Chapter 8
Tablet Use in Schools: Impact, Affordances and Considerations

Louis Major, Bjoern Haßler, and Sara Hennessy

Abstract The increased popularity of tablets in general has led to uptake in education. This chapter builds upon the past research and experience of the authors, in particular the findings of a critical systematic literature review that reports on the use of tablets in schools (see Haßler, Major & Hennessy, 2015). The aim of that review is to determine if, when and how using tablets impacts on learning outcomes: Do the knowledge and skills of students increase following the use of tablets for particular purposes, and, if so, what factors contribute to successful or unsuccessful use? Outcomes of the review enable us to reflect on the impact and affordances of using tablets educationally, and allow us to consider factors related to the successful integration of tablets in schools. This chapter provides information and advice for educators (including initial teacher educators) and school policy makers interested in the educational use of tablets. Overall, tablets have significant potential for enhancing learning—but, as with all technology—the most important element remains the teacher, and their classroom practice.

Keywords Tablet use • Schools • Today • K-12 learning environments • Impact of these digital tools • Student knowledge • Skills • Technology • Educators • ITE initial teacher educators • School policy makers • Teacher • Individual classroom practice

Mobile Learning and Tablet Computers

Since the early 1980s schools, colleges and universities have experimented with technology for learning (Sharples, Taylor, & Vavoula, 2010). As the adoption of mobile technologies in education becomes more widespread, research is starting to demonstrate the value of incorporating such devices in teaching (Hwang & Wu, 2014; McFarlane, Triggs, & Yee, 2008). Mobile devices can enhance, extend and enrich the concept of learning in a number of ways (Traxler & Wishart, 2011): (1)

L. Major (✉) • B. Haßler • S. Hennessy
Faculty of Education, University of Cambridge, Cambridge, UK
e-mail: lcm54@cam.ac.uk

A. Marcus-Quinn, T. Hourigan (eds.), *Handbook on Digital Learning for K-12 Schools*, DOI 10.1007/978-3-319-33808-8_8

contingent mobile learning and teaching (where learners can respond and react to their environment and changing experiences, and where learning and teaching opportunities are no longer predetermined); (2) situated learning (where learning takes place in surroundings that make it more meaningful); (3) authentic learning (where learning tasks are meaningfully related to immediate learning goals); (4) context-aware learning (where learning is informed by the history, surroundings and environment of the learner); and (5) personalised learning (where learning is customised for the interests, preferences and capabilities of learners). Cost, adaptability and scalability are among motivations often cited for using mobile technologies to support learning (Ozdamli, 2012). Greater affordability of such technology, along with the rapid development and expansion of wireless internet access, has resulted in mobile learning becoming increasingly prevalent (Hwang & Tsai, 2011; Martin & Ertzberger, 2013). This has led some commentators to predict that by 2020 every student in the USA, across all grades, will have access to a mobile computing device 24/7 (Norris & Soloway, 2015). A range of different mobile technologies have been used educationally (Frohberg, Göth, & Schwabe, 2009; Kearney, Schuck, Burden, & Aubusson, 2012; Naismith, Sharples, Vavoula, & Lonsdale, 2004; Traxler, 2010), including specialised handheld devices such as data loggers, phones and smartphones, low-power computers such as the Raspberry Pi,[1] as well as tablets.

Tablets, sometimes referred to as tablet computers, feature the integration of several components and sensors (e.g. GPS, built-in camera) within a single relatively light-weight device, typically with a touch screen, no built-in keyboard or mouse, (at least nominally) good battery life and at a comparatively low price compared to 'traditional' computers. Tablets became commercially available in 2002 (El-Gayar, Moran, & Hawkes, 2011) and, by 2009, around 14 million had been sold worldwide (Ozok, Benson, Chakraborty, & Norcio, 2008). With the launch of the first Google Android-based tablets (2009) and the Apple iPad (2010), the popularity of tablets increased (Geyer & Felske, 2011). Sales of tablets have grown greatly since then, and in 2015 a projected 321 million tablets will be sold, overtaking sales of 'traditional' PCs for the first time.[2] By 2018, the number of tablet users worldwide has been predicted to stand at 1.43 billion.[3] The popularity of tablets has led to interest in educational applications, particularly in schools. As with many digital classroom resources, the use of tablets has the potential to enhance learning (Kim & Frick, 2011), for instance contributing to raised motivation (Furió, Juan, Seguí, & Vivó, 2015), knowledge acquisition (Lai, Yang, Chen, Ho, & Chan, 2007), and enquiry-based learning (e.g. Haßler et al., 2011; Haßler, Hennessy, & Cross, 2014; Hennessy, Haßler, & Hofmann, 2015a, 2015b).

---

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

[2] Forecast: *PCs, Ultramobiles, and Mobile Phones, Worldwide, 2011–2018*, 2014 Update Retrieved October 09, 2015, from http://www.gartner.com/document/2780117.

[3] *Tablet Users to Surpass 1 Billion Worldwide in 2015*. Retrieved October 09, 2015, from http://www.emarketer.com/Article/Tablet-Users-Surpass-1-Billion-Worldwide-2015/1011806.

This chapter builds upon the past research and experience of the authors, in particular the findings of a critical systematic literature review that reports on the use of tablets in schools (see Haßler, Major, & Hennessy, 2015). The aim of this review was to determine if, when and how using tablets impacts on learning outcomes: *Do the knowledge and skills of students increase following the use of tablets for particular purposes*, *and*, *if so*, *what factors contribute to successful or unsuccessful use*? Outcomes of the review enable us to reflect on the impact and affordances of using tablets educationally, and allow us to consider factors related to the successful integration of tablets in schools.

The review used the systematic review methodology, informed by Kitchenham and Charters (2007) and the EPPI-Centre (2010), and focused on literature reporting the use of tablets by primary and secondary school children. It built on and advanced previous research through considering the literature on actual learning outcomes rather than just motivational affordances associated with using tablet technology. Systematic reviews are trustworthy, rigorous and auditable tools (Kitchenham, 2004) that allow existing evidence to be collected and summarised and enable identification of gaps in current research (Kitchenham & Charters, 2007). A mixed search strategy, involving manual and automated searches of electronic resources, was undertaken in May/June 2014. Technology- and education-based resources were searched. Inclusion and exclusion criteria ensured that only relevant literature was included. Each study in the final set was also assessed for its quality based on a set of guidelines produced to guide the quality assessment process. This quality assessment involved assessing studies according to their methodological trustworthiness (non-review specific; the trustworthiness of a study's results based on an evaluation of the research approach used) and relevance to the review (review specific; relevance of a study for determining whether the knowledge and skills of students increase following the use of tablets). Several stages of screening were used to identify studies: (1) *Initial Search* (i.e. implementing the search strategy, identifying potentially relevant literature based on analysis of titles and abstracts)—103 studies progressed to Stage Two; (2) *Detailed Examination* (i.e. reading the full text of identified studies, applying the inclusion criteria and checking reference lists for other potentially relevant work)—33 studies progressed to Stage Three; (3) *Data Extraction and Quality Assessment* (i.e. detailed analysis and quality assessment of studies identified as relevant)—drawing on the 33 studies identified.

The final set of 33 studies included in the review, the reported findings of which we draw on in this chapter, are varied in their research scope: using a number of methodological approaches; involving diverse numbers of participants aged 5–20; employing different tablets (including different brands); involving individual (one-to-one), shared, (i.e. many-to-one) and mixed (i.e. individual and shared) use of tablets by students. Together, the current chapter and the systematic review help to address the need for guidance arising out of the growing interest in the meaningful use of tablets for education in schools (Johnson, 2014).

The Impact of Tablet Use on Students' Subject Knowledge and Skills

Fewer studies focus on learning gains compared to other aspects of tablet use (e.g. motivational gains; Haßler, Major, & Hennessy, 2015). However, within the studies focussing on learning gains, tablets are largely reported as having a positive impact on student learning. Indeed, positive learning outcomes have been reported following the use of tablets to support activities related to science (Furió et al., 2013; Liu, Lin, & Paas, 2013, 2014; Liu, Lin, Tsai, & Paas, 2012; Ward, Finley, Keil, & Clay, 2013), social studies (Lin, Wong, & Shao, 2012) and mathematics (Riconscente, 2013). In addition, positive outcomes are reported in teaching multiple subjects (Cumming, Strnadová, & Singh, 2014; Ferrer, Belvís, & Pàmies, 2011; Goodwin, 2012; Heinrich, 2012; Li, Pow, Wong, & Fung, 2010), and assisting students with special educational needs (Fernández-López, Rodríguez-Fórtiz, Rodríguez-Almendros, & Martínez-Segura, 2013; Gasparini & Culén, 2012; McClanahan, Williams, Kennedy, & Tate, 2012; Miller, Krockover, & Doughty, 2013). Examples of specific topics where knowledge and skills improved include those relating to the water cycle (Furió et al., 2013), plant morphology (Liu et al., 2012, 2013, 2014), fractions (Riconscente, 2013), food-chain dynamics (Ward et al., 2013) and financial management and economics (Lin et al., 2012). Below, details of three studies (all of which were determined to be of high trustworthiness and relevance during the quality assessment undertaken as part of the systematic review) are provided to illustrate some of the ways in which tablets have successfully helped to support learning.

Case Study of Practice: Reinforcing Knowledge of the Water Cycle: Furió et al. (2013)

Investigated differences between a mobile phone and tablet, in terms of size and weight, as platforms for an educational game designed to reinforce children's knowledge about the water cycle. The intervention was developed based on controversial educational theory (Gardner's theory of Multiple Intelligences and Kolb's Learning Styles). Seventy-nine Spanish students, aged 8–10 years old, participated during a 1-day session. The game included multiple interaction forms (touchscreen and accelerometer) and combined augmented reality (AR) mini-games with non-AR mini-games. No significant differences were found between the two mobile devices and positive results were found for both.

Case Study of Practice: Supporting Social Studies Lessons: Lin et al. (2012)

Investigated the effect of using collaborative concept mapping activities, using the Group Scribbles system, in Social Studies lessons. Based in Taiwan, and involving 64 students aged 12, tablets facilitated learning in both one-to-one and many-to-one settings over a period of around 1 month. Members of each one-to-one group carried out their discussion and posted ideas or concepts to their Group Board, using their individual tablets. Conversely, having only one shared tablet, each many-to-one group identified a team member to assume the responsibility of creating and editing the concept map, while the rest provided only verbal opinions. In both one-to-one and many-to-one settings students demonstrated learning gains. While one-to-one groups demonstrated more consistency in group participation, improved communication and interaction, however, the many-to-one groups instead generated superior artefacts due to group discussion.

Case Study of Practice: Strengthening Students Knowledge of Fractions: Riconscente (2013)

Investigated whether an iPad-based fractions game, Motion Math, improves student's fractions knowledge and attitudes. Motion Math intends to help children strengthen their understanding of the relationship between fractions, proportions, and percentages to the number line and involves the "player" physically tilting a mobile device (using the accelerometer) to direct a falling star to the correct place on the number line at the bottom of the screen. This US-based study, involving 122 fourth grade students (aged 9–10), found students' fractions test scores improved an average of 15 % over a 1-week period, representing a significant increase compared to a control group. Children's' self-efficacy for fractions, as well as their liking of fractions, each improved an average of 10 % also.

We note, however, that the literature does not exclusively report positive learning outcomes. Indeed, neutral outcomes are reported by research involving the use of tablets to support activities in literacy and reading (Huang, Liang, Su, & Chen, 2012), mathematics (Carr, 2012), basic life support and cardiopulmonary resuscitation skills (Iserbyt, Charlier, & Mols, 2014), and science (laboratory simulation software for conducting experiments; Nedungadi, Raman, & McGregor, 2013). Additionally, no significant difference was found with regard to reading speed or level of comprehension when students' electronic text reading performance with tablets was compared to printed books (Dundar & Akcayir, 2012). Other research reports negative or neutral impact on reading comprehension following use of tablets three times a week, for 45–60 min a time, over a period of several weeks (Sheppard, 2011). Teachers also found learning outcomes to be inferior where tablets were used to support collaborative tasks that aimed to enhance student creativity and writing skills, compared to non-technology based tasks that were completed during previous academic years (Culén & Gasparini, 2011).

Across these studies there is no single overarching explanation for the neutral or negative learning outcomes. However, it is interesting that such outcomes were not considered as being linked to the nature of tablets. Indeed, studies suggest that students: had positive attitudes and enjoyed interacting with tablets (Dundar & Akcayir, 2012; Huang et al., 2012; Nedungadi et al., 2013); did not have difficulty adapting to the use of tablets (Dundar & Akcayir, 2012); and found tablets to be convenient and usable (Huang et al., 2012). Furthermore, studies reporting neutral findings do not dismiss the use of tablets in the classroom but rather encourage educators, school leaders and school officials to further investigate the potential of such devices (e.g. Carr, 2012).

Affordances of Tablets That Contribute to Improving Learning

In this section we consider the various affordances of tablets which may be relevant factors contributing to a positive impact on student learning outcomes.

High usability and integration of multiple features within one device. Use of built-in cameras (Cumming et al., 2014), accelerometers (Furió et al., 2013; Riconscente, 2013), microphones (Miller et al., 2013) and easy access to tools such as dictionaries and screen readers (Cumming et al., 2014) within a single device, has the potential for supporting learning and facilitating a diverse range of educational experiences (Goodwin, 2012). Sometimes students do not require an introduction on how to use tablets because they have prior experience (Cumming et al., 2014). Training sessions can, however, help them become familiar with tablets (Fernández-López et al., 2013).

Easy customisation and supporting inclusion. Adjusting text colour (Cumming et al., 2014) and size (Dundar & Akcayir, 2012), as well as using synthetic voices and screen viewing modes (portrait, landscape, zoom; Gasparini & Culén, 2012), allows learners to adapt tablet-based resources to their individual needs. Tablets can be useful to all students, and in environments where they are routinely used by all, stigmatisation commonly associated with bespoke assistive technologies is minimised, raising academic confidence (Gasparini & Culén, 2012; Miller et al., 2013). Tablets can also be used in implementing personalised learning environments, tracking learning processes in a manner potentially superior to other methods (Huang et al., 2012).

Touch screen. Displays can provide rich and more vivid pictorial representations than traditional paper books (Cumming et al., 2014), and tablet displays in particular can be more user-friendly and ergonomic than bulkier display types (Dundar & Akcayir, 2012). Moreover, manipulative touch screens can promote the use of several modalities, including visual and tactile/kinaesthetic, and this may facilitate engagement in a way that typical classroom experiences do not (McClanahan et al., 2012).

Availability and portability. Tablets can create immersive learning experiences with elements that are arguably similar to those at museums or historical sites (i.e. environments that are not always accessible due to geographical, practical or financial constraints; Cumming et al., 2014). The potential of an augmented reality approach using tablets has been likened to children exploring the world and discovering new elements with a magnifying glass (Furió et al., 2013). Tablet devices are easy for students to carry (Dundar & Akcayir, 2012), and this mobility can enable situated as well as anytime-anywhere learning due to timely and easy access to information and appropriate learning aids such as translation tools (Fernández-López et al., 2013; Heinrich, 2012). Students were also found to have strong awareness in organising and self-regulating their learning following the use of tablets (Li et al., 2010).

In addition to the above factors, applications designed to run on tablets may be simpler and more "intuitive" to use than their counterparts used with technologies such as laptops (running "traditional" computer programs) because tablet-based applications are designed to work with a range of screen sizes and as they often lack the notion of opening and closing applications, and, in many cases, without the need to explicitly save data. This may have both educational advantages (e.g. less complexity leading to faster learning curves) and disadvantages (e.g. reduced functionality, less customisability). Other factors include that tablets are increasingly designed to work with cloud storage (facilitating the storage and exchange of data) and are available at price points that make them very competitive to comparable technology (Johnson, 2014). Indeed, one of the advantages of lost-cost technologies is that they can support all students and thus meet specific needs without stigmatisation, which may not necessarily be the case with 'traditional' assistive technologies.

How do the affordances of tablets compare to those of other devices? Some research hints at the possibility that introducing tablets is reducing the use of desktop computers in computer labs, but only inasmuch as this use was to do with basic activities (such as looking up information and taking pictures: Chesterton Community College, 2014). Unsurprisingly, certain technologies are more appropriate for particular tasks than others and this is also true when considering uses for tablets: e.g. keyboards, larger screens and specialised software (perhaps only available for certain operating systems) may be needed to support specialised tasks such as extensive writing, mathematical constructions and computer programming.

Considerations for the Integration of Tablets in Schools

Infrastructure, Technology Management and Professional Development

Effective technology management, underpinned by sound change management principles, is critical to the successful introduction of tablets (Heinrich, 2012). An existing technical team may successfully play the role of a change agent

(Li et al., 2010). Cultivating a supportive school culture that fosters collegiality and teacher empowerment at different levels can be pivotal for the effective introduction of tablets (ibid.). Teachers have identified benefits for their workload following tablet implementation, as lessons had greater variety and pace, in addition to cost savings such as reduced photocopying costs (Heinrich, 2012).

It is important that schools looking to invest in tablets ensure that they have a robust wireless infrastructure, with sufficient capacity to accommodate entire class sets of tablets connecting simultaneously (Sheppard, 2011; Ward et al., 2013). The model and operating system of the tablet selected must be taken into account as certain models may be better suited for schools who wish to exert full control over content and exploit open-source options (Sheppard, 2011). A related issue includes new tablet models being released midway through implementation (Culén & Gasparini, 2011), and an occasional need to purchase supplementary technology such as VGA display adapters (ibid.). Other factors identified include the difficulty younger children can experience in handling tablets, although external cases (with handles) may help to remedy this (Furió et al., 2013). Another important question is whether students have access to tablets outside school: Carr (2012) suggests that giving students continuous access to technology outside of school may help to improve learning outcomes.

While we did not identify a research study which reports that the implementation of tablets failed as a result of ineffective project management, poor management and technological issues have led to the collapse of similar initiatives previously.[4] There are high profile schemes, such as the $1 billion Los Angeles School District iPad scheme,[5] that have been affected by a number of significant challenges. The development of rigorous contingency plans is, therefore, essential from the outset for school-based tablet projects. Schools looking to invest in tablets should also acknowledge that educational technologies are most effective when there is an holistic strategy to integrate digital and non-digital resources, and that learning is improved when a school's infrastructure facilitates the use of a new technology (Diaz, Nussbaum, & Varela, 2014).

Finally, schools ought not to assume that teaching staff are ready to effectively use tablets from the outset (Melhuish & Falloon, 2010), but should pro-actively create adequate opportunities for professional development. A lack of relevant training, a shortage of technical support and the absence of the tablets from school policy can prevent staff from using tablets on a regular basis (Oliviera, 2014). Often where induction is provided it is usually minimal and technically focussed. It is, therefore, essential that technical support is provided particularly to teachers charged with introducing tablets. The fact that new educational interventions require time to

[4] *Why one New Jersey school district killed its student laptop program*. Retrieved October 09, 2015, from http://arstechnica.com/tech-policy/2014/07/why-one-new-jersey-school-district-killed-its-student-laptop-program.

[5] *US schools seek refund over $1.3bn iPad project*. Retrieved October 09, 2015, from http://www.bbc.co.uk/news/technology-32347651.

become embedded in classroom practice must also be appreciated, and school leaders should acknowledge that the benefits of a new technology are not immediate (Carr, 2012; Silvernail & Gritter, 2007).

Pedagogy and Instructional Design

Pedagogical practice is not an outcome of technology, and does not change as a result of introducing new technology (Osborne & Hennessy, 2003). On the contrary, the power of using technology in the classroom relies on the premise that technology is integrated into the existing pedagogy (Hennessy & London, 2013).

Tablets can simulate real-world situations such as laboratory experiments, and in the process potentially allow a greater degree of enquiry, as tasks can be repeated many times (Nedungadi et al., 2013). For practitioners, supports such as dictation software leave less to interpretation and can also enable more accurate assessment (Miller et al., 2013). However, other studies report distraction as tablets can add additional layers of complexity (due to technical problems with tablet and applications used) compared to traditional means of completing similar tasks (Culén & Gasparini, 2011). The addition of entertaining features to increase the interest of a lesson may ultimately distract learners and lead to poorer learning outcomes (Iserbyt et al., 2014).

The use of mobile technologies in conjunction with real objects in a physical environment may represent a promising approach for learning environments. It is clear that digital cues can be used to increase the effectiveness and efficiency of such environments by supporting learners to mentally integrate different spatially separated sources of information (Liu et al., 2013). There are nevertheless cognitive challenges in mobile device-based learning environments that need to be considered in order to make those environments effective (ibid.).

The utility of a tablet in providing novel lessons is clearly limited by the availability of suitable content (Ward et al., 2013) and issues with software can negatively impact upon students' work (Culén & Gasparini, 2011). Certain constraints of tablet platforms imposed by manufacturers, such as the inability to use Java and Flash-based web content on the Apple iPad, have also been found to have a limiting effect (Ward et al., 2013). A rethink of the pedagogical approach is also necessary in order to take into account new issues arising during multimodal interactions and collaborations between students sharing tablets (Culén & Gasparini, 2011).

Both boys and girls indicated that they participated more in learning tasks when tablets were used (Ferrer et al., 2011), and enhanced levels of collaborative working were evident (Heinrich, 2012). The use of tablets resulted in an increase in students sharing their digitally produced work (including via interactive whiteboards) and provided opportunities for teachers to offer ongoing feedback and to collect cumulative assessment data (Goodwin, 2012). Teachers were able to use tablets to modify and redefine student learning by employing transformative pedagogical models, and the technology acted as a catalyst for more creative pursuits and exploration of new pedagogical approaches (Goodwin, 2012). The Technological Pedagogical Content

Knowledge (TPACK) framework (Koehler & Mishra, 2009) is relevant to tablet use, and teachers have successfully applied their TPACK to choose how to implement tablet-based learning (Cumming et al., 2014). Learner-centred approaches may be a particularly valuable strategy for students who learn from multimedia content on tablets (Iserbyt et al., 2014).

It has been suggested, partly due to technical considerations (synchronising content and recharging batteries), that tablets may be best suited for individual rather than collaborative use (Sheppard, 2011). The customisability of tablets can also cause problems in shared use situations, as the ability to change font and font size can alter page numbers which makes referring back to earlier pages problematic (ibid.). Some students are reluctant to share 'their' tablet with fellow learners (Culén & Gasparini, 2011). In another study, students working in groups of two to three all responded that they felt that they were able to spend enough time using the tablet, although a proportion of students in groups of four responded that they would have liked more time to use the device (Ward et al., 2013).

It is sometimes taken for granted that the one-to-one setting is most effective, rather than considering a variety of settings. In our systematic review, only one study explicitly considered the differences between one-to-one and many-to-one use of tablets (Lin et al., 2012), indicating that using tablets can improve learning outcomes in both settings. Importantly though, in the one-to-one setting there is no competition for tablets among students, and in the studies reviewed there was consistently high group participation, improved communication and interaction. However, the many-to-one groups exhibited more peer collaboration and generated superior artefacts as all the notes were well discussed among the group members (ibid.). Because of the high connectivity and the capability of co-construction supported by tablet technology, students' roles, participation and contributions within a group were found to be more equal in the tablet class when compared to the pattern of collaboration found in a non-tablet class (Li et al., 2010).

Another factor that is not investigated is screen size: 7″ vs. 10″, or even larger sizes (such as 13″). We would expect smaller tablets to be more suited to personal tasks, and larger tablets to be more appropriate for collaborative working (e.g. facilitating group work by jointly working on a tablet in the centre of a table). Clearly, the characteristics of the device need to be such that they support learning intentions (in one-to-one and many-to-one settings, which can both represent effective strategies, depending on the task). However, each tablet feature (as well as the overall number of tablets) also has cost implications.

While evidence is limited on which approach facilitates the greatest learning gains, specific affordances available with tablets (such as portability and typically long battery life) potentially make them well suited for supporting collaborative activities. For tablets to be used effectively in shared settings, however, constraints may have to be overcome. Issues identified include problems synchronising content (potentially because of a limited number of user accounts), in addition to factors related to customisability (such as modifying elements like font type). Tablets may enable a greater degree of enquiry as certain learning tasks and situations (e.g. a laboratory-based chemistry experiment) can be varied and repeated a number of times.

Conclusion and Outlook

Overall, favourable results are reported in the literature regarding the impact of tablets on learning outcomes. There is little doubt that in principle, tablets—like other educational technologies—can viably be used to support school children of all ages to learn in a variety of settings. Several affordances appear to be specific to tablets: the integration of multiple features within one device (including multiple sensors), easy customisation and portability (which can also be supportive for ubiquitous use supporting inclusion without stigmatisation), and high quality touch interfaces (allowing for manipulation of objects).

We undertook the review on which this chapter is based expecting existing research to focus on learning activities drawing on the specific affordances unique to tablets, such as the availability of accelerometer (e.g. for multimodal interaction; Furió et al., 2013; Riconscente, 2013) and GPS sensors (e.g. to enrich environmental data logging). We also anticipated that portability would lead to greater situated learning and it is surprising that there is not more emphasis on using tablets for investigative work, including project work outdoors (using sensors for mapping and measurement, i.e. location, velocity, acceleration of objects). While few studies have investigated these affordances yet, this is not to say that such features cannot successfully be used to support the learning of school age students.

Tablets could be considered like any other resource that might be used in the classroom: If used appropriately, this can lead to learning gains. Also, tablets are likely to be best used in conjunction with other resources (in the widest sense, including digital and non-digital). There is strong evidence for the benefits of collaborative work (Higgins et al., 2013), and it would seem prudent to look at how tablets could support such established practices. While evidence is limited on which approach (i.e. students working individually or in a group) facilitates the greatest learning gains, specific affordances available with tablets potentially make them well suited for supporting collaborative activities.

With regard to physical affordances, overall we conjecture that smaller (7″) tablets may lend themselves more to individual activities (e.g. reading), while larger tablets (10″–13″) may be much more suitable for supporting group work. Moreover, while for some activities "integrated" devices such as tablets may be beneficial (such as supporting student working outdoors), for other activities a component-based system (such as a Raspberry Pi with the new low-cost touch screen) may be more advantageous (e.g. for supporting physical computing). Initially designed as single-user devices, tablets have a large market share, and so costs for educational use (including informal educational use) are driven down, perhaps even more so than the overall affordability of other devices. However, the consumer-driven nature also entails frequent software updates, which are potentially disruptive to learning environments. In order to exploit the new opportunities for student-led inquiry-based learning that are afforded by tablets, investment in teacher development is essential. Use of peer support may help to keep costs low, particularly where colleagues have sufficient expertise and experience, or where there is an inquiry culture among staff in the school.

Acknowledgements We gratefully acknowledge support from ARM Holdings Ltd that partially supported our original literature review (Haßler et al., 2015).

References

Carr, J. M. (2012). Does math achievement h'APP'en when iPads and game-based learning are incorporated into fifth-grade mathematics instruction? *Journal of Information Technology Education, 11*(1), 269.

Chesterton Community College. (2014). *Chesterton tablet learning scheme - Evaluation report*. Retrieved from http://chestertoncc.net/tabletlearning/thescheme/evaluation-report/.

Culén, A. L., & Gasparini, A. (2011). iPad: A new classroom technology? A report from two pilot studies. In *INFuture Proceedings* (pp. 199–208).

Cumming, T. M., Strnadová, I., & Singh, S. (2014). iPads as instructional tools to enhance learning opportunities for students with developmental disabilities: An action research project. *Action Research, 12*(2), 151–176.

Diaz, A., Nussbaum, M., & Varela, I. (2014). Orchestrating the XO computer with digital and conventional resources to teach mathematics. *Journal of Computer Assisted Learning, 31*(3), 202–219.

Dundar, H., & Akcayir, M. (2012). Tablet vs. paper: The effect on learners' reading performance. *International Electronic Journal of Elementary Education, 4*(3), 441–450.

El-Gayar, O. F., Moran, M., & Hawkes, M. (2011). Students' acceptance of tablet PCs and implications for educational institutions. *Educational Technology & Society, 14*(2), 58–70.

EPPI-Centre. (2010). *EPPI-Centre methods for conducting systematic reviews*. Retrieved from https://eppi.ioe.ac.uk/cms/LinkClick.aspx?fileticket=hQBu8y4uVwI%3D&tabid=88/.

Fernández-López, Á., Rodríguez-Fórtiz, M. J., Rodríguez-Almendros, M. L., & Martínez-Segura, M. J. (2013). Mobile learning technology based on iOS devices to support students with special education needs. *Computers & Education, 61*, 77–90.

Ferrer, F., Belvís, E., & Pàmies, J. (2011). Tablet PCs, academic results and educational inequalities. *Computers & Education, 56*(1), 280–288.

Frohberg, D., Göth, C., & Schwabe, G. (2009). Mobile learning projects – A critical analysis of the state of the art. *Journal of Computer Assisted Learning, 25*(4), 307–331.

Furió, D., González-Gancedo, S., Juan, M., Seguí, I., Costa, M. (2013). The effects of the size and weight of a mobile device on an educational game. *Computers & Education, 64*, 24–41.

Furió, D., Juan, M.-C., Seguí, I., & Vivó, R. (2015). Mobile learning vs. traditional classroom lessons: A comparative study. *Journal of Computer Assisted Learning, 31*(3), 189–201.

Gasparini, A. A., & Culén, A. L. (2012). Tablet PCs – An assistive technology for students with reading difficulties? In *Fifth International Conference on Advances in Computer-Human Interactions (ACHI 2012)* (pp. 28–34).

Geyer, M., & Felske, F. (2011). Consumer toy or corporate tool: The iPad enters the workplace. *Interactions, 18*(4), 45–49.

Goodwin, K. (2012). *Use of tablet technology in the classroom*. Sydney, NSW: NSW Department of Education and Communities.

Haßler, B., Hennessy, S., Lord, T., Cross, A., Jackson, A., & Simpson, M. (2011). *An investigation of appropriate new technologies to support interactive teaching in Zambian schools (ANTSIT)*. A joint report from Aptivate and the Centre for Commonwealth Education (University of Cambridge). Final Report to DfID. Cambridge: Activate and University of Cambridge. Retrieved from http://www.educ.cam.ac.uk/centres/cce/initiatives/projects/antsit/.

Haßler, B., Hennessy, S., & Cross, A. (2014). School-based professional development in a developing context: Lessons learnt from a case study in Zambia. *Professional Development in Education, 41*(5), 806–825.

Haßler, B., Major, L., & Hennessy, S. (2015). Tablet use in schools: a critical review of the evidence for learning outcomes. *Journal of Computer Assisted Learning, 32*(2), 139–156.

Heinrich, P. (2012). *The iPad as a tool for education - A case study.* Naace Research Papers.

Hennessy, S., Haßler, B., & Hofmann, R. (2015a). Challenges and opportunities for teacher professional development in interactive use of technology in African schools. *Technology, Pedagogy and Education 24(5).* Invited paper for Special Section on "Capacity Building for 21st Century Learning in Africa: A Focus on ICT Integration in Education" edited by J. Tondeur & J. Voogt. Retrieved from http://www.tandfonline.com/doi/full/10.1080/1475939X.2015.1092466.

Hennessy, S., Haßler, B., & Hofmann, R. (2015b). Pedagogic change by Zambian primary school teachers participating in the OERS4Schools professional development programme for one year. *Research Papers in Education.* Retrieved from http://dx.doi.org/10.1080/02671522.2015.1073343.

Hennessy, S., & London, L. (2013). *Learning from international experiences with interactive whiteboards: The role of professional development in integrating the technology*. Paris: OECD Publishing. Retrieved from http://tinyurl.com/OECDIWBS.

Higgins, S., Katsipataki, M., Kokotsaki, D., Coleman, R., Major, L. E., & Coe, R. (2013). *The Sutton Trust-Education Endowment Foundation Teaching and Learning Toolkit*. Retrieved from https://educationendowmentfoundation.org.uk/toolkit/.

Huang, Y.-M., Liang, T.-H., Su, Y.-N., & Chen, N.-S. (2012). Empowering personalized learning with an interactive e-book learning system for elementary school students. *Educational Technology Research and Development, 60*(4), 703–722.

Hwang, G.-J., & Tsai, C.-C. (2011). Research trends in mobile and ubiquitous learning: A review of publications in selected journals from 2001 to 2010. *British Journal of Educational Technology, 42*(4), E65–E70.

Hwang, G. J., & Wu, P. H. (2014). Applications, impacts and trends of mobile technology-enhanced learning: A review of 2008–2012 publications in selected SSCI journals. *International Journal of Mobile Learning and Organisation, 8*(2), 83–95.

Iserbyt, P., Charlier, N., & Mols, L. (2014). Learning basic life support (BLS) with tablet PCs in reciprocal learning at school: Are videos superior to pictures? A randomized controlled trial. *Resuscitation, 85*(6), 809–813.

Johnson, D. P. (2014). *Implementing a one-to-one iPad program in a secondary school*. Ed. D. Thesis, University of Nebraska at Omah.

Kearney, M., Schuck, S., Burden, K., & Aubusson, P. (2012). Viewing mobile learning from a pedagogical perspective. *Research in Learning Technology, 20*(1), 14406.

Kim, K.-J., & Frick, T. W. (2011). Changes in student motivation during online learning. *Journal of Educational Computing Research, 44*(1), 1–23.

Kitchenham, B. (2004). *Procedures for undertaking systematic reviews*. Joint Technical Report No. TR/SE-0401 and NICTA 0400011T. Keele University and National ICT Australia Ltd.

Kitchenham, B., & Charters, S. (2007). *Guidelines for performing systematic literature reviews in software engineering*. Technical report, EBSE Technical Report EBSE-2007-01. Retrieved from https://www.cs.auckland.ac.nz/~norsaremah/2007%20Guidelines%20for%20performing%20SLR%20in%20SE%20v2.3.pdf/.

Koehler, M., & Mishra, P. (2009). What is technological pedagogical content knowledge (TPACK)? *Contemporary Issues in Technology and Teacher Education, 9*(1), 60–70.

Lai, C.-H., Yang, J.-C., Chen, F.-C., Ho, C.-W., & Chan, T.-W. (2007). Affordances of mobile technologies for experiential learning: The interplay of technology and pedagogical practices. *Journal of Computer Assisted Learning, 23*(4), 326–337.

Li, S. C., Pow, J. W., Wong, E. M., & Fung, A. C. (2010). Empowering student learning through Tablet PCs: A case study. *Education and Information Technologies, 15*(3), 171–180.

Lin, C.-P., Wong, L.-H., & Shao, Y.-J. (2012). Comparison of 1:1 and 1:m CSCL environment for collaborative concept mapping. *Journal of Computer Assisted Learning, 28*(2), 99–113.

Liu, T.-C., Lin, Y.-C., Tsai, M.-J., & Paas, F. (2012). Split-attention and redundancy effects on mobile learning in physical environments. *Computers & Education, 58*(1), 172–180.

Liu, T.-C., Lin, Y.-C., & Paas, F. (2013). Effects of cues and real objects on learning in a mobile device supported environment. *British Journal of Educational Technology, 44*(3), 386–399.

Liu, T.-C., Lin, Y.-C., & Paas, F. (2014). Effects of prior knowledge on learning from different compositions of representations in a mobile learning environment. *Computers & Education, 72*, 328–338.

Martin, F., & Ertzberger, J. (2013). Here and now mobile learning: An experimental study on the use of mobile technology. *Computers & Education, 68*, 76–85.

McClanahan, B., Williams, K., Kennedy, E., & Tate, S. (2012). A breakthrough for Josh: How use of an iPad facilitated reading improvement. *TechTrends, 56*(3), 20–28.

McFarlane, A., Triggs, P., & Yee, W. (2008). *Researching mobile learning - Interim report to Becta*. Coventry: Becta.

Melhuish, K., & Falloon, G. (2010). Looking to the future: M-learning with the iPad. *Computers in New Zealand Schools: Learning, Leading, Technology, 22*(3), 1–16.

Miller, B. T., Krockover, G. H., & Doughty, T. (2013). Using iPads to teach inquiry science to students with a moderate to severe intellectual disability: A pilot study. *Journal of Research in Science Teaching, 50*(8), 887–911.

Naismith, L., Sharples, M., Vavoula, G., & Lonsdale, P. (2004). *Literature review in mobile technologies and learning*. Retrieved from http://telearn.archivesouvertes.fr/docs/00/19/01/43/PDF/Naismith_2004.pdf.

Nedungadi, P., Raman, R., & McGregor, M. (2013). Enhanced STEM learning with online labs: Empirical study comparing physical labs, tablets and desktops. In *Frontiers in Education Conference* (pp. 1585–1590). Washington, DC: IEEE.

Norris, C. A., & Soloway, E. (2015). Mobile technology in 2020: Predictions and implications for K–12 education. *Educational Technology, 12*, 12–18.

Oliviera, J. (2014). *Students' and teachers' attitudes and views on employing the use of iPads in science lessons*. M. Phil. Dissertation, Faculty of Education, University of Cambridge.

Osborne, J., & Hennessy, S. (2003). *Literature review in science education and the role of ICT: Promise, problems and future directions (No. 6)*. Bristol: Nesta FutureLab. Retrieved from http://www.nestafuturelab.org/research/reviews/se01.htm.

Ozdamli, F. (2012). Pedagogical framework of m-learning. *Social and Behavioral Sciences, 31*, 927–931.

Ozok, A. A., Benson, D., Chakraborty, J., & Norcio, A. F. (2008). A comparative study between tablet and laptop PCs: User satisfaction and preferences. *International Journal of Human–Computer Interaction, 24*(3), 329–352.

Riconscente, M. M. (2013). Results from a controlled study of the iPad fractions game motion math. *Games and Culture, 8*(4), 186–214.

Sharples, M., Taylor, J., & Vavoula, G. (2010). A theory of learning for the mobile age. In *Medienbildung in neuen Kulturräumen* (pp. 87–99). New York, NY: Springer.

Sheppard, D. (2011). Reading with iPads–The difference makes a difference. *Education Today, 11*(3), 12–15.

Silvernail, D. L., & Gritter, A. K. (2007). *Maine's middle school laptop program: Creating better writers*. Gorham, ME: Maine Education Policy Research Institute.

Traxler, J. (2010). Students and mobile devices. *Research in Learning Technology, 18*(2), 149.

Traxler, J., & Wishart, J. (2011). *Making mobile learning work: Case studies of practice*. Bristol: ESCalate, HEA Subject Centre for Education, University of Bristol. Retrieved from http://escalate.ac.uk/8250.

Ward, N. D., Finley, R. J., Keil, R. G., & Clay, T. G. (2013). Benefits and limitations of iPads in the high school science classroom and a trophic cascade lesson plan. *Journal of Geoscience Education, 61*(4), 378–384.