Does iPad use support learning in students aged 9-14 years? A Systematic Review

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The recent development of an increasing number of new information and communication technologies has had a significant impact on the role these technologies now play in daily life. In 2010, Apple introduced the iPad, a personal mobile technology device with a touchscreen, also known as a tablet computer. Since the launch of this new technology, the iPad has rapidly become integrated into people's work, home, and social lives (Nguyen, Barton, & Nguyen, 2014). This is particularly the case with the younger generation of 'Digital Natives' who have grown up with digital technology (Thompson, 2015; Emanuel, 2013). 'Digital Natives' are individuals who prefer speed, multitasking and have learning habits that develop through early and extended exposure to computers, online games and videos, and various other digital technologies (Thompson, 2015). The integration of iPads into the classroom is no exception. Many schools are now utilizing mobile technology devices, such as iPads, to support teaching practices and student learning.

Due to the personal and mobile nature of iPads, many scholars have predicted advantages in the use of mobile technology devices in the education sector. In particular, it has been claimed that iPads have the potential to encourage collaboration, develop multimodal literacy, support students' individual learning needs, and motivate student learning (Churches & Dickens, 2012; Murray & Olcese, 2011; Molnár, 2013). Moreover, iPads offer students the ability to access educational information at will, irrespective of time or location, which is thought to allow for a significantly enhanced learning experience (Johnson, Smith, Willis, Levine, & Haywood, 2011).

While the consensus is that iPads and other mobile technology devices have these potential benefits, it is not clear whether iPad-based learning is as effective in practice as it is in theory. In other words, is there evidence that learning is enhanced when iPads or touch screen devices are used rather than other learning methods? A systematic literature review to examine

the impact of print and digital mediums upon reading comprehension (Singer & Alexander, 2017) revealed that the medium is influential for learning attainment as it affected particular tasks for certain readers. Additionally, a large German study (Lenhard, Schroeders, & Lenhard, 2017) comparing paper with screen reading at word, sentence, and text level with in 2,807 children in grades 1 to 6 found that while reading from a screen was faster for children this was at the expense of accuracy and comprehension with significant differences increasing for younger children.

So whether iPads or touch screens enhance learning is a valid question because a range of studies indicate that handwriting may enhance memory and recollection in children and adults in a way not seen with typewriting or touch screen writing (Mueller, & Oppenheimer, 2014; Longcamp, Anton, Roth, & Velay, 2005; Longcamp et al., 2008). Research with Finnish university students showed that recall of hand-written data was significantly higher than recall of the same data written on a tablet or typewriter in a within- subject controlled study (Frangou, Ruokamo, Parviainen, & Wikgren, 2018). Such findings in adults with mature fine motor skills raise questions around the efficacy of touch screens for learning, particularly in children whose fine motor skills are still developing right up to adolescence.

Since it has been estimated that typically 46% of a child's school day is spent engaging in fine-motor skill based activities such as writing, colouring, cutting and pasting (Marr, Cermak, Cohn & Henderson, 2003) it is critical to know how, and if, by replacing some or most of these activities with the use of iPads, the acquisition of these fine motor skills is affected. This is an important consideration because it has been shown that fine motor skill development is strongly linked to cognitive development and executive function development in children up to puberty (van der Fels, et al, 2015); in turn, executive function predicts both literacy outcomes and mathematics (Cameron et al., 2016).

Executive functions include cognitive processes that contribute to the regulation of purposeful reasoning and behaviour. They thus play a major role in an extremely wide range of activities. Core components of executive function, which depend on one another to some extent, are inhibition, updating the content of working memory during the course of a task, and cognitive flexibility in shifting between mental sets or reallocating attention to different tasks. Since 2005 the importance of fine motor skills in children's reading outcomes has been validated through large-scale analyses of multiple datasets across the OECD countries (Grissmer et al., 2010; Son & Meisels, 2006). These studies also indicate there is strong evidence of robust connections between fine motor measures and reading measures that include both word decoding and vocabulary (Grissmer et al., 2010; Son & Meisels, 2006). The brain's visuo-motor integration which is involved in fine motor skills, and which coordinates visual perceptions with motor movements, has been positively linked to literacy and mathematics outcomes in a growing number of samples (McClelland & Cameron, 2019). For example, one study of school readiness among 522 children living in a poor urban area, showed that children who had good fine motor and perceptual skills had better number knowledge, fewer inattentive and hyperactive behaviours, and engaged better in classroom activities (Pagani & Messier, 2012).

The use of technology by children is expanding. Up to 95% of Australian children aged 5 – 14 years, have access to, and use technology at home for extended durations of time (ABS, 2011) with similar trends observed in the USA as 83% of children were reported to have a computer at home in 2011 (Child Trends Databank, 2013). The use of iPads in educational settings needs to be investigated for its efficacy in supporting skill and cognitive development given that it potentially replaces more traditional learning processes which involve handwriting, drawing and the deployment of children's other fine motor skills.

This report explored iPad efficacy in educational settings by providing a systematic review of studies published between 2010 and 2019 which investigated the outcomes of the use of iPads and other mobile technology devices on student learning. The targeted population of interest for this review was 9-14 year old students because Lenhard et al. (2017) using a sample of 2807 Grade 1- 6 students found there were few differences in reading linked to digital screen reading in older students which could confound the learning outcomes in specific content areas. Older students' learning, that is those over 14 years old, is also less likely to be impacted by the decreased use of fine motor skills involved in touch typing (Lenhard et al (2017; van der Fels et al 2015). Lenhard et al (2017 also noted that younger children are still gaining competence in reading since their accuracy and comprehension of texts was significantly lower than older children, and therefore a focus on this younger age range could also confound the observed efficacy of mobile technology use for subject specific learning, the purpose of the investigation of this review. The search focus on studies reported in years 2010 – 2019 was based on the hypothesis that older research would inform the basis of more sophisticated recent research. While iPads were available from 2010, earlier research on tablets and computers which were already in use would inform later studies on the use and efficacy of digital technologies.

Method

Search Strategy

A systematic review follows specific steps to produce results that are replicable. Borrowed from researchers in the health sciences the PRISMA model of systematic reviews was undertaken (Moher, Liberati, Tetzlaff, & Altman, 2009). A systematic review helps avoid the trap of cherry-picking, where a small number of studies are chosen in order to support pre-determined conclusions, creating a weak evidence base that might not hold up to scrutiny from stakeholders. In this review we used four databases in March 2019 to conduct a comprehensive

and exhaustive search of available peer reviewed research articles published in English from 2010 to 2019. Each search was conducted using a database specific search engine: Proquest (CSA Illumina) was used to search both the Education Resources Information Center (ERIC) and PsycINFO databases; PubMed was used to search the United States (U.S) National Library of Medicine (MedLine) database; EBSCOhost (EBSCO publishing, Ipswich, MA) was used to search the Cumulative Index to Nursing and Allied Health Literature (CINAHL) database. Search terms were consistent across all four databases however database specific filters were applied in each instance (Table 1). Articles identified first as pertaining to the population of interest, were then interrogated for the specific criterion of iPad or tablet or personal computer. Search terms used were: ((child*) AND (iPad OR personal computer OR tablet) AND (school) AND (develop* OR cognition) AND (elementary OR primary OR secondary OR classroom)).

Table 1. *Database specific filters applied to search strategy*

CINHAL	**ERIC**	**PsycINFO**	**PubMed**
Child*, preschool: 2-5	Early childhood education	Preschool Age (2-5yrs)	Child*
Child: 6-12 years	Elementary education	Childhood (Birth-12yrs)	Adolescent
Adolescent: 12-18 years	Elementary secondary education	School Age (6-12yrs)	
All child*	Grade 1 - 12	Adolescence (13-17yrs)	
	High school equivalency programs		
	High schools		
	Intermediate grades		
	Junior high schools		
	Middle schools		

	Primary education		
	Secondary education		

Search Execution and Article Screening

Articles identified through searching (*n* = 221) were imported into citation management software Endnote X8 and duplicate articles were identified and removed (*n* = 20). A list of keywords was generated and used to exclude articles (*n* = 22) which pertained to areas that did not address areas targeted during our database searches (see Table 2 for full list of keywords used for exclusion).

Table 2. *Keywords used to exclude irrelevant articles identified through database searches*

Age range	**Educational setting**	**Population focus**	**Topic focus**
Infant	Postsecondary Education	In-service Teacher Education	Dementia
Infant, Newborn	Undergraduate Study	Teacher Education Programs	
Young Adult	Bachelor's Degrees	Teacher Educators	
Young Adults	Higher Education	Teacher Improvement	
Middle Aged	College Students	Teacher Leadership	
Adult	College School Cooperation		
Adult Education	Private Colleges		
Aged	Graduate Students		
Elderly people	Student Teachers		
	Preservice Teachers		
	Preservice Teacher Education		

From this, a final data set (n = 179) was generated and citations and abstracts were reviewed against inclusion criteria: 1) iPad or tablet, or personal computer use; 2) children 9-14 years old; 3) skill or cognitive development. The search strategy is summarised in Figure 1.

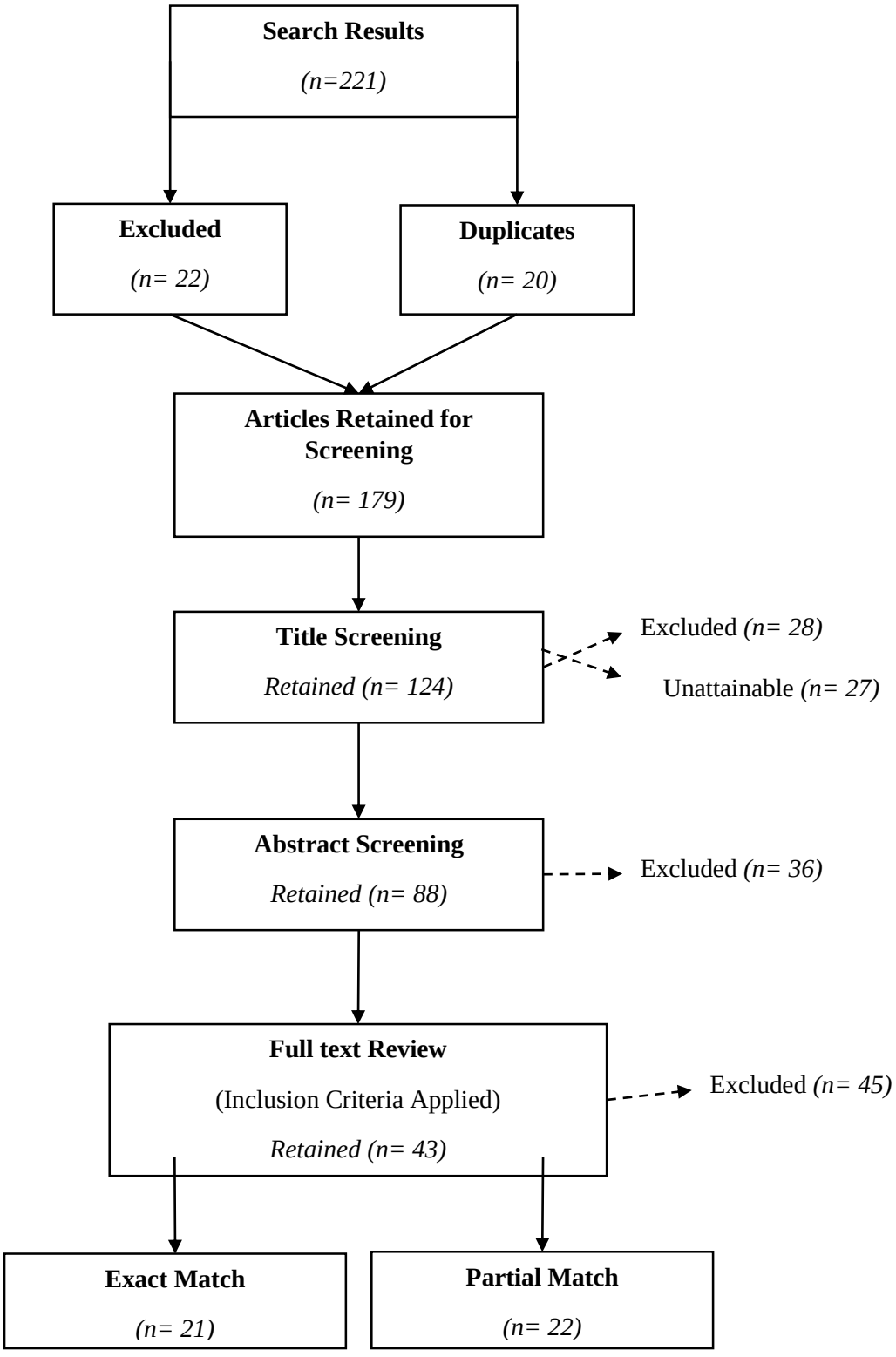

Figure 1. Screening process and search results

Figure 1. Screening process and search results

Reasons for the exclusion of studies include the following identified research protocols:

- iPad use for assessing students
- Ease of teaching with iPads
- iPad use for teachers' professional development
- iPad professional development to support use in classroom
- Participants outside age range
- iPad use for other school staff
- iPads to support student inclusion
- Other reasons/effects/uses

Appendix 2 lists these articles and the citations.

Data Analysis

The data in each of the 43 retained papers was analysed by 2 researchers. Each paper was read through and the following elements were identified: research aim, research methods, sampling, and the key findings. The findings were then broadly categorised into those that were relevant to general learning outcomes or those relevant to subject-specific learning outcomes. The subject-specific findings were subcategorised by the subjects to which they pertained. This data was then summarised in a table (Appendix 1). Next, any studies which employed a primarily experimental research design were identified for a more detailed analysis of the findings. A summary of the data analyses and relevant findings are outlined in the Results section.

Results

Overview

All of the papers that were included in this report had findings relevant to the impact of using iPads and other mobile technology devices in learning outcomes. Of the 43 research

papers that reported on findings related to iPads in school-aged children, 21 papers dealt exclusively with students within the age range of 9-14 years.

The majority of the research methods employed in the identified studies were exploratory, qualitative in nature, and therefore lack generalisability. Many were designed around classroom observations and teacher and/or student interviews. The iPad interventions were usually for a short duration, as noted in the limitations of these studies. Research methods employed in the reported research include the following:

a. **case study** (Arthanat, Curtin, & Kontak, 2015; Beal & Rosenblum, 2018; Bergeson & Rosheim, 2018; Biggs, Carter, & Gustafson, 2017; Browder, Root, & Wood, 2017; Bruhn, Vogelgesang, Fernando, & Lugo, 2016; Bryant, et al., 2015; Cardullo, Zygouris- Coe, I, & Wilson, 2017; Ditzler, Hong, & Strudler, 2016; Douglas, Uphold, Steffen, & Kroesch, 2018; Falloon, 2017; Flewitt, Messer, & Kucirkova, 2015; Flores, et al., 2012; Hill & Flores, 2014; Hong, Hwang, Tai, & Tsai, 2017; Kwan, et al., 2015; Li & Wang, 2018; Monem, Bennett, & Barbetta, 2018; Ok & Bryant, 2016; Pifarré, 2019; Prince, 2017; Rivera, Hudson, Weiss, & Zambone, 2017; Saarinen, Seitamaa-Hakkarainen, & Hakkarainen, 2016; Sankardas & Rajanahally, 2017; Santori & Smith, 2018; Smith & Santori, 2015; Vogelgesang, Bruhn, Coghill-Behrends, Kern, & Troughton, 2016; Ward, Finley, Keil, & Clay, 2013), including researcher observations (Cartier, 2014).

b. **survey** (Chambers, et al., 2018; Chen, 2015; Hilton A. , 2018; Ockert, 2014; Patterson & Young, 2013).

c. **experimental** (Carr, 2012; Felix, Mena, Ostos, & Maestre, 2017; Huang, Liang, Su, & Chen, 2012; Knight & Davies, 2016; Najmuldeen, 2017; Perry & Steck, 2015; Regan, et al., 2018), and

d. **clinical trial** (Holmes, et al., 2016).

Study sample sizes ranged from two students (Bruhn, Vogelgesang, Fernando, & Lugo, 2016) to 1123 students (Kwan, et al., 2015).

Findings by Subject Area

The findings of these papers were concerned with the following subject areas: **English** (Browder, Root, & Wood, 2017; Cardullo, Zygouris- Coe, I, & Wilson, 2017; Felix, Mena, Ostos, & Maestre, 2017; Flewitt, Messer, & Kucirkova, 2015; Huang, Liang, Su, & Chen, 2012; McKeown, Kimball, & Ledford, 2015; Prince, 2017; Regan, et al., 2018; Rivera, Hudson, Weiss, & Zambone, 2017), **mathematics** (Beal & Rosenblum, 2018; Bryant, et al., 2015; Carr, 2012; Hilton A. , 2018; Ok & Bryant, 2016; Patterson & Young, 2013; Perry & Steck, 2015; Smith & Santori, 2015; Ward, Finley, Keil, & Clay, 2013), **science** (Bergeson & Rosheim, 2018; Falloon, 2017; Hong, Hwang, Tai, & Tsai, 2017; Knight & Davies, 2016; Smith & Santori, 2015; Ward, Finley, Keil, & Clay, 2013), **music** (Chen, 2015), **history** (Monem, Bennett, & Barbetta, 2018), **engineering** (Li & Wang, 2018; Ward, Finley, Keil, & Clay, 2013), **sex education** (Kwan, et al., 2015), **social studies** (Najmuldeen, 2017; Smith & Santori, 2015), **foreign language learning** (Ockert, 2014; Prince, 2017), **craft education** (Saarinen, Seitamaa-Hakkarainen, & Hakkarainen, 2016), **technology** (Ward, Finley, Keil, & Clay, 2013), and **language arts** (Smith & Santori, 2015). Overall, the majority of studies relate to English, mathematics, and science.

Findings related to **English** can be broadly divided into those concerned with **students' reading skills** (Browder, Root, & Wood, 2017; Cardullo, Zygouris- Coe, I, & Wilson, 2017; Huang, Liang, Su, & Chen, 2012; Rivera, Hudson, Weiss, & Zambone, 2017), **students' English writing skills** (McKeown, Kimball, & Ledford, 2015; Regan, et al., 2018), or **both English writing and reading** (Felix, Mena, Ostos, & Maestre, 2017; Flewitt, Messer, & Kucirkova, 2015; Prince, 2017). In all studies pertaining to English writing, students showed improvement after the iPad intervention; increased story/ essay lengths were observed and the

quality of writing improved. The results were less clear regarding students' reading skills after the iPad intervention.

The findings in some reading studies suggest that iPads can provide students with ease of access to reference materials (Cardullo, Zygouris- Coe, I, & Wilson, 2017), support vocabulary building (Browder, Root, & Wood, 2017), and increase student comprehension of texts (Browder, Root, & Wood, 2017). However, other researchers reported that they proved to be less effective in promoting student reading accuracy (Huang, Liang, Su, & Chen, 2012), vocabulary building (Rivera, Hudson, Weiss, & Zambone, 2017), or comprehension, particularly of complex texts (Cardullo, Zygouris- Coe, I, & Wilson, 2017).

Similarly, in relation to **mathematics**, the results were mixed. Participants generally reported that iPad intervention supported mathematics learning (Patterson & Young, 2013; Smith & Santori, 2015; Ward, Finley, Keil, & Clay, 2013). Some researchers found that iPads could motivate student learning (Beal & Rosenblum, 2018; Hilton, 2018; Smith & Santori, 2015; Ward, Finley, Keil, & Clay, 2013), increase the number of students' correct answers (Beal & Rosenblum, 2018; Ok & Bryant, 2016), and improve students' mathematical self-perceptions (Hilton, 2018). However, other studies showed either no significant difference in learning outcomes in mathematics for those students using iPads compared to those using other non-technology-based methods (Bryant, et al., 2015; Carr, 2012) or inconsistent results in student learning outcomes (Bryant, et al., 2015). One study showed that the participants involved in the iPad intervention scored lower than the control group and had higher levels of off-task behaviours (Perry & Steck, 2015).

These mixed results were also evident in the area of **science**. In science learning, it was suggested that iPads could motivate student learning (Hong, Hwang, Tai, & Tsai, 2017; Smith & Santori, 2015; Ward, Finley, Keil, & Clay, 2013), support conceptual learning (Ward, Finley, Keil, & Clay, 2013), and improve student academic performance (Hong, Hwang, Tai, & Tsai,

2017). However, while more competent students were shown to benefit from iPad intervention, developing learners showed no improvement without teacher intervention (Bergeson & Rosheim, 2018). iPad intervention was shown to have some benefits in structuring experiments (Falloon, 2017), but the findings suggest that iPads do not support conceptual knowledge development (Falloon, 2017; Knight & Davies, 2016). Moreover, Knight and Davies (2016) reported no differences in improvement of science learning outcomes between the control group and the iPad intervention group.

A number of studies were not subject-specific, but instead focused on the impact of iPads on students more generally, in relation to factors such as **motivation to learn** (Arthanat, Curtin, & Kontak, 2015; Bruhn, Vogelgesang, Fernando, & Lugo, 2016; Chambers, et al., 2018; Ditzler, Hong, & Strudler, 2016; Vogelgesang, Bruhn, Coghill-Behrends, Kern, & Troughton, 2016), **creativity** (Pifarré, 2019), **development of communication and social skills** (Biggs, Carter, & Gustafson, 2017; Bruhn, Vogelgesang, Fernando, & Lugo, 2016; Chambers, et al., 2018; Douglas, Uphold, Steffen, & Kroesch, 2018; Flores, et al., 2012; Hill & Flores, 2014; Sankardas & Rajanahally, 2017), **increased learner independence** (Cartier, 2014; Chambers, et al., 2018; Douglas, Uphold, Steffen, & Kroesch, 2018), **multi-literacy development** (Santori & Smith, 2018), and **improvement of behaviour** (Bruhn, Vogelgesang, Fernando, & Lugo, 2016).

iPad use for students with disabilities

Nineteen (19) studies were concerned with the ways in which mobile technology devices were used to support students with disabilities. This is a significant focus area in current studies, making up nearly half of the total research analysed. In particular, the findings related to children with **developmental/learning disabilities** (Arthanat, Curtin, & Kontak, 2015; Biggs, Carter, & Gustafson, 2017; Bruhn, Vogelgesang, Fernando, & Lugo, 2016; Bryant, et

al., 2015; Chambers, et al., 2018; Douglas, Uphold, Steffen, & Kroesch, 2018; Flewitt, Messer, & Kucirkova, 2015; Flores, et al., 2012; Hill & Flores, 2014; Monem, Bennett, & Barbetta, 2018; Ok & Bryant, 2016; Rivera, Hudson, Weiss, & Zambone, 2017), **Down Syndrome** (Felix, Mena, Ostos, & Maestre, 2017), **Autism Spectrum Disorder (ASD)** (Browder, Root, & Wood, 2017; Hill & Flores, 2014; Sankardas & Rajanahally, 2017), **emotional/behavioural disorders** (McKeown, Kimball, & Ledford, 2015), **Attention Deficit and Hyperactivity Disorder (ADHD)** (Vogelgesang, Bruhn, Coghill-Behrends, Kern, & Troughton, 2016), **amblyopia** (Holmes, et al., 2016) and **visual impairment** (Beal & Rosenblum, 2018).

The findings from this research suggest that iPads can improve **student engagement** (Arthanat, Curtin, & Kontak, 2015; Bruhn, Vogelgesang, Fernando, & Lugo, 2016; Chambers, et al., 2018; Flewitt, Messer, & Kucirkova, 2015; Sankardas & Rajanahally, 2017; Vogelgesang, Bruhn, Coghill-Behrends, Kern, & Troughton, 2016), **communication** (Biggs, Carter, & Gustafson, 2017; Chambers, et al., 2018; Flores, et al., 2012; Hill & Flores, 2014; Sankardas & Rajanahally, 2017), **academic achievement** (Chambers, et al., 2018; Monem, Bennett, & Barbetta, 2018; Ok & Bryant, 2016), **reading skills** (Browder, Root, & Wood, 2017; Douglas, Uphold, Steffen, & Kroesch, 2018; Felix, Mena, Ostos, & Maestre, 2017), **English writing skills** (Felix, Mena, Ostos, & Maestre, 2017; McKeown, Kimball, & Ledford, 2015), **digital skills** (Rivera, Hudson, Weiss, & Zambone, 2017), **social/life skills** (Chambers, et al., 2018; Douglas, Uphold, Steffen, & Kroesch, 2018), and **behaviour** (Bruhn, Vogelgesang, Fernando, & Lugo, 2016). Although other researchers reported inconsistent/inconclusive results with iPad interventions for children with learning disabilities (Bryant, et al., 2015; Flores, et al., 2012; Hill & Flores, 2014; Rivera, Hudson, Weiss, & Zambone, 2017) and amblyopia (Holmes, et al., 2016).

Experimental studies

Out of the 43 articles retained for a full analysis, seven (7) employed an experimental design, using quantitative methods, that included a control group and an experimental group. It is important to note that these studies are still only quasi-experimental, and, in the majority of cases, the control and experimental groups were not matched. There were no studies identified that involved an experimental design that could lead to generalisability of findings. Of these quasi-experimental studies, there were three (3) which examined English learning outcomes (Felix, Mena, Ostos, & Maestre, 2017; Huang, Liang, Su, & Chen, 2012; Regan, et al., 2018), two (2) examining mathematics (Carr, 2012; Perry & Steck, 2015), one (1) examining social studies outcomes (Najmuldeen, 2017), and one (1) focused on science outcomes (Knight & Davies, 2016).

In the context of English, researchers tested the ability to write persuasive essays (Regan, et al., 2018), reading accuracy (Huang, Liang, Su, & Chen, 2012), and literacy achievement (Felix, Mena, Ostos, & Maestre, 2017). Regan, et al.'s (2018) study collected data from 94 middle school students, 23% of whom had disabilities. The study employed a pre-test/post-test design, measuring writing performance using indicators such as the number of words, sentences, and transitions, as well as the holistic quality of writing. The experimental group had an intervention with MBGO (Mobile-Based Graphic Organizer) on an iPad over eight 30-40 minute sessions, while the control group had similar sessions using an iPad application all students had access to an application called: *Pages*. The results indicated that the students in the experimental group using the MBGO outperformed the control group in terms of both number of transition words and the holistic quailty of writing. The limitations of this study were reported to be a small sample size with non-equivalent control and experimental groups, the difficulting controlling for the variable of the teacher in the intervention, and the level of technological literacy already present in the school.

The study by Felix, Mena, Ostos, and Maestre (2017) also reported modest positive findings around mobile technology devices for learning Spanish. This study specifically analysied the efficacy of such technologies in the classroom as the experimental group, six students with intellectual disabilities, had a 16 week intervention using the application *HATLE* on Android tablet computers, whereas the matched control group was taught the same content without using technology. This study also used a pre-test/post-test design, measuring literacy skills through indicatorss such as letter identification, single-word reading, and handwriting quality. The findings showed that the experimental group performed better than the control group in terms of single-word reading and handwriting form, but did not show a significant difference between the groups in the other measures: handwriting legibility, spelling and letter identification. It appears that the computer-assisted intervention proved to be beneficial in assisting children with learning disabilities in some areas. As this study drew on data from a sample size of only twelve students, this was identified as a significant limitation.

Huang, Liang, Su, and Chen's (2012) research followed a similar method to the previous two studies, investigating the impact of e-books on reading accuracy in 166 elementary school students using matched control and experimental groups. The control group was taught using a printed book and the experimental group was taught using an e-book. While the results showed no difference in the students' learning outcomes, it was found that the learning tracking logs provided by mobile technology devices could be used to support learning by offering further assistance to the individual learner based on their actual learning processes.

Two quasi-experimental studies focused on mathematics: one on the mathematics achievement of 104 children in grade 5 (Carr, 2012), and the other on the engagement and academic achievement in geometry of 110 students in a secondary level geometry course (Perry & Steck, 2015). In both cases, the findings did not support mobile technology devices. Both studies used a pre-test/post-test research model with a non-iPad control group and an iPad-

based intervention experimental group. Carr's (2012) research found that there was no statistically significant difference between the scores of the control and experimental group. In the study by Perry and Steck (2015), the experimental group performed worse than the control group, and also exhibited higher levels of off-task behaviours. In both studies, there were serious limitations which included using not matched control and experimental groups and differences in the teachers' instructional style.

A study investigating the impact of iPad applications on childrens' learning of social studies was conducted by Najmuldeen (2017). In this research, 48 chidren in grade 6 were the subjects of a six week intervention, the experimental group being taught with the use of game-based iPad applications, and the control group without. Findings of this study revealed that the participants in the experimental group performed better than those in the control group in both the post-test and the delayed test, which measured students' knowledge and reasoning in social studies. In the discussion of the results and recommendations of the study, Najmuldeen notes the importance of the teacher's confidence in using iPads and professional development in employing iPads as an educational tool.

In relation to science, Knight and Davies's (2016) research investigated the potential benefit of using a Mobile Dichotomous Key iPad application to teach with the purpose of improving students' scientific observation skills. Groups of students in grade 5 and grade 7 participated in the study. The students were divided into two categories: those who had the educator-led intervention, and those who used the iPad application. The results suggest that the iPad application was as effective, if not more so in some areas, than educator-led intervention. The students in the iPad-intevention group were found to have improved in the level of detail they provided when making scientific observations, and in the number of scientific terms they used. However, iPad intervention was not shown to be effective in increasing the number of

valid inferences students made. Results of this study were likely due at least partly to the increased student engagement effected by the use of iPads.

Discussion and Conclusions

This report provides a synthesis of the identified research conducted between 2010 and 2019 that explored the use of iPads and other mobile technology devices in classrooms. Peer-reviewed research from 2010 onwards was reviewed against specific search criteria outlined above. While the volume of studies conducted on iPad and mobile technology devices in the education sector is growing, findings of this review show that the research is still at the initial stages of exploration. Many of the studies were pilot studies and there was a distinct lack of longitudinal studies and studies involving within-subject experimental designs to test the efficacy of iPads on specific subject learning outcomes.

Overall the data gathered from the 43 studies indicate that a majority of teachers and students are positively disposed towards the use of iPads in educational settings. However the results concerning the impact of iPads and mobile technology devices are mixed. Some studies have suggested that iPads are a useful tool in the classroom, promoting collaborative learning, communication and access to information. On the other hand the potential for iPads to be a distraction in the classroom has also been frequently reported (e.g., Ditzler, Hong, & Strudler, 2016; Ferguson, & Oigara, 2017). Concerning the achievement of learning outcomes, findings of this review also indicate mixed results, with some studies reporting statistically significant results in favour of the experimental iPad-intervention group (Felix, Mena, Ostos, & Maestre, 2017; Knight & Davies, 2016; Najmuldeen, 2017; Regan, et al., 2018), while others report statistically significant results for the control groups (Carr, 2012; Huang, Liang, Su, & Chen, 2012; Perry & Steck, 2015). It appears that the overall impact of iPads on student learning and academic achievement is still inconclusive.

What may be surmised from these findings is that iPads and other mobile technology devices can be used as educational tools, but their efficacy is very much dependent on a range of other factors. The research thus far has raised several issues that may affect the students' ability to learn using iPads: teachers' digital literacy, the level of digital literacy of the students, the way iPads are used in the classroom, and the other methods of teaching being used in conjunction with the iPad. Although iPads with easy to use touch screens may appear user friendly, deployment in school requires specialist equipment (access to high cost and high bandwidth WiFi and charging stations), organisational structure (downloading, charging, security, ownership and child protection) and expertise (knowledge of apps and operating systems). In particular, some studies emphasised the importance of the role of the teacher in effectively employing and managing iPad-based learning. However, there is also a lack of pedagogical guidelines as to how to support academic learning and achievement using iPads. Further research is necessary in order to elucidate the relationship between mobile technology devices and student learning outcomes.

Finally, and more critically, we do not know what the effects of iPad use are on the development of fine motor skills which are linked to cognitive skill development in children right up to puberty. This is important since iPad use in classroom activities designed to enhance specific subject knowledge might impede children's fine motor skill development because it reduces the time available to children to practice handwriting, drawing and other fine motor skill activities. Touch-screen devices like iPads require simple basic actions: tapping, double-tapping, pressing, sweeping, dragging, or zooming (Ling-Yi Lin, Rong-Ju Cherng & Yung-Jung Chen, 2017), quite different to actions that involve grasping pencils, pens rulers and other drawing and handwriting instruments with the involvement of muscle coordination, and dexterity (Mangen & Velay, 2010). Scholars have cautioned that the extensive use of touch-screen devices might lead to a significant negative effect on the acquisition of fine motor skills

(Venetsanou & Kambas, 2010). Although researchers in health sciences, such as occupational therapy, have examined the use of iPad apps specifically employed to increase fine motor skills in young children (e.g., Axford, Joosten, & Harris, 2018), such studies are explicitly aimed to assess the efficacy of particular applications designed to increase the manual dexterity of young children, not school subject knowledge. Other concerns around the decline of cognitive skills around some parts of the world have been hypothesised to be due to a greater immersion in modern visual and aural electronic culture (Flynn, & Shayer, 2018). These researchers also postulate that more time spent on digital media decreases attention span and precipitates the decline of cognitive skill attainment.

The rapid digitalisation of classrooms and the shift from handwriting to typing or touch screen use will have cognitive and educational implications that have not yet been identified. Fine motor skills, manual dexterity and learning might be altered by not using handwriting which is known to influence cognitive development. More research is required in populations of different age groups to assess and take account of their varied experiences of different writing methods in order to understand the possible effects of iPad use on cognitive performance. Additionally, further longitudinal research is needed to investigate the developmental and neural factors associated with different writing modalities. Studies need to be done to compare the effects of writing versus touch screen learning activities using within person research designs. Only then would we have a more accurate understanding of the efficacy of iPad use in classrooms. In conclusion, results of this review point to a need for further investigation. This is required so that educators can make balanced, fully informed decisions about any potential benefits of iPad use in enhancing learning outcomes, weighed against any possible disadvantages that iPad use might impose on fine motor skill development in children aged 9 -14 years old.

Limitations

This review has some potential limitations. These consist of the exclusion of grey literature from review which might have contained pertinent research findings, the exclusion of articles published in languages other than English, articles not available or accessible and articles which did not specify the precise ages of the study participants. Lastly, publication bias could have led to the exclusion of research papers reporting important findings pertaining to the review goal. Evidence has demonstrated that studies that report relatively high effect sizes are more likely to be published than studies that report lower effect sizes. If the excluded studies were systematically different than the ones we were able to locate, then our collection of studies and overall review will be biased (Borenstein, Hedges, Higgins, & Rothstein, 2011).

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Appendix 1: Analysis of included studies for full review

Authors (date)	*Title*	*Research methods*	*Subject area*	*Participants*	*Apps*	*Relevant findings*
Arthanat, Sajay; Curtin, Christine; Kontak, David (2015)	An Evaluation Protocol for Selection of Educational Technologies for Students with Developmental Disabilities: A Demonstration Study Using iPad Apps	Case study (observations)	General	Six students aged between 10-14 years with developmental disabilities	Multiple applications	Participants showed greater participation in learning when an app was systematically chosen in comparison to when a random app was used.
Beal, Carole R; Rosenblum, L. Penny (2018)	Evaluation of the Effectiveness of a Tablet Computer Application (App) in Helping Students with Visual Impairments	Multiple case studies (teacher interviews)	Mathematics	43 visually impaired students in grades 4-10, and thirty teachers of visually impaired students	Mathematics app	Participants using the app answered more problems correctly than they did previously. Teachers believe that iPads

	Solve Mathematics Problems					motivated student learning.
Bergeson, Kristi; Rosheim, Kay (2018)	Literacy, Equity, and the Employment of iPads in the Classroom: A Comparison of Secure and Developing Readers	Case study (mixed methods)	Science	Six students in grade 6	Minnesota Grade 6 Science FlexBook	Secure reader participants benefitted from reading the science text on the iPad. However, developing reader participants did not improved in either self-efficacy or navigational skills.

Authors (date)	*Title*	*Research methods*	*Subject area*	*Sampling*	*Apps*	*Relevant findings*
Biggs, Elizabeth E; Carter, Erik W; Gustafson, Jenny (2017)	Efficacy of peer support arrangements to increase peer interaction and AAC use	Case study (mixed methods)	General (communication)	Four students with severe disabilities resulting in complex communication needs aged between 10-16 years	Proloquo2Go	After the communication intervention using the Proloquo2Go application, the instances of communication of participants increased in comparison to their previous volume of communication.
Browder, Diane M; Root, Jenny R; Wood, Leah; Allison, Caryn (2017)	Effects of a story-mapping procedure using the iPad on the comprehension of narrative texts by students	Case study (mixed methods)	English (reading)	Three students with autism aged between 8-10 years	SMART notebook	Participants who used the SMART notebook application showed improvement in several areas of their learning, including their ability to

	with autism spectrum disorder					build their vocabulary, their reading, and their general comprehension of texts.
Bruhn, Alison Leigh; Vogelgesang, Kari; Fernando, Josephine; Lugo, Wilbeth (2016)	Using Data to Individualize a Multicomponent, Technology-Based Self-Monitoring Intervention	Case study (mixed methods)	General	Two students with disabilities in grades 6-7	*SCORE IT*	Participants showed increased academic engagement and improved behaviour after intervention using the SCORE IT application as a method of self-monitoring.

Authors (date)	*Title*	*Research methods*	*Subject area*	*Sampling*	*Apps*	*Relevant findings*
Bryant, Brian R; Ok, Minwook; Kang, Eun Young; Kim, Min Kyung; Lang, Russell; Bryant, Diane Pedrotty; Pfannestiel, Kathleen (2015)	Performance of Fourth-Grade Students with Learning Disabilities on Multiplication Facts Comparing Teacher-Mediated and Technology-Mediated Interventions: A Preliminary Investigation	Case study (mixed methods)	Mathematics	Six students with learning disabilities in grade 4	Math Drills Math Evolve	Inconsistent results in learning outcomes in mathematics for the participants when taught via app-based instruction, teacher-directed instruction, or a combination of both.
Cardullo, Victoria; Zygouris-Coe; I, Vassiliki; Wilson, Nance S (2017)	Reading Nonfiction Text on an iPad in a Secondary Classroom	Case study (observations and interviews)	English (reading)	Seven students aged 13-14 years	Several key iPad features including highlighting, hyperlinks,	iPads can make accessing information quick and support student learning, but does not ensure deep reading of increasingly complex texts.

					search and sticky notes	
Carr, Jennie M (2012)	Does Math Achievement "h'APP'en" when iPads and Game-Based Learning Are Incorporated into Fifth-Grade Mathematics Instruction?	Experiment	Mathematics	104 students in grade 5	Multiple applications	Participants showed no significant difference in mathematics achievement in comparison to the control group.

Authors (date)	*Title*	*Research methods*	*Subject area*	*Sampling*	*Apps*	*Relevant findings*
Cartier, Leslie C (2014)	The Flexible Learning Lab	Researcher observations	General	Unspecified; some 3rd grade	NA	iPads can give students more opportunities to learn.
Chambers, Dianne; Jones, Phyllis; McGhie-Richmond, Donna; Riley, Michael; May-Poole, Sarah; Orlando, Ann Marie; Simsek, Orhan; Wilcox, Catherine (2018)	An exploration of teacher's use of iPads for students with learning support needs	Survey	General	393 teachers of students with special needs	NA	Teachers generally believe that students respond favorably to iPads, and that iPads can support the social, academic, communication, and functional learning of students with learning disabilities and learning support needs.

Chen, Chi Wai Jason (2015)	Mobile learning: Using application Auralbook to learn aural skills	Survey and interviews	Music	196 users of Auralbook Grades 1–3, Grades 4–5, and Grades 6–8.	Auralbook	Teachers and students believe that iPads can improve students' aural skills and motivation to learn music.
Ditzler, Christine; Hong, Eunsook; Strudler, Neal (2016)	How Tablets Are Utilized in the Classroom	Case study (observations and interviews)	General	23 students ; grades 6-8; three teachers	Multiple applications	Participants had mixed views about the iPads. Some teachers found the iPads distracted students.

Authors (date)	*Title*	*Research methods*	*Subject area*	*Sampling*	*Apps*	*Relevant findings*
Douglas, Karen H; Uphold, Nicole M; Steffen, Shannon; Kroesch, Allison M (2018)	Promoting Literacy with Self-Created Grocery Lists on Mobile Devices	Case study (mixed methods)	General (life skills)	Four students with developmental disabilities aged 11-14 years	Photo Grocery List	Participants' reading skills and independent life skills improved through using the app.
Falloon, Garry (2017)	Mobile devices and apps as scaffolds to science learning in the primary classroom	Case study (observations)	Science	65 students aged 10-11 years	Okiwibook science apps	The apps helped students to structure their science experiments, understand procedures, think about variables, and communicate outcomes. However, the apps were not shown to support

						students' conceptual knowledge development.
Felix, Vanessa G; Mena, Luis J; Ostos, Rodolfo; Maestre, Gladys E (2017)	A pilot study of the use of emerging computer technologies to improve the effectiveness of reading and writing therapies in children with Down syndrome	Experiment	English (reading and writing)	Twelve students with intellectual disabilities aged between 6-15 years	HATLE	Participants' handwriting-form and ability to single-word read showed greater improvement than the participants in the control group.

Authors (date)	*Title*	*Research methods*	*Subject area*	*Sampling*	*Apps*	*Relevant findings*
Flewitt, Rosie; Messer, David; Kucirkova, Natalia (2015)	New directions for early literacy in a digital age: The iPad	Case study (interviews)	English (reading and writing)	Approximately 60 children with and without learning disabilities aged between 3-13 years	Our Story My Colouring Book App Doodlefind English Alphabet for kids for iPad	Teachers believe that iPads can benefit children's self-esteem and motivate engagement with a range of reading and writing activities.
Flores, Margaret; Musgrove, Kate; Renner, Scott; Hinton, Vanessa; Strozier, Shaunita; Franklin, Susan; Hil, Doris	A comparison of communication using the Apple iPad and a picture-based system	Case study (observations)	General (communication)	Five students with disabilities aged between 8-11 years	Pick a Word	Participants showed more communication behaviours when using the iPads, but the results were mixed as to whether communication skills are being developed.

(2012)						
Hill, Doris Adams; Flores, Margaret M. (2014)	Comparing the Picture Exchange Communication System and the iPad(TM) for Communication of Students with Autism Spectrum Disorder and Developmental Delay	Case study (mixed methods)	General (communication)	Four students with either development delays or autism aged between 4-9 years	Proloquo2go	Some participants were more responsive to communication intervention via the app and others to the Picture Exchange Communication System.

Authors (date)	*Title*	*Research methods*	*Subject area*	*Sampling*	*Apps*	*Relevant findings*
Hilton, Annette (2018)	Engaging Primary School Students in Mathematics: Can iPads Make a Difference?	Survey and interviews	Mathematics	829 students aged between 7-11 years, and seven teachers	Multiple applications	Learning mathematics with iPads had a positive influence on students' mathematical self-perceptions and boys' enjoyment of mathematics. Both teachers and students generally believe that iPads can increase student motivation and engagement with mathematics. Both teachers and students generally reported

						positive attitudes towards iPads.
Holmes, Jonathan M; Manh, Vivian M; Lazar, Elizabeth L; Beck, Roy W; Birch, Eileen E; Kraker, Raymond T; Crouch, Eric R; Erzurum, S. Ayse; Khuddus, Nausheen; Summers, Allison I; Wallace, David (2016)	Effect of a binocular iPad game vs part-time patching in children aged 5 to 12 years with amblyopia a randomized clinical trial	Clinical trial	NA	385 children with amblyopia aged between 5-13 years	Binocular falling blocks iPad game	It could not be established whether iPad game play was not worse than part-time patching in improving visual acuity in children with amblyopic-eye.

Authors (date)	*Title*	*Research methods*	*Subject area*	*Sampling*	*Apps*	*Relevant findings*
Hong, Jon-Chao; Hwang, Ming-Yueh; Tai, Kai-Hsin; Tsai, Chi-Ruei (2017)	An Exploration of Students' Science Learning Interest Related to Their Cognitive Anxiety, Cognitive Load, Self-Confidence and Learning Progress Using Inquiry-Based Learning With an iPad	Case study (mixed methods)	Science	183 students in grade 5	WhyWhy	iPads can motivate students to learn science and improve academic performance.
Huang, Yueh-Min; Liang, Tsung-Ho; Su, Yen-Ning; Chen, Nian-Shing (2012)	Empowering Personalized Learning with an Interactive E-Book Learning System for	Experiment	English (reading)	166 elementary school students; 85 male, 81 female. Age not specified	Interactive e-book learning system	Participants' reading accuracy in the iPad group showed no significant difference to

	Elementary School Students					that of participants in the printed book group.
Knight, Kathryn; Davies, Randall (2016)	Using a Mobile Dichotomous Key iPad Application as a Scaffolding Tool in a Museum Setting	Experiment	Science	150 students in grades 5-7	Mobile Dichotomous Key	Participants in MDK group showed similar level of improvement in scientific observation skills than the educator-led participants. However, iPads were not effective at improving the number of valid inferences students made.

Authors (date)	*Title*	*Research methods*	*Subject area*	*Sampling*	*Apps*	*Relevant findings*
Kwan, Alvin; Chu, Samuel; Hong, Athena W.L; Tam, Frankie; Lee, Grace M.Y; Mellecker, Robin (2015)	Making Smart Choices: A Serious Game for Sex Education for Young Adolescents	Case study (mixed methods)	Sex education	1,123 students aged between 12-16 years	*Making Smart Choices*	Findings suggest that iPads can improve students' sex knowledge and motivation to learn in this area.
Li, Yulong; Wang, Lixun (2018)	Using iPad-Based Mobile Learning to Teach Creative Engineering within a Problem-Based Learning Pedagogy	Case study (observations and interviews)	Engineering	A class of students in secondary school	Multiple applications	Participants reported that iPads supported student learning and problem solving in creative engineering.

McKeown, Debra; Kimball, Kathleen; Ledford, Jennifer R (2015)	Effects of Asynchronous Audio Feedback on the Story Revision Practices of Students with Emotional/Behavioral Disorders	Case study (mixed methods)	English	Six students with emotional/behavioural disorders in grade 6	Notability	After the intervention with the iPad application Notability, participants were more likely to revise, resulting in increased story length and quality.
Monem, Ruba; Bennett, Kyle D; Barbetta, Patricia M (2018)	The Effects of Low-Tech and High-Tech Active Student Responding Strategies during History Instruction for Students with SLD	Case study	History	Seven students with learning disabilities aged between 13-15 years	Quizlet	Participants' answers to history questions were slightly more correct after the iPad intervention in comparison to other notebook strategy intervention.

Authors (date)	*Title*	*Research methods*	*Subject area*	*Sampling*	*Apps*	*Relevant findings*
Najmuldeen, Hanan A (2017)	The Impact of Educational Games-Based iPad Applications on the Development of Social Studies Achievement and Learning Retention among Sixth Grade Students in Jeddah	Experiment	Social studies	48 students in grade 6	Multiple applications	Participants using the iPads achieved higher academic results in social studies in comparison to the control group.
Ockert, David M (2014)	The Influence of Technology in the Classroom: An Analysis of an iPad and Video Intervention on JHS	Survey	Foreign language learning	120 students in junior high school	iPad record feature	The results indicate that video recording and self-viewing in the classroom with an iPad may promote confidence and willingness to communicate in a foreign

	Students' Confidence, Anxiety, and FL WTC					language, and lower anxiety.
Ok, Min Wook; Bryant, Diane Pedrotty (2016)	Effects of a strategic intervention with iPad practice on the multiplication fact performance of fifth-grade students with learning disabilities	Case study	Mathematics	Four students with learning disabilities in grade 5	Math Evolve	Participants' multiplication fact performance improved after iPad intervention.

Authors (date)	*Title*	*Research methods*	*Subject area*	*Sampling*	*Apps*	*Relevant findings*
Patterson, Lynn Gannon; Young, Ashlee Futrell (2013)	The Power of Math Dictionaries in the Classroom	Survey and interview	Mathematics	A class of elementary school students; ages not specified	Math Dictionary app	Students believe the app intervention helped them learn mathematics.
Perry, David R; Steck, Andy K (2015)	Increasing Student Engagement, Self-Efficacy, and Meta-Cognitive Self-Regulation in the High School Geometry Classroom: Do iPads Help?	Experiment	Mathematics	110 students in secondary school, and two teachers	Multiple applications	Findings show that participants in the iPad intervention group had lower levels of geometry proficiency scores, higher levels of off-task behaviors, and similar levels of self-efficacy and meta-cognitive self-regulation in comparison to the control group.

Pifarré, Manoli (2019)	Using interactive technologies to promote a dialogic space for creating collaboratively: A study in secondary education	Case study (observations and interviews)	General	25 students aged between 12-13 years, and three teachers	NA	The findings suggest that interactive technologies can promote collaboration and creativity in students.
Prince, Johanna (2017)	English Language Learners in a Digital Classroom	Case study (observations and interviews)	English as a foreign language	Eight students in grade 4	Inspiration Pages Notability	Students believe that iPads can support language skills in English language learner students.

Authors (date)	*Title*	*Research methods*	*Subject area*	*Sampling*	*Apps*	*Relevant findings*
Regan, Kelley; Evmenova, Anya S; Good, Kevin; Legget, Alicia; Ahn, Soo Y; Gafurov, Boris; Mastropieri, Margo (2018)	Persuasive Writing with Mobile-Based Graphic Organizers in Inclusive Classrooms across the Curriculum	Experiment	English (writing)	94 middle school students, and six teachers	Mobile-based graphic organizer	Participants in the experimental with and without disabilities significantly outperformed the control group on all measures related to writing skills.
Rivera, Christopher J; Hudson, Melissa E; Weiss, Stacy L; Zambone, Alana (2017)	Using a multicomponent multimedia shared story intervention with an iPad to teach content picture vocabulary to students with developmental disabilities	Case study	English	Three elementary-aged students with intellectual disabilities	iBooks Author	Findings suggest that iPads can improve the digital skills of students with developmental disabilities, but performance varied in vocabulary skills

Saarinen, Auli; Seitamaa-Hakkarainen, Pirita; Hakkarainen, Kai (2016)	The Functions and Benefits of the ePortfolio in Craft Education at the Primary Level	Case study (observations and interviews)	Craft education	38 students in grades 3-5	Book Creator (ePortfolio)	The use of ePortfolios on iPads can improve students' memory of learning and strengthen their understanding.

Authors (date)	*Title*	*Research methods*	*Subject area*	*Sampling*	*Apps*	*Relevant findings*
Sankardas, Sulata Ajit; Rajanahally, Jayashree (2017)	iPad: efficacy of electronic devices to help children with autism spectrum disorder to communicate in the classroom	Case study	General (communication)	20 students with autism aged between 4-10 years	AVAZ	Participants showed increased motivation to learning and improved communication.
Santori, Diane; Smith, Carol A (2018)	Teaching and Learning with iPads to Support Dialogic Construction of Multiliteracies	Case study (observations and interviews)	General (multiliteracy)	Six classes of middle grade students and their teachers; ages not specified	Multiple applications	Teachers and students believe that iPads motivate student learning and develop multiliteracies.
Smith, Carol A; Santori, Diane (2015)	An Exploration of iPad-Based Teaching and Learning: How Middle-Grades Teachers and	Case study (observations and interviews)	Science Social studies Mathematics	Six classes of middle grade students and their teachers; ages not specified.	Multiple applications	Participants reported that iPads made learning engaging, collaborative, and interactive, and

	Students Are Realizing the Potential		Language arts			facilitated visualization of content and concepts.
Vogelgesang, Kari L; Bruhn, Allison L; Coghill-Behrends, William L; Kern, Amanda M; Troughton, Leonard C. W (2016)	A Single-Subject Study of a Technology-Based Self-Monitoring Intervention	Case study (mixed methods)	General	Three students with or at risk of ADHD in grade 5, and one teacher	SCORE IT	The findings suggest that the use of SCORE IT was well perceived and effective in improving student academic engagement.

Authors (date)	*Title*	*Research methods*	*Subject area*	*Sampling*	*Apps*	*Relevant findings*
Ward, Nicholas D; Finley, Rachel J; Keil, Richard G; Clay, Tansy G (2013)	Benefits and Limitations of iPads in the High School Science Classroom and a Trophic Cascade Lesson Plan	Case study (mixed methods)	Science Technology Engineering Mathematics	Three classes of student in grades 9-12; 30 students per class.	Food Chain-The Game	The results of this study indicate that student engagement and concept building is enhanced by iPad intervention.

Appendix 2 Reasons for the exclusion of studies include the following identified research protocols:

- **iPad use for assessing students** (Jorgensen & Larkin, 2017; Larkin & Jorgensen, 2016; Soto & Ambrose, 2016)
- **Ease of teaching with iPads** (Attard & Northcote, 2012; Beal & Rosenblum, 2015; Bucci, 2018; Dagenais, Toohey, Bennett Fox, & Singh, 2017; Dunn & Sweeney, 2018; Evans, Nino, Deater-deckard, & Chang, 2015; Henderson-Rosser & Sauers, 2017; Hughes, Ko, & Boklage, 2017; Hutchison & Beschorner, 2015; Hutchison, Beschorner, & Schmidt-Crawford, 2012; Liu, et al., 2016; Milman, Carlson-Bancroft, & Boogart, 2014; Polly, 2016; Saudelli & Ciampa, 2016; Young, 2016)
- **iPad use for teachers' professional development** (Barbour, Grzebyk, Grant, & Siko, 2017; Beauchamp, Burden, & Abbinett, 2015; Fenton, 2017; Liu, Ko, Willmann, & Fickert, 2018; Tilton & Hartnett, 2016; Vaughan & Beers, 2017)
- **How to support use in classroom** (MacKinnon, et al., 2016; Marty, et al., 2013; Murray & Olcese, 2011; Picard, Martin, & Tsao, 2014; Riley, 2016; Sakow & Karaman, 2015; Walsh & Farren, 2018; Williams, 2014; Wood & Jocius, 2014)
- **Participants outside age range** (Birch, 2013; Burton & Pearsall, 2016; Chmiliar, 2017; Clarke & Abbott, 2016; Crowley, McLaughlin, & Kahn, 2013; Dacewicz, Szymaszek, Nowak, & Szelag, 2018; D'Agostino, Rodgers, Harmey, & Brownfield, 2016; Falloon, 2014; Hawes, Moss, Caswell, & Poliszczuk, 2015; Ho, Lee, Wood, Kassies, & Heinbuck, 2018; Hung, et al., 2015; Jenson, de Castell, Muehrer, & McLaughlin-Jenkins, 2016; Jones, et al., 2018; Kervin & Mantei, 2016; Kirsch, 2018; Larabee, Burns, & McComas, 2014; Lee & Tu, 2016; Li, et al., 2015; Lorah & Parnell, 2017; Lu, Ottenbreit-Leftwich, Ding, & Glazewski, 2017; Lynch & Redpath, 2014; McKenzie, Spence, & Nicholas, 2018; Miller & Martin, 2016; Neely, Rispoli,

Camargo, Davis, & Boles, 2013; Papadakis, Kalogiannakis, & Zaranis, 2018; Peters & Scott, 2017; Radley, Dart, & O'Handley, 2016; Redcay & Preston, 2016; Reeves, Gunter, & Lacey, 2017; Shanley, Strand Cary, Clarke, Guerreiro, & Thier, 2017; Siddiqui, et al., 2016; Siok & Liu, 2018; Sterkin, et al., 2018; Stone-MacDonald, 2015; Sulaymani & Fleer, 2019; Sulaymani, Fleer, & Chapman, 2018; Tailor, et al., 2015; Therrien & Light, 2016; Turkestani, 2015; Wells, Sulak, Saxon, & Howell, 2016; Whitehouse, et al., 2017; Woloshyn, Bajovic, & Worden, 2017; Xie, et al., 2018; Yun, Choi, Park, Bong, & Yoo, 2017)

- **iPad use for other school staff** (Cunningham & Caldwell, 2012; Dogan & Almus, 2014; Ensor, 2012; Kucirkova, Messer, Sheehy, & Fernández Panadero, 2014; Thompson, 2013)
- **iPads to support student inclusion** (Kucirkova 2019; Maich & Hall, 2016)
- **Other reasons/effects/uses** (Bossi, et al., 2017; Brown-Johnson, 2015; Bruggers, et al., 2018; Fulton, Collins, Poeltler, & Pearson, 2018; Guo, et al., 2016; Hamm, et al., 2017; Hirsh-Pasek, et al., 2015; Kalb, et al., 2018; Kraus & Culican, 2018; Kwon, Wiecek, Dakin, & Bex, 2015; Light & McNaughton, 2013; Marsh, Ni Mhurchu, Jiang, & Maddison, 2015; Ninci, Rispoli, Burke, & Neely, 2018; Nussbaum, et al., 2019; Palmer, 2013; Roska & Sahel, 2018; Roy, Benedict, Drake, & Weinstock-Guttman, 2016; Sahin, Keshav, Salisbury, & Vahabzadeh, 2018; Saulsburry, Kilpatrick, Wolbers, & Dostal, 2015; Sinelnikov, 2012; Siu & Murphy, 2018; Sng, Carter, & Stephenson, 2017; Sumowski, et al., 2018; Sun & Jiang, 2015; Zein, et al., 2016)

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