Tablet use in schools: A critical review of the evidence for learning outcomes

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Abstract

The increased popularity of tablets in general has led to uptake in education. We critically review the literature reporting use of tablets by primary and secondary school children across the curriculum, with a particular emphasis on learning outcomes. The Systematic Review methodology was used and our literature search resulted in 33 relevant studies meeting the inclusion criteria. A total of 23 met the minimum quality criteria and were examined in detail (16 reporting positive learning outcomes, 5 no difference and 2 negative learning outcomes). Explanations underlying these observations were analysed, and factors contributing to successful uses of tablets are discussed. While we hypothesise how tablets can viably support children in completing a variety of learning tasks (across a range of contexts and academic subjects), the fragmented nature of the current knowledge base, and the scarcity of rigorous studies, make it difficult to draw firm conclusions. The generalisability of evidence is limited and detailed explanations as to how, or why, using tablets within certain activities can improve learning remain elusive. We recommend that future research moves beyond exploration towards systematic and in-depth investigations building on the existing findings documented here.

Keywords

tablets; schools; systematic review; iPad; Android; learning outcomes

1. Introduction

Since the early 1980s schools, colleges and universities have experimented with technology for learning (Sharples et al., 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 (McFarlane et al., 2008). Mobile devices can enhance, extend and enrich the concept of learning in a number of ways (Traxler & Wishart, 2011): (1) 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). A range of different mobile devices has been used educationally (Kearney et al., 2012; Frohberg, 2009; Naismith et al., 2004; Traxler, 2010), and includes devices such as 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 device, typically with a touch screen, no built-in keyboard or mouse, lightweight, (at least nominally) good battery life and at a comparatively low price compared to other ‘traditional’ computing devices. Tablets became commercially available in 2002 (El-Gayar et al., 2011) and, by 2009, around 14 million had been sold worldwide (Ozok et al., 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]. The popularity of tablets has led to interest in

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

[2] "Forecast: PCs, Ultramobiles, and Mobile Phones, Worldwide, 2011-2018, 2Q14 Update" available online: http://www.gartner.com/document/2780117 (Accessed 20/10/14).

applications in education, 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 et al., 2015), knowledge acquisition (Lai et al., 2007), and enquiry-based learning (e.g. Haßler et al., 2011; Haßler et al., 2014; Hennessy et al., in press; Hennessy et al., forthcoming). There is great potential to research use of tablets in schools, particularly as the technology becomes more accessible and capable (Johnson et al., 2014).

A handful of previous literature reviews have investigated the use of tablets in educational settings. Nguyen et al. (2014) systematically reviewed research on the use of iPads in higher education (HE) and reported that, while students' learning experience was enhanced, better learning outcomes did not necessarily occur. Shortcomings in existing research were also identified, and an absence of longitudinal and large-scale evaluations considering the use of tablets in HE was noted. A review of empirical and theoretical findings by Dhir et al. (2013) investigated the instructional benefits of using iPads in classrooms, and laboratories and concluded that while tablets (iPads) can motivate learners, overall the research on the actual impact of tablet use on learning is limited.

The motivational affordances of tablets have previously been investigated, and teamwork, scaffolding, self-directed learning and device personalisation were found to be important for learners (Ciampa, 2014). A longitudinal study that aimed to model the acceptance of tablets as learning devices for high school pupils highlights how this evolves over time (Courtois et al., 2014). The common perception that students always find tablets to be motivating has also been challenged, and teachers have been advised to diligently monitor student interactions with the technology, and to be critical in their selection of apps, if the devices are to fulfil their educational potential (Falloon, 2013). A detailed investigation into teacher beliefs, undertaken by Ifenthaler and Schweinbenz (2013), demonstrates diversity in the attitudes of practitioners in addition to wide ranging expectations of performance and facilitating conditions.

In our study, we critically review literature that reports on the use of tablets by children in school, with a particular focus on learning outcomes. Our aim is to determine if, when and how using tablets might impact 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? As described shortly, studies that only consider the motivational affordances of tablets have been excluded from the analysis. Our approach is based on the Systematic Review (SR) methodology, informed by Kitchenham and Charters (2007), and the EPPI-Centre (2010). SR is a trustworthy, rigorous and auditable tool (Kitchenham, 2004), allowing existing evidence to be collected and summarised, while identifying gaps in current research (Kitchenham & Charters, 2007) and assessing methodological rigour. This work builds on, and advances, previous research through considering uses of all brands of tablet (not just one specific manufacturer) and through reviewing the literature focused on actual learning outcomes, not just motivational affordances. It addresses an identified need for greater information on the nature of, and triggers for, learning outcomes due to growing interest in use of tablets for education in schools (Johnson, 2014).

2. Methods

In this section, details of the methodological approach are outlined.

2.1. Research Questions

Our review focuses on learning gains experienced by school pupils (defined as those in primary or secondary school aged between 5 and 18) following the use of tablets in lessons. Two research questions are addressed:

- **[RQ1]** Do subject knowledge and skills of students increase following the use of tablets to support educational activities?

- **[RQ2]** What factors contribute to (un)successful use of tablets?

RQ2 included the nature of the specific activities engaged in, as well as more technical and implementation issues.

2.2. Search Process

A protocol was developed and reviewed by members of the research team prior to the search commencing. A mixed search strategy, involving manual and automated searches of electronic resources, was undertaken in May/June 2014). Technology- and education-based resources were used. These included:

- ACM Digital Library (http://dl.acm.org/).
- IEEE Digital Library (http://ieeexplore.ieee.org/).
- EBSCO[3] (http://search.ebscohost.com/).
- Google Scholar (http://scholar.google.co.uk/).

[3] EBSCO indexes a number of relevant databases including the British Education Index (BEI) and Education Resources Information Centre (ERIC).

Two sets of keywords and their permutations facilitated searches:

A - Tablets: tablet; iPad; handheld; Android; iOS; “educational apps”; “education apps”; “educational applications”; “education applications”; touchscreen; “touch-screen”.

B - Education: “primary school”; “secondary school”; “high school”; “junior school”; “junior high”; school; pupils; students; teacher; education, educational, instruction, instructional, learning, teaching, class.

Search terms were selected after analysing the titles and keywords of three papers previously identified as potentially relevant (Carr, 2012; Falloon & Khoo, 2014; Henderson & Yeow, 2012). Boolean logic searches (e.g. “tablet” OR “iPad”) were used where possible. When a database did not allow Boolean logic, individual combinations of the search terms were used. The search strategy was considered effective following trial searches. Other validation activities included using a ‘snowball strategy’ (checking the reference lists and bibliographies of included studies for other relevant work), and manually searching two prominent journal volumes known to have published work on the use of tablets in education (*Journal of Computer Assisted Learning* and *Computers & Education*).

2.3. Inclusion and Exclusion Criteria

Inclusion and exclusion criteria ensured that only relevant literature was included.

Studies were included if they:

- reported on the use of tablets (e.g. iPads, Android-based tablets),
- considered changes in students’ knowledge and skills,
- described primary empirical research (i.e. that acquired by means of observation or experimentation),
- were published post-2009 (corresponding with the launch of Android-based and Apple iPad devices in 2009 and 2010 respectively), and
- were written in English.

Studies were excluded if they:

- only considered motivational affordances of tablets,
- provided a “lessons learned” account, or description of an approach, without any empirical evidence, or

- focused on the use of tablets in higher education, informal education (e.g. home learning) or pre-school education (children under 5).

"Grey literature" (e.g. non-peer reviewed technical reports) was accepted if all other inclusion criteria were satisfied.

2.4. Quality Assessment

Each study in the final set was assessed for its quality based on our modified version of the Weight of Evidence (WoE) framework outlined in Gough (2007). A full set of guidelines was produced to guide the quality assessment process, see **Supporting Document 1 (quality appraisal, WoE)**. Two WoE categories were established:

1. ***Methodological trustworthiness [<u>non-review specific</u>]*****:** The trustworthiness of a study's results based on an evaluation of the research approach used.

2. ***Relevance to the review [<u>review specific</u>]***: Relevance of a study for the specific purposes of the review (i.e. to determine whether the knowledge and skills of students increase following the use of tablets).

For *methodological trustworthiness* (Category One), a rating of high/medium/low trustworthiness was determined for each study. This was done by two reviewers independently reading the full text of each study and assigning a score indicating to what extent they considered each of the following criteria to be satisfied:

- ***DESIGN:*** Is an appropriate study design used to address the research questions? How rigorous is the design?

- ***CONTEXT:*** Is there an adequate description of the context in which the research was carried out?

- ***SAMPLING:*** Is the sampling strategy appropriate and clearly described?

- ***DATA COLLECTION:*** Is the method(s) of data collection appropriate and clearly described?

- ***DATA ANALYSIS:*** Is the data analysis and interpretation process appropriate and clearly described?

- ***CLAIMS and EVIDENCE:*** Are claims made credible and are there sufficient data to support the findings?

Three possible scores were awarded (0: not at all; 0.5: to some extent; 1: fully) and recorded. The rating for trustworthiness was determined by the reviewer making an overall judgement after taking into account the scores they awarded for each individual criterion.

For *relevance to the review* (Category Two), a rating of high/medium/low relevance was determined by a reviewer making a judgment after taking into account:

- the ***RELEVANCE*** of each study for determining changes in students' knowledge and skills following the use of tablets, and

- whether the ***STUDY DESIGN*** was such that changes in students' knowledge and skills were considered from the outset (or whether changes were observed incidentally during the course of research with other intentions).

One of the authors (L.M.) undertook the quality assessment, while another author (B.H.) independently appraised a random selection of studies (8 of the 33 studies included in the final set). There was full agreement on the overall quality ratings awarded to the sample.

2.5. Data Extraction

To answer the research questions, the following data were extracted:

- study aim/objective;

- learning outcome reported (positive, neutral, negative, unable to determine);

- research design and methods applied, including how learning was measured;

- number of participants;

- whether individual (one-to-one) or shared use of tablets (many-to-one) was reported;

- contributing factors to successful / unsuccessful use of tablets;

- country in which research was executed;

- tablet technologies used;

- curriculum topics taught;

- participant characteristics (e.g. age);

- type of publication (e.g. journal, grey literature).

All data were initially extracted by one of the authors (L.M.), while another author (B.H.) extracted information from a random sample of eight studies whilst validating the quality assessment. As no significant anomalies were evident, the data extraction strategy was deemed to be appropriate. Extracted data were stored in a spreadsheet.

3. Results

3.1. Overview of the search process and quality assessment

Several stages of screening were used to identify studies relevant to the review.

1. ***Initial Search:*** Implementing the search strategy, identifying potentially relevant literature related to the use of tablets in schools based on analysis of titles and abstracts. 103 studies progressed to Stage Two.

2. ***Detailed Examination:*** 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. 70 studies were excluded because they did not consider learning outcomes (but instead addressed topics such as student motivation after using tablets), or considered learning outcomes incidentally and not as an explicit part of the research process. See **Supporting Document 2 (Bibliography of publications not discussing learning gains)** for references of excluded studies.

3. ***Data Extraction and Quality Assessment:*** Detailed analysis and quality assessment of the 33 identified studies according to the procedure outlined in Section Two.

The results of the quality assessment are provided in Appendix 1.

With regard to methodological trustworthiness (T) and relevance (R):

- 6 studies were rated as T:High/R:High;
- 8 studies were rated as T:High/R:Medium (5 studies) or T:Medium/R:High (3 studies);
- 9 studies were rated as T:Medium/R:Medium;
- 10 studies were rated as T:Medium/R:Low (6 studies), T:Low/R:Medium (2 studies) or T:Low/R:Low (2 studies).

To ensure that low quality or low relevance studies did not affect the outcomes of the review, a minimum quality threshold of (T:Medium/R:Medium) was adopted. Any study categorised as ‘Low’ for trustworthiness or relevance (or both) has been omitted from the analysis presented. The decision to exclude these studies was motivated by previous work which found that research judged to be of a low quality reported significantly larger effects (i.e. impact of the intervention) than that considered to be of a higher quality (Moher et al., 1998), and our assumption that studies of low relevance were unlikely to make a strong contribution to the review in any case. Four studies were excluded on grounds of trustworthiness because it was judged that they offered limited information about the research context, sample and/or methodology, or presented largely anecdotal observations with insufficient evidence for claims made. No studies were categorised as T:High/R:Low or T:Low/R:High. Answers to the research questions defined in Section Two are now considered by drawing on the 23 studies that satisfied the WoE minimum quality threshold of T:Medium/R:Medium.

3.2. Study characteristics

Studies included in the review were very varied in scope, reporting on research:

- using a number of research approaches;
- involving diverse numbers of participants (e.g. four studies involved fewer than 10 participants, while seven involved more than 100);
- involving participants aged 5 to 20, with a mean age of 12 years;
- employing tablets including iPads (12 studies), Windows-based devices (five studies) and Android-based devices (one study). It was not possible to identify the tablet(s) used in five studies;
- including individual (one-to-one) tablet use (15 studies); shared use, ie. many-to-one (four studies); and mixed (i.e. individual and shared) use of tablets (four studies); and
- undertaken in 10 countries: USA (five studies), Taiwan (five studies), Australia (three studies), Spain (three studies), Norway (two studies), Belgium (one study), Hong Kong (one study), India (one study), Turkey (one study) and UK (one study).

An overview of data extracted from each study is presented in **Supporting Document 3 (data extraction spreadsheet).** This provides specific details related to the aims, scope, approach and outcomes of included studies. Answers to the research questions outlined in Section 2 will now be provided by considering the information reported in included studies.

3.3. [RQ1] Do the knowledge and skills of students improve following the use of tablets to support educational activities?

Of the 23 studies included in the final set:

- 16 reported positive learning outcomes;
- 5 reported no difference in learning outcomes; and
- 2 reported negative learning outcomes.

Positive learning outcomes [16 studies]. Sixteen studies described positive learning outcomes where tablets supported learning activities related to science (Furio et al., 2013; Liu et al., 2012; Liu et al., 2013; Liu et al., 2014; Ward, 2013), social studies (Lin et al., 2012) and mathematics (Riconscente, 2013). In addition, positive outcomes are reported in teaching multiple subjects (Cumming et al., 2014; Ferrer et al., 2011; Goodwin, 2012; Heinrich, 2012; Li et al., 2010), and assisting students with special educational needs (Lopez et al., 2013; Gasparini and Culen, 2012; McLanahan et al., 2012; Miller et al., 2013). Examples of specific topics where knowledge and skills improved include those relating to the water cycle (Furio et al., 2013), plant morphology (Liu et al., 2012; Liu et al., 2013; Liu et al., 2014), fractions (Riconscente, 2013), food-chain dynamics (Ward, 2013) and financial management and economics (Lin et al., 2012).

A diverse spread of sample sizes is present in the studies that report positive learning outcomes, ranging from research that involved one participant (McLanahan et al., 2012) to several thousand (Ferrer et al., 2011). In Figures 1 through 4 below, details of four studies (all of which were determined to be of high trustworthiness and relevance during the quality assessment) are provided to illustrate some ways in which the affordances of tablets have successfully helped to support learning.

Figure 1 - Affordances of tablets to support learning: Furio 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 to 10 years old, participated during a one-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 devices and positive results were found for both. It was suggested that device form, however, may not be a decisive factor for learning outcomes.

Figure 2 - Affordances of tablets to support learning: 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 1:1 and 1:m settings over a period of around one month. Members of each 1:1 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 1:m 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 1:1 and 1:m settings students demonstrated learning gains, although neither setting resulted in significant differences. While 1:1 groups demonstrated more consistency in group participation, improved communication and interaction, however, the 1:m groups instead generated superior artefacts due to group discussion.

Figure 3 - Affordances of tablets to support learning: Lin et al. (2013).

Investigated whether arrow-line cues improve the effectiveness of learning in a tablet-supported environment on leaf morphology of plants, either with or without real plants. Seventy-four Taiwanese students aged 11 were involved. Cued and uncued conditions using a tablet were compared with a cued and uncued condition using a tablet and real plants. Results show higher efficiency of the cued conditions than the uncued conditions, and no difference was found between the cued conditions with or without real plants. Implications for practitioners include applying arrow-line cues in designing learning materials for mobile device supported learning in the physical environment, although the negative impact of cognitive overload must be considered. The use of mobile devices with real objects in a physical environment represents a promising composition for learning environments. The study design means it is difficult, however, to determine the specific value added due to the use of tablets.

Figure 4 - Affordances of tablets to support learning: 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 one-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.

Neutral [5 studies]. The studies reporting no difference in learning outcomes investigated the use of tablets in activities in literacy and reading (Huang et al., 2012), mathematics (Carr, 2012), basic life support and cardiopulmonary resuscitation (Iserbyt et al., 2014), and science (laboratory simulation software for conducting experiments; Nedungadi et al., 2013). One study compared students' electronic text reading performance with tablet PCs and printed books and found no significant difference between groups with regard to reading speed or level of comprehension (Dundar & Akcayir, 2012).

Negative learning outcomes [2 studies]. Negative or neutral impact on reading comprehension occurred following use of tablets three times a week, for 45-60 minutes 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 (Culen & Gasparini, 2012).

Across the seven studies there is no single overarching explanation for the neutral or negative learning outcomes. However, such outcomes were not reported 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). Studies which report 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). Issues concerning tablets distracting students (Sheppard, 2011) and negatively impacting on the quality of work produced (Culen & Gasparnini, 2012), however, are areas that warrant further investigation, as mentioned below.

See **Supporting Document 3 (data extraction spreadsheet)** for further details of data that were extracted from each study.

3.4. [RQ2] What factors contribute to successful / unsuccessful use of tablets?

3.4.1. Affordances of tablet hardware perceived to contribute to improving learning outcomes

High usability and integration of multiple features within one device. Use of built-in cameras (Cumming et al., 2014), accelerometers (Furio 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 (Lopez 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 & Culen, 2012), has allowed 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 & Culen, 2012; Miller et al., 2013). They 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. History and geography teachers have perceived touch screens to provide richer and more vivid pictorial representations (of topics such as the life cycle) than traditional paper books (Cumming et al., 2014), while tablet displays are reported to be more user-friendly and ergonomic than display types such as CRT and LCD (Dundar & Akcayir, 2012). Moreover, manipulative touch screens promote the use of several modalities, especially visual and tactile/kinaesthetic, and this may facilitate engagement in a way that typical classroom experiences do not (McLanahan et al., 2012).

Availability and portability. Tablets can create immersive learning experiences 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 (Furio et al., 2013). Tablet devices are easy for students to carry (Dundar & Akcayir, 2012), and this mobility can enable anytime-anywhere learning due to timely and easy access to information and appropriate learning aids such as translation tools (Heinrich, 2012; Lopez et al., 2013). Students were also found to have strong awareness in organising and self-regulating their learning following the use of tablets (Li et al., 2010).

3.4.2. Implementation of tablet-based learning environments in schools

Effective technology management is critical to the successful introduction of tablets and this should be underpinned by sound change management principles (Heinrich, 2012). Furthermore, 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 bills (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 classes of tablets connecting simultaneously (Sheppard, 2011; Ward, 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 (Culen & Gasparini, 2012), and an occasional need to purchase supplementary technology such as VGA display adapters (ibid.). Other issues identified include the difficulty younger children can experience in handling tablets, although external cases can help to remedy this (Furio 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.

3.4.3. Tablet content and instructional design

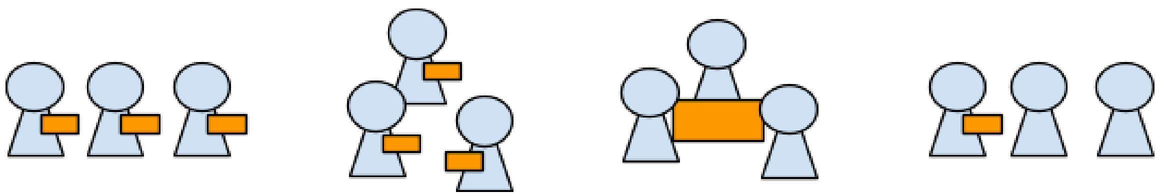
Tablets can simulate real-world situations such as laboratory experiments, in the process potentially allowing for a greater degree of enquiry, as tasks can be repeated many times (Nedungadi et al., 2013). For practitioners, supports such as dictation software leave less to interpretation and can also 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 (Culen & Gasparini, 2012). 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 utility of a tablet in providing novel lessons is clearly limited by the availability of suitable content (Ward, 2013) and issues with software can negatively impact upon students' work (Culen & Gasparini, 2012). 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, 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 (Culen & Gasparini, 2012).

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.).

3.4.4. Interaction of pedagogy and technology: Collaborative learning, one-to-one vs. shared use of tablets

Figure 5. Ways in which tablets can be deployed in classrooms.



one-to-one without collaboration	one-to-one with collaboration	many-to-one with collaboration	tablet use on an individual basis

Both boys and girls indicated that they participated more in learning tasks when tablets were used (Ferrer et al., 2012), 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).

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 (Culen & Gasparini, 2012). 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, 2013).

Importantly, an analysis of student performance following the use of tablets showed that both one-to-one and many-to-one settings can improve learning outcomes (Figure 2: Lin et al., 2012). 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 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).

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 (Mishra & Koehler, 2006) is relevant to tablet use, and teachers have successfully applied their TPACK to choose how to implement tablet-based learning (Cumming et al., 2014). A learner-centred approach may be a particularly valuable strategy for students who learn from multimedia content on tablets (Iserbyt et al. 2014).

3.5. Methodological limitations and threats to validity

This review is subject to the usual limitations and threats to validity. Despite trial searches, and examining the reference lists of included studies for other relevant work, it is possible, albeit unlikely, that some relevant studies have not been identified. As our search only covers studies published in 2009 onwards, there is a chance that earlier relevant work may have been omitted. Only English-language resources were searched systematically, and an English-language bias is therefore possible.

The findings of the review are inherently limited by the quality of evidence that is available. The development of a protocol and quality assessment checklist, in addition to quality checking by two reviewers, help to ensure that low-quality studies did not adversely affect the review outcomes.

Three studies, included in the final set of 16 which report positive learning outcomes, have the same lead author and describe similar work relating to plant morphology (Liu et al., 2012; Liu et al., 2013; Liu et al., 2014). All three studies were included in the review as independent entities, however, as they were considered to be sufficiently distinct after scrutinising the focus and setting of each, and given that the research was conducted at different points in time.

Tablets are still a relatively new technology. Even in the short period since the completion of our search, new reports have become available, offering new insights. Details of literature identified following the conclusion of our search are presented in the following section.

4. Discussion

4.1 Discussion of learning outcomes

The majority of the included studies report positive learning outcomes, and the nature of tablets appears to be a relevant factor in this. However, we may ask how far this is due to the specific affordances of tablets, and to what extent these affordances differ from other (particularly mobile) technologies. As a thought experiment, it is possible to construct scenarios where the differences between types of mobile devices is minimised, such as a tablet with a keyboard being similar to a small netbook. In reality, however, the choice of mobile devices (and corresponding software) is constrained by what is commercially available and financially feasible.

Our review identified several affordances specific to tablets: the integration of multiple features within one device, easy customisation and portability, and high quality touch interfaces. 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 they often lack the notion of opening and closing applications, and, in many cases, of saving data. This may have both educational advantages (e.g. less complexity leading to faster learning curves) and disadvantages (e.g. reduced functionality, less customisability). Additional factors, outside the reviewed literature, include the fact 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 et al., 2014). Indeed, one of the advantages of lost-cost technologies is that they can support all students and 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.

It is sometimes taken for granted that the one-to-one setting is most effective, rather than considering a variety of settings (see Figure 1 for a diagram depicting some of the ways tablets can be deployed in classrooms). In our literature search, 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, it was the many-to-one groups that exhibited more peer collaboration and produced higher quality artifacts. The lack of direct comparison between one-to-one and one-to-many scenarios in tablet research appears to mirror the laptop research literature. For instance a special issue (Bebell and O'Dwyr, 2010) focuses on various aspects of one-to-one educational use of laptops, with one study comparing one-to-one to no technology (Shapley et al., 2010), but no discussion of one-to-one to one-to-many. An exception to this is Larkin's (2011) comparison, suggesting that two-to-one laptop use is preferable to one-to-one, achieving a better balance between productivity, student engagement, social activity, and individualised learning in primary schools.

Another factor that is not discussed 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 sharing a tablet during discussions around 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. The trade-off between number of devices, screen size, cost, and corresponding effective learning scenarios, remains completely unexplored in the research literature, and needs to be urgently considered.

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 through this review 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.

When undertaking this review, we expected that existing research would focus on learning activities drawing on the specific affordances unique to tablets, such as the availability of accelerometer (e.g. for multimodal interaction; Furio et al., 2013; Riconscente, 2013) and GPS sensors (e.g. to enrich environmental data logging). We also expected that portability would lead to more tablet use in situated learning (Liu et al., 2013). Few studies were found to investigate affordances such as these, however, thus highlighting a potentially fruitful area for future rigorous research. Among the excluded papers we note two papers discussing GPS and outdoor learning (Jong, et al., 2012; Pittarello & Bertani, 2012).

4.2 Tablet-based learning in international development

The use of technology in international development clearly has specific requirements. While tablets are starting to be used in developing countries, and broad claims about effectiveness are made, research on this is in its infancy and few studies discussing learning gains surfaced during our literature search. In the absence of conclusive formal research on learning, we also draw on other available literature to at least offer initial insights.

Regarding India, the work by Nedungadi et al. (2013) was included in this review, and research on the low-cost Aakash tablets is ongoing (Gasu & Gujjari, 2015). Similarly, the paper by Farias et al. (2013) about large scale deployment of tablet computers in high schools in Brazil summarises some of the issues and points to future research about the impact. In Thailand, a number of publications discuss the use of tablets (and the "One Tablet Per Child" project), although the majority do not discuss learning gains (Van de Bogart, W., 2012; Harfield et al. 2013; Prasertsilp & Olfman, 2014). One publication fell slightly short of meeting our quality criteria (Viriyapong & Harfield, 2013), but nevertheless provides a good overview of the challenges, and urges that "considerable work is needed on a much wider range of issues if the impact of OTPC on primary school education is to be better understood" (ibid., p. 183). The paper by Chang et al. (2013; which was rated low on our quality scale), offers an account of tablet use in Sierra Leone.

The Kenyan Primary Math and Reading Initiative (PRIMR) programme studied the effectiveness of three interventions for literacy using: tablets for teacher educators, tablets for teachers, and eReaders for students. Gains in student learning outcomes were shown for all three treatments, with no statistical difference between groups in terms of learning gains, but significant differences in cost per student (Piper & Kwayumba, 2014). Moreover, the authors conclude that the programme for teacher educators (with tablets) was "not noticeably different from the base, non-ICT PRIMR intervention" (ibid. p.45), i.e. overall learning gains were due to the instructional approach, rather than the use of ICT.

A randomised control trial in Malawi, associated with the OneBillion project and involving 400 children using a tablet-based maths-teaching app for 30 minutes a day found tablet use to be more effective for learning mathematics than existing practice (Pitchford, 2015; peer-reviewed, but published after our literature search). In addition, we note the study described by Outhwaite (2014) of a trial with the same app in Scotland, which offers an interesting comparison. The Zambian-based iSchool.zm (http://ischool.zm) has developed a multimedia eLearning package, which uses customised Android tablets, and is designed to cover the entire primary school curriculum (in all eight official languages for early grades). Preliminary evaluation of learning gains in subject knowledge and critical thinking skills (with tablet use in pairs, and overall student-device ratios of 12:1) looks promising. There is some evidence that touch screens can be of benefit when used to support students working collaboratively because they allow for more equal device access, e.g. compared to a mouse (Haßler et al. 2011, p. 44-45).

Whilst formal research is ongoing, it is likely to be the case that there are further unpublished reports, e.g. by NGOs, that detail the use of tablets in various educational contexts. Notwithstanding the limitations that such reports may have, we would urge NGOs and sponsors to provide access to such information. Given the aspirations of many governments (including developing nations) to roll out large-scale educational technology initiatives, it is critical that all relevant evidence is made available to inform secondary reviews and policy decisions.

Some of the research in developed contexts (reviewed here) may also apply to developing contexts, but even where it does, the importance of specific factors may be different (Hennessy et al. 2010; Power et al., 2014). For instance, while schools in developed countries are likely to have access to other technologies (to which tablets are supplementary), for those in developing countries tablets may be the only available technology. Battery life (or solar power) is clearly more critical (as reliable and affordable mains power is often scarce), as is versatility (e.g. being able to add keyboards). Connectivity also remains a significant issue and has implications for access to resources (see e.g. Haßler & Jackson, 2010). Given the diversity of the low-cost tablet market, client-side assessment of quality and reliability remains a significant issue, as the case of the One Tablet Per Child initiative in Thailand demonstrated (Intathep, L., 2013). The Android One initiative (http://www.android.com/one/) addresses basic phone requirements in developing contexts (such as battery life and power provision, usability in areas with poor connectivity), and a similar initiative aimed at tablets in education is highly desirable in order to ensure that investments are effective. For the time being, laptops are still perceived as clear frontrunners: a recent survey of 1444 e-learning professionals across 55 African countries found that 29% of respondents perceived laptops as having greater potential in education and training in Africa than tablets (18%), smartphones (17%) and basic mobile phones (16%) respectively (Elletson & MacKinnon, 2014).

4.3 Reliability, replicability and generalisability of evidence

Our quality assessment indicates that the evidence within the 23 studies subjected to our detailed analysis is largely secure. There is clearly potential, however, to enhance the methodological rigour of future research that investigates the use of tablets in schools, as only 11 included studies were judged to be of “high” trustworthiness. We suggest that the guidelines produced for the quality assessment process (see Section 2) may be used as a planning tool to improve rigour of future work in this area, which should be explicitly focussed on learning outcomes in the context of longitudinal and teacher-focussed studies, and with meaningful control.

The relatively limited and fragmented nature of the current knowledge base (compared to research on better established technologies or mobile learning more broadly) makes it difficult to draw general conclusions. The fact that included studies investigated a diverse range of (often very specific) topics using a variety of research approaches limits the generalisability of evidence, and means definitive explanations as to how or why tablet use facilitates learning remain elusive. Despite this, 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.

While it has been possible to identify a number of technical factors that contributed to (un)successful learning using tablets, it proved more difficult to draw out pedagogical factors. This may be because a large proportion of identified research, including some of that judged to be of high quality, is relatively limited in both scope and duration.

Research conducted soon after the introduction of a new educational technology is often “scoping” in nature, and concerned primarily with the completion of a restricted initial evaluation of viability. A number of the included studies are examples of such research; results to date are generally favourable and there is clearly potential for more comprehensive research. We therefore recommend allocation of greater resources to undertake research that is more specific and extensive. Ways in which this may be achieved are now outlined.

Traxler and Wishart (2011)’s five ways in which the use of mobile technology can enhance learning are partially considered only in some studies (e.g. Dalla Longa & Mich, 2013; Huang et al., 2012; Li & Pow, 2011), leaving plenty of scope for the systematic exploration of such frameworks in future research. Importantly, the majority of included studies report research conducted in a "controlled" environment with limited teacher involvement (i.e. with actual 'teaching' being led by the researcher(s)). We strongly recommend, if successful pedagogical approaches are to be comprehensively documented, that future evaluations involve use of tablet technology with practitioners and their students over a sustained period of time (e.g. at least one academic year; certainly not at a single point in time). Moreover, a large proportion of identified research offers limited or no details of the activities that learners engaged in. This makes it hard or impossible to identify effective uses of the technology. It also impedes replicability of the research or implementation of corresponding classroom practices (i.e. schools making decisions on what learning activities to undertake), as sufficient information is not available for these purposes. Studies should provide enough detail about the learning approach, content, and teacher background to allow replication by other teachers, a point also made by Quinan et al. (2014) in their rapid literature review on teaching and learning for East Africa.

Tablets are new technology and research in the area is constantly evolving. Since the conclusion of our search, work has emerged that offers new insights. An evaluation was undertaken at one English school to establish the impact of children using iPads to improve their self-directed learning, which proved to be a success with better results than envisaged (Chesterton Community College, 2014). Recent work at Cardiff Metropolitan University has also investigated the implementation of tablets in six primary schools, although it was not possible to assess the impact of tablet use on learning and attainment due to several factors (Beauchamp & Hillier, 2014). Key findings from the first two phases of a 3-year study exploring primary school students' use of tablets for developing literacy, numeracy and problem-solving skills have also been reported, and the emerging practice of exploratory talk was identified as having potential for improving the quality of student outputs (Falloon, 2014). Whilst relating to the use of laptops and not tablets, recent work found how increased uses of simulations and spreadsheets, by both students and teachers, were responsible for a greater effect size in terms of learning gains observed (Crook et al., 2014).

5. Conclusion and outlook

Much of the general writing and policy advocating the use of tablets does so indiscriminately without reference to existing evidence, perhaps implicitly suggesting that there is no such evidence to refer to. This review challenges that belief and clearly demonstrates that a reasonable amount of research investigating the impact of tablet use on school-age students' knowledge and skills is available.

Among the 12 studies rated as 'high' for methodological trustworthiness, nine report positive learning outcomes and three no difference in learning outcomes; none report negative learning outcomes. There appears little doubt that tablets (and other mobile technologies) can viably support children so they are able to complete a variety of learning tasks. As outlined previously, however, there is significant potential to enhance the methodological rigour and design of research investigating the use of tablets to support learning.

We also note that while no included study 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]. Even high profile schemes, such as the the $1 billion Los Angeles School District iPad scheme[5], 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 acknowledge that educational technologies are most effective when there is an orchestrated 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 et al., 2014).

Schools ought not to assume that teaching staff are ready to operate tablets from the outset (Melhuish & Falloon, 2010), but should actively create adequate opportunities for professional development. A lack of relevant training, a shortage of technical support and the absence of a tablet policy can prevent staff from using tablets on a regular basis (Oliviera, 2014). It is, therefore, essential that adequate support is provided to teachers charged with introducing tablets, as the established pedagogy observed in schools does not change simply with the introduction of new technology (Osborne & Hennessy, 2003). On the contrary, the power of using technology in some lessons relies on the premise that technology is integrated into the existing pedagogy (Hennessy & London, 2013).

Researchers investigating what it is about tablets that supports students to learn should seek to establish ways in which the technology can be used more effectively than other similar devices to promote learning in the classroom. There is also potential for a greater emphasis to incorporate teacher perspectives during future research. The fact that new educational interventions require time to become embedded in classroom practice must also be appreciated, and school leaders and researchers should acknowledge that the benefits of a new technology might not be immediate (Carr, 2012; Silvernail & Gritter, 2004).

In international development, resources are often tightly constrained, and a number of research questions need to be addressed with urgency. For instance, given our findings here, and research outcomes indicating that learning with other mobile technology is enhanced through collaboration, we conjecture that a student-device ratio of one-to-one is not the most effective scenario (both in terms of value for money and learning gains). We suspect that most of the learning gains can be obtained at much higher student-device ratios, and even where sufficient resources are available, activities with (e.g.) two-to-one

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4 "Why one New Jersey school district killed its student laptop program". Available at: http://arstechnica.com/tech-policy/2014/07/why-one-new-jersey-school-district-killed-its-student-laptop-program (Accessed 21/10/14).

5 "US schools seek refund over $1.3bn iPad project". Available at: http://www.bbc.co.uk/news/technology-32347651 (Accessed 28/04/15).

may lead to higher learning gains than one-to-one. In line with the general research on technology use in education in international development, we suggest that it may not be the student-device ratio, but adequate and effective professional development opportunities for teachers that are the limiting factor for student learning (Hennessy et al., 2010; Power et al., 2014).

Globally, while educational technologies can be considered "complex interventions", and generating evidence in such a context is often difficult (Craig et al., 2008), future work is encouraged to move beyond the exploratory and to offer a thorough investigation that counters the observed trend of considering narrow research topics. Additional randomised control trials (RCTs) and longitudinal studies would offer further evidence that supports or contradicts the findings reported in this review. Some caution must be exercised when using RCTs to evaluate educational technology interventions, however, as such an approach is not feasible or suitable in all situations (Power et al., 2014). Moreover, a simple comparison of new technology vs. business as usual is not credible: RCTs must compare like-for-like, for instance in terms of investment, comparing new technology to the utilisation of other strategies (Higgins et al., 2013).

Future research must take great care to deliver findings that are generalisable to real-world settings and appropriate for underpinning policy and strategic decision making in schools.

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Appendix 1

Study Name	**High / Medium / Low Trustworthiness Rating**	**High / Medium / Low Relevance Rating**	**Overall**
Burden et al., 2012	Medium	Low	M/L
Carr 2012	High	High	H/H
Chang et al., 2013	Low	Low	L/L
Culen & Gasparini. 2012	Medium	Medium	M/M
Cumming et al., 2014	High	Medium	H/M
Della Longa & Mich, 2013	Low	Medium	L/M
Dundar & Akcayir, 2012	Medium	High	M/H
Fernandez-Lopez et al., 2013	High	High	H/H
Ferrer et al., 2011	Medium	Medium	M/M
Furio et al., 2013	High	High	H/H
Gasparini & Culen, 2012	Medium	Medium	M/M
Goodwin 2012	Medium	Medium	M/M
Heinrich 2012	Medium	Medium	M/M
Huang et al., 2012	Medium	Medium	M/M
Iserbyt et al., 2014	High	Medium	H/M
Li et al., 2010	Medium	Medium	M/M
Li & Pow., 2011	Medium	Low	M/L
Lin et al., 2012	High	High	H/H
Liu et al., 2013	High	High	H/H
Liu et al., 2014	High	Medium	H/M
Liu et al., 2012	High	Medium	H/M
McLanahan et al., 2012	Medium	Medium	M/M
Miller et al., 2013	High	Medium	H/M
Nedungadi et al., 2013	Medium	High	M/H
Pegrum et al., 2013	Medium	Low	M/L
Pittarello & Bertani, 2012	Medium	Low	M/L
Preciado-Babb, 2012	Low	Low	L/L
Price, 2011	Low	Medium	L/M
Riconscente, 2013	High	High	H/H
Sheppard, 2011	Medium	Medium	M/M

Viriyapong & Harfield, 2013	Medium	Low	M/L
Ward, 2013	Medium	High	M/H
Watts et al., 2012	Medium	Low	M/L

Supporting Document 1

Quality Appraisal - Weight of Evidence (WoE)

WoE Category One: Methodological Trustworthiness [Non-review specific]

The trustworthiness of results reported by each study based on an evaluation of the research approach used.

For each study, consider the following criteria and assign an overall rating of **high / medium / low** trustworthiness.

***Take into account*:**

- **DESIGN:** Is an appropriate study design used to address the research questions? How rigorous is the design?
  Consider:
  - E.g. an experiment to determine if changes in one variable lead to changes in another / a qualitative study to explore behaviour, reasoning or beliefs etc.
  - Is there a pre- to post-test design?
  - Is there a comparison or control group?
  - Has the research design selected been justified (e.g. have the authors discussed how they decided which method(s) to use)?

- **CONTEXT:** Is there an adequate description of the context in which the research was carried out?
  Consider:
  - Educational setting (e.g. primary school, secondary school, etc).
  - Subject(s) taught.
  - Participant and institutional characteristics.
- **SAMPLING:** Is the sampling strategy appropriate and clearly described?
  Consider:
  - Description of how participants were selected.
  - Description of why participants were selected.
  - Is the sample sufficiently large?
- **DATA COLLECTION:** Are the method(s) of data collection appropriate and clearly described?
  Consider:
  - Is it clear what methods were used to collect data?
  - Is there sufficient detail of the methods used?
  - Were quality control methods used to ensure completeness and accuracy of collected data (e.g. member checking of interview transcripts).
- **DATA ANALYSIS:** Is the data analysis/interpretation process appropriate and clearly described?
  Consider:
  - Is it clear how the themes and concepts were identified in the data?
  - Was the analysis performed by more than one researcher?
  - Are negative/conflicting results taken into account?
  - Is the analysis sufficiently rigorous?
  - Is data triangulated?
- **CLAIMS and EVIDENCE:** Are claims made credible and are there sufficient data to support the findings?
  Consider:
  - Are sequences from the original data presented (e.g. quotations) and were these fairly selected?

- Are the explanations for the results plausible?
- Are study limitations considered?
- Do the researchers examine their own role and influence?
- Is the credibility of findings discussed (e.g. respondent validation, more than one analyst, sponsor influence)?

WoE Category Two: Relevance [Review specific]

Assess the appropriateness of each study for answering the overall literature review question, "Do the knowledge and skills of students improve following the use of tablets to support educational activities?".

Consider:

- How relevant is each study in terms of determining changes in students' knowledge and skills following the use of tablets?
- Is the study design such that changes in students' knowledge and skills were considered from the outset (or were these changes observed incidentally during the course of research with other intentions)?

Assign a rating of **high/medium/low** relevance.

<u>Supporting Document 2</u>

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Supporting Document 3

Data Extraction Spreadsheet

(see separate document)