support effective use of one-to-one access via a mobile learning device to educational resources and tools?
- What impact on attainment and other defined learning outcomes can be linked to this intervention?
- What are the implications of mobile technologies for practitioners, particularly in terms of continuing professional development (CPD), barriers to engagement and embedding in pedagogy?
- Has there been a quantifiable impact on teachers' productive use of time as a result of this intervention?
- How have the relationships with homes and communities been developed through these interventions?
- What are the technical challenges for this kind of access and use, and how have they been met?

In addition, in the final phase, in response to the findings from Phases 1 and 2, the analysis focused on the characteristics of teachers and learners as users of mobile devices. In the first two phases, it had become clear that patterns of use were complex and heterogeneous. The focus therefore shifted slightly in order to investigate and attempt to understand both the nature of the patterns of use and their underlying causes.

Findings that relate to the research questions

Each research question is explored below.

What pedagogic models best support effective use of one-to-one access via a mobile learning device to educational resources and tools?

We have seen teachers employ a range of pedagogic models over the course of the research. No one model of best practice was imposed on teachers by either of the projects. Teachers were encouraged to use the devices in whatever way they thought would support their students' learning.

Early in the project, we identified three models of teaching and/or learning that were evident in teachers' practice with devices. These three models persisted over the two years. Each approach has been seen to be effective.

- **Teacher-directed activity**: Use is planned by the teacher within a teacher-controlled environment; device use is integrated but may be controlled by the teacher and incorporate the whiteboard. There may be some degree of choice about how the device is used within the activity. Teachers who are reluctant to give control to the learners or are concerned about doing so feel more confident with this approach; it has also increased learners' participation in whole-class lessons and resulted in effective learning.
- **Teacher-set activity**: The teacher sets the task and specifies the desired outcomes; processes and format are defined by the learners; device use may be an option. This more open-ended approach appeals to higher attainers; students with more limited learning strategies (not always technologically related) cope less well.
  Increasingly, we have seen teachers giving students 'choice' in lessons and for homework about using the device or not. Equally, we have seen more indications of teachers responding to students' suggestions for use of the device in lessons.
- **Autonomous learning activity**: This is pupil-initiated activity. This work may relate to, or extend, work done in lessons, and/or use applications on the device to personalise learning, for example to find more information, re-present what has been learnt in another format, iterate learning in class using material from the lesson, or anticipate learning to come. It may also be related to the learning process, for example learners deciding to make notes or taking a photograph of the board.
  We have seen over the project an increase in learner-directed, school-related activity out of school, especially in the primary school.

It is important to note, however, that there are some dangers associated with learner autonomy and with teachers giving students choice about device use. In relation to choice, it could be argued that this is in line with personalisation in learning and that

students should be free to learn as they wish. Our data, however, suggest that in the majority of cases, choosing not to use a device is not a choice that relates to learning style. It is rather a way of avoiding using the device because students do not feel confident and in control of it; they have not learned what it can do and (especially in the secondary phase) feel embarrassed about admitting this. The 'digital native' narrative does not apply to a large number of students in the project, even if they can use a mobile phone. Exploiting the full learning potential of a PDA, for many students, requires more attention and training over time than they are currently receiving.

Equally, increased learner autonomy requires a more sustained and explicit focus than we have seen on developing skills in locating and evaluating information, critical thinking and reflecting on learning. 'Looking things up on the internet' was the most frequently reported activity by students. Students viewed positively being able to search on the internet, but our observations suggest that few learners know how to do this intelligently and effectively.

After internet searches, the most frequently cited activity using devices was making presentations. Students reported this as the activity most likely to be required by teachers in both phases. There are signs that they thought this activity was becoming repetitive.

The potential that the device affords for iteration in learning was increasingly recognised as the project progressed. Opportunities for reviewing work and consolidating understanding were used by teachers in class and for homework. Students' accounts of learning increasingly involved iteration facilitated by online resources or material created by teachers and made available for downloading. The students said that they this helps them understand topics that they did not understand in the lesson. Learners were more likely to revisit work on the device than paper-based work.

Within the project, there were teachers who experimented and innovated with devices. We did see learning-related use that involved the full interactive, communicative, mobile potential of the device, but these instances were exceptional, not routine. In general, work (completed or in progress) was rarely shared and discussed via devices, and devices were not used to share ideas or to support co-operation or collaboration in an activity in which the mobility of the device was exploited or where devices were used in concert with other technology (eg in the creation of an e-book). The mobility of the device was exploited most in out-of-school projects such as school camp or work experience modules. Examples of students leaving the classroom and moving around the school building, the grounds or the near neighbourhood were rarer. Where the device potential was more fully used, the students were enthusiastic.

What impact on attainment and other defined learning outcomes can be linked to this intervention?

Data from interviews with teachers and students and from student surveys indicate a belief that the use of devices had a positive impact. Specific mention was made of revision, drill and practice, concept development by iteration, and extended writing building confidence and contributing positively to attainment. The use of video for paired analysis – for example of an aspect of skill or performance in PE or dance – has raised skill levels. Similarly, the use of audio in MFL has been positive in developing confidence and competence.

Actual achievements in Key Stage 2 tests cannot, however, be mapped to use. Some high-level users achieved beyond their predicted levels; others did not. Similarly, some low-level users exceeded their predicted levels and other did not.

However, current national assessment data is unlikely to capture (fully) the skills and more subtle learning that takes place with device use. Current assessment data (levels achieved) captures specific aspects of learning. Many other aspects of what has been learned (with or without devices) are not reflected in the current form of assessment. For example, GCSE assessment does not incorporate digitally produced multimedia productions, so skills in communicating in multimodal formats (animations, presentations, hyperlinks, and by combining sound and image) are not currently assessed. Many learners in Key Stage 2 and Key Stage 4 provided evidence of skill in this area – skills that, given more time, would have been developed and refined. Also, learning-related gains from device use may focus more on longer-term orientation towards and skills for learning rather than shorter-term key stage outcomes.

A personally owned device that makes possible a wide range of activities is a powerful tool for learning, especially in conjunction with other technologies. The potential it affords for iteration and transformation (using multimedia) can arguably support deep learning – we have some indication of this. In the current context, however, attitudes to the allocation of time and a preoccupation with coverage mean that we have insufficient evidence to support this hypothesis.

The research produced evidence of learning-related gains oriented towards longer-term learning-related goals. Some use of devices in collaborative or co-operative team activity showed potential in the area of the development of skills for learning. However, lack of time and pressure of other perceived priorities meant that learning-related skills were not specifically addressed or developed, nor did the learners have sufficient chance to fully explore and understand the role of the technology in achieving a successful outcome.

The one-to-one, screen-focused video interviews with students suggest (unplanned) gains that are strongly related to independent learning and indicate possibilities. There is, for example, evidence of the impact of device ownership on some students'

ability to organise themselves and their learning. At the extreme, there are students who attribute changed attitudes and new skills in self-management entirely to their devices.

Data on the students' perspective show that students clearly associate the use of handheld devices with learning, in school and out of school, and see them as supporting effective learning, even where their own levels of use are low. A number of students used the device extensively and autonomously as a tool to support their learning. (For these secondary students, a prohibition on use in some subjects was particularly discouraging.)

A majority of learners say (in different ways) that device use increases engagement: they get involved and stick at things for longer. This effect was also observed in the research and remarked on by teachers. There is also general agreement that device use makes learning more interactive and more enjoyable, a feature that was maintained throughout the research period.

There is also evidence that the boundaries between formal and informal learning are being blurred. We saw (particularly in the primary phase) the application of learning in school to student-initiated activity at home, for example the creation of a family tree, holiday journals, book publishing, planning and budgeting for a party using spreadsheets, and designing a dress. These activities are all possible without a device, but the students suggested that the presence of the device prompted them.

Not measurable, but also related to longer-term learning, is the impact of devices on siblings, parents and other family members. There is some evidence that, at best, devices increase family involvement in and understanding of learning, because others also make use of the device.

Assessment for learning quickly emerged as an important area in the research and remained so throughout the project. Teachers who were accustomed to moving around the class and giving formative feedback based on what learners were writing found that the size of the screen on a mobile device was a problem because they could not see the children's work without asking to see the device and so disturbing the activity. Without this source of information, they felt de-skilled. Software solutions to viewing learners' screens were initially beset with technical problems, and although these have been overcome, teachers still need training in ways to use the solutions to inform and facilitate feedback to learners.

Marking work on paper is powerfully embedded as a practice. Teachers feel they need evidence of summative and formative feedback for parents and Ofsted. Early in the project, few could envisage a digital alternative to a pile of exercise books annotated with teachers' comments and grades, and in most settings there was no reliable system for storing digital work and moving it around. In the second year of the research, there were more robust methods of moving and managing digital work in both primary and secondary phases; these included school networks, Bluetooth,

SD cards, and file explorer systems developed by project technicians. Many learners became practised in moving files around and organising their devices, and we saw some innovative examples of formative and summative assessment, with the teacher using the voice recorder, or, in another case, asking pupils to send a screen capture from a game to indicate their learning.

However, learners still infrequently report that teachers require work to be done in digital format. Writing on paper remains the highest-status activity for assessment. Feedback on digital work was given only rarely by receiving and sending back to the learner a file with some form of comment or response attached or embedded. Most often, it was reported that feedback was given face to face in class or written in an exercise book. There were examples where no feedback was given. To embed device use in learning, ways of providing digital feedback on digitally produced work are important.

Device use is making activities that students choose to undertake out of school more visible and increasing the amount of directly school-related work done independently, challenging teachers to know how to make the best use of this for the benefit of all.

What are the implications of mobile technologies for practitioners, particularly in terms of CPD, barriers to engagement and embedding in pedagogy?

Barriers to engagement and embedding device use in pedagogy

We have seen various patterns of device use across teachers, learners and subjects. Explanations of these variations in the take-up of devices and their integration in teaching and learning are complex. There are many barriers.

The most evident barrier to teachers' engagement with mobile technologies is the powerful, high-stakes assessment regime. Even teachers who are enthusiastic about handheld devices and who developed innovative and productive uses for them used them much less from January to May/June in the run-up to key assessment points. The teachers thought that they could not risk giving up tried and tested ways of delivering expected levels of attainment at Key Stage 2 and expected grades at GCSE. Uses of the device for revision and exam preparation prevailed over more open-ended learning.

Associated with the constraints of assessment is the impact of a crowded curriculum. Teachers rightly feel that more open-ended, learner-centred approaches that give learners more autonomy require more time than is available. As a result, device use is not securely embedded in pedagogy. For example, we recorded examples showing the potential for iteration, reflection and transformation that the device affords, but lessons using these features remained rare even after two years. Insufficient time was given for in-depth projects that utilise the potential of the device as a portable tool for research and data collection, for product creation, to operate in conjunction with other tools, or for collaborative activity. Work started was frequently not finished, suggesting it carried low status. However, time constraints are not

unique to work on devices – rather they seem endemic in current school practice. The opportunity for iterative, productive models of working, where digital technologies afford major support, are rare. We have seen examples of learners choosing to work further in their own time on something they started on the device at school. This again shows a potential for learning support but is an interesting exception rather than a widespread practice at this time.

Teachers' levels of confidence in using the device successfully (personally and then with learners), their attitude to risk, their relationship with their students, and the degree to which they are willing to adapt or change practices which they feel have served them well all constitute barriers. Variations in take-up (rate and amount) by teachers are, in some cases, linked with teachers' backgrounds, including their experience of technology. Interestingly, this analysis can be extended to learners. Home context and availability of expertise in a peer group have emerged as salient factors in accounting for variations in levels of device use by students.

Technical problems, especially with wireless connectivity, were a deterrent in the early stages. Although many technical problems were overcome, some teachers are still reluctant to risk having their lessons interrupted by slow or unreliable connections.

There is a symbiotic relationship between teachers' use and learners' attitudes. If teachers do not integrate use in lessons, some learners assume that devices have no real value in learning and cease to bring devices to school or keep them charged. There is a threshold of use necessary to ensure learners' commitment. When teachers cannot rely on all students having working devices, they are forced to have contingency plans or improvise. This is demotivating and time-consuming, so increasingly teachers cease to think about and plan to use devices. The stock of devices for temporary loan has been helpful.

Some secondary teachers are uneasy about the use of devices in class and forbid it. They are concerned that students will be distracted, play games, listen to music, use instant messaging, or make inappropriate use of the video or still camera. There is some evidence that these fears are not groundless, although most students claim to deplore such behaviour.

Teachers and learners expressed issues around writing. There is evidence of device use for planning (mind-mapping), note-making, drafting and creating the finished product (including essays and coursework at secondary level). However, some students say they prefer books, pen and paper; this preference may be linked to the higher assessment status of these media. Teachers and students in both phases are concerned about the impact of device use on handwriting. Some find writing on screen difficult or limiting. (Left-handed students felt less disadvantaged.) Some say they write more on screen – we have some evidence of this with boys. Many students say they hate writing, but seem more inclined to produce work on the device. Teachers point out that presentation software has no spelling or grammar

checker, so students may not realise that they have to correct their text. Use of the transcriber facility and of portable keyboards works for some.

Innovation can be easily thrown off course. Senior managers in schools and governors had to work hard to create and maintain a positive climate, develop policy, sustain enthusiasm, and anticipate and deal with issues such as parents' possible opposition, pupils' e-safety, and inclusion. For successful engagement of teachers and learners, and to enable pedagogy to become embedded, these barriers should ideally be dealt with as part of whole-school planning and teachers' CPD.

CPD

There are, of course, barriers to CPD. There is enormous pressure on teachers' time, and many of those involved in the research had a large number of other roles and responsibilities. Both projects found it difficult to take teachers out of school for centrally organised CPD sessions in school time or for twilight sessions. Increasingly, the strategy was to work alongside teachers in school. This has been very effective but is expensive and may not be sustainable.

The teachers most involved in leading innovation would welcome in-school CPD time for reflection on the contribution that the device is making or could make to pedagogy for the subject domain or age group. Frequently, enthusiastic and excited about device use and development, hard-working innovators can also feel isolated. In spite of having many conflicting priorities, some teachers suggested that contact with other teachers as buddies/mentors or as part of a teacher network would help to encourage and support the 'viral' effect. A supportive group within a school, or a wider community to feel part of, is beneficial in sustaining development. Time is a huge issue and, especially in the secondary phase, the time assigned for sharing with colleagues or disseminating to other subject teachers is too little to encourage their engagement.

As the projects mature, there is more evidence of schools taking control, and an enhanced sense of collaboration and purpose.

The early strategy of introducing teachers to devices in advance of the students in the expectation that they would use them in their teaching was necessary but not sufficient to bring about large-scale change, especially in the secondary phase. The decision to equip only one year group of students also meant that some secondary teachers did not think that the effort to adapt their pedagogy would pay dividends when they had perhaps only one class equipped with devices. In the second phase, allocation of new devices was limited, focusing again on a year group, but only one or two subject areas. This made CPD more possible; however, learners were in classes with teachers who did not have the same device as them, were not inclined to use them, and were receiving no training.

Effective elements of CPD identified in the project are:

- Teachers given time to experiment with devices first
- Support from mentors and colleagues
- Starting small with activities that exploit the device and will succeed
- Provision of authentic examples (eg classroom video), and validation by other teachers and external agencies (The pace of take-up increases when teachers find materials and/or an approach they are comfortable with, and are offered examples of effective use.).

Close collaboration and consultation between projects and teachers had a beneficial impact on teachers' sense of ownership and willingness to experiment. Working alongside teachers and supporting them by providing training and resources that they say they want and need has been very productive. For example, in one secondary school, software was designed by the project in response to teachers' desire to develop a specific aspect of teaching and learning. Teachers were closely involved as collaborators.

Has there been a quantifiable impact on teachers' productive use of time as a result of this intervention?

A considerable investment of teachers' time was needed at first. Those prepared to make this investment reaped rewards later. There is increasing evidence from teachers who are using devices that this initial effort is productive in class and cuts preparation time.

However, little teacher time is allocated for reflection, development, dissemination and mutual support, so that teachers who are developing professionally from their involvement in this intervention have few opportunities for refining their learning or effectively spreading that learning among colleagues. This may be a feature of most interventions, especially those involving technology, but it remains an issue.

The data from the student interviews in the final phase of the research provided examples of resources being made available by teachers for learners to download. In a student survey at the end of the spring term in the second year, about half the respondents said they downloaded files that their teacher had placed on the shared drive at least sometimes. Some did so much more regularly. There is evidence from both primary and secondary phases that use of a shared drive by teachers can save time. Students are made responsible for downloading files before a lesson in which they are going to be used. Similarly, homework or revision materials can be made available in this way.

How have the relationships with homes and communities been developed through these interventions?

The first launch of devices to homes aroused much enthusiasm and created high expectations. In most cases, this has been sustained. However, in the first phase, technical problems, delays in delivery of devices and relatively low levels of use by

secondary teachers severely tested the relationships between homes and schools. It is to the credit of the schools and the projects that, in the main, they were able to survive this and retain the trust and support of parents and carers. In a few cases in secondary schools, problems with the initial launch produced a very high level of parent dissatisfaction with the initiative, which was seen as an expensive waste of time.

Nevertheless, there was a high level of support among parents for the re-launched initiatives in Year 10 and Year 7, although parents in 'new' projects wanted reassurance that devices would be used in lessons.

In the few homes without internet access, students reported the impact of devices equipped with 3G to be considerable. There is also evidence that having individual access to the internet took the pressure off competition for computer access at home.

In homes with high levels of digital technologies and very good internet access, some students reported low levels of out-of-school use and minimum involvement from the family. However, this is not universal, and in some hi-tech homes, use of handheld devices by students is very high, and other people at home are interested and involved. In relation to levels of use, the data suggest a connection between home attitudes, practices and experiences and the extent of autonomous device use by students. One indicator of this is the number of students who can and do regularly change the generic wireless password (the WEP key) to enable them to have device-based internet access at home as well as at school.

Teachers and schools hoped that devices would increase parental involvement in students' learning. In many cases, this hope appears to have been realised. Primary students, not unexpectedly, report very high levels of showing work done for school on the device, at home. Students report that people at home like this and know more about what is happening in school than they did when they had to wait to see exercise books at a parents' evening. Primary students are also likely to be using devices for learning autonomously and producing creatively out of school. This is also shared with parents/carers, siblings and other family members. More surprising is the evidence from students that many in Year 10 were showing work done on the device to people at home.

A large majority of parents/carers were very positive about students owning a device. However, in spite of schools' careful communication there was evidence early in the project of the impact of small but significant amounts of parental opposition. A small number of families in both phases were resistant to any form of technology in the home, but did not object to their children using loan devices in school. More frequent were concerns about e-safety, especially around internet access in and out of school. However home attitudes to barring sites varied, and many students complained of more restricted levels of internet access in school. All schools developed contracts of responsible use with parents or carers and students.

What are the technical challenges for this kind of access and use, and how they have been met?

The two-year period of this project has been an ongoing saga of technical challenges, each of which has been determinedly met, by Learning2Go and CLC3, and eventually overcome. The impact of technical problems on the initiative cannot be overestimated. The main lesson learned is the value of a thorough and exhaustive technical audit of any setting where devices are to be used, to ensure good wireless connectivity, including when large groups are online simultaneously.

Sufficient levels of technical support are also crucial. Devices and systems have become more reliable, but problems still arose and needed attention. In the few cases of extreme and persistent technical problems, frustration was acute. The time required for dealing with technical problems in the early stages of the project, especially by primary teachers, detracted from a focus on pedagogy.

The need for in-school technical support is likely to increase with the spread of devices within a school, especially in the secondary phase. Closer involvement of members of the technical team with teachers to identify and meet teaching and learning needs has been valuable.

Facilities to manage and store digitally produced work have developed rapidly during the project.

The imminent arrival of learning platforms, portals, VLEs and/or MLEs in schools is likely to have a positive impact on device use.

Sustainability is still an issue in relation to the more widespread use of mobile technologies for learning. The real costs to schools need to be assessed, and funding models are needed which consider the implications of continued parental contributions, and the cost of licences for generic and domain-specific software to meet teachers' and learners needs. The lack of availability of a range of appropriate devices in a market which, in the main, does not (as yet) specifically cater for education, is an issue. In relation to 3G, broadband wireless service contracts also have to be negotiated.

Teachers and learners as users

The final phase of the research went beyond the original research questions to analyse the characteristics of teachers and learners as users.

One of the most important findings was the variability in patterns of use by learners, and the connection of these patterns to use with teachers in class. It is evident that not all young people will adopt and adapt digital devices to their own use without clear leadership and training. Although there are always some learners, of all ages, who become expert and frequent users of devices for a range of purposes, in and out of school, many associated with learning, there are at least as many who do not.

The learners who do adopt device use are more likely to be those with teachers who make frequent use of devices in class, a family context where technology use is present, and friendship groups in which someone has a good grasp of the technical operation of the device.

One of the most frequent reasons given for non-use of the device by learners is a lack of understanding of how to operate it. This can be hard to admit to peers, and not always picked up by teachers, and it may be masked if learners get their friends to do things for them, for example download files from the network. In some schools, keen students seek out the dedicated technical help in lunch hours and after school – this could be formalised. Other schools have used tutor time or lesson time (more so in primary schools) to encourage the sharing of ideas and expertise around the device. In Year 7, devices were a central part of a Building Learning Power programme. However, the sharing of learning was not consistent for all groups. In all approaches, some learners were much less skilled than they needed to be, and some developed a dependence on other students. If schools are to ensure universal use of devices, they need to monitor whether tuition is needed in exploiting the various functions of the device as a tool, and they need to devise practicable ways to ensure such tuition is clearly available.

Understanding why some teachers use devices in class and others do not is complex. Obviously, when teachers do not have a device, do not have knowledge of context-specific uses of the device, teach only one or two groups who have devices, or the technology proves unreliable, the barriers to use are very high. When teachers are shown effective practices by other teachers – for example, through videos of classroom use – and they and the learners have access to devices, software and networking that is reliable and effective, then barriers to use are very low. However, as well as the essentially technology-related factors listed above, issues of pedagogical culture come into play. This is perhaps most evident when teachers who are active users reduce use as assessment points approach. If there is a fundamental mismatch between a teacher's view of effective teaching and learning and use of the device, then clearly use will remain low or, at best, only some of the functions will be used (eg practise software for maths; access to revision websites).

Ultimately, the whole-school culture of teaching and learning and the attitude to the use of digital technologies within that culture will determine the extent to which teachers and therefore learners embed the use of these technologies within their practices. The whole-school culture will inevitably be affected by the wider social and political context. The current movement towards more integrated learning in the primary phase, the removal of high-stakes assessment at age 14, and the reform of the 14–19 landscape with the introduction of Diplomas, presents schools with both opportunities and challenges. How schools choose to respond will have a profound effect on the extent to which digital technologies are used by teachers and learners and also, therefore, on the roles in education for mobile devices and the tools and processes they offer.