Meta-Analysis Examining the Effects of Electronic Storybooks On Language and Literacy Outcomes for Children in Grades Pre-K to Grade 2

Marilena Savva (Durham University)

Steven E. Higgins (Durham University)

Nadin Beckmann (Durham University)

Corresponding author:

Marilena Savva

School of Education

Durham University

Leazes Road

Durham, DH1 TA, UK

marilena.savva@durham.ac.uk

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Abstract

Background

The array of availability of diverse digital reading applications, the mixed results emerging from small-scale experimental studies, as well as the long-standing tradition and range of known positive developmental outcomes gained from adult-child storybook reading warrant an investigation into electronic storybooks (e-books) by performing a meta-analysis, which includes recent studies.

Objectives

The overall purpose of this meta-analysis, is to examine the impact of e-book reading on language and literacy development of young children when compared to traditional reading of print books with or without adult scaffolding in a structured and controlled environment.

Methods

This meta-analysis includes experimental studies published between 2008 and 2021 with a target population of 3–8 year-olds (n = 2.317).

Results and Conclusions

Analyses indicated a small positive effect for e-books when compared to print books on language and literacy development (g = 0.25; 95% CI = [0.09, 0.42]). A moderate positive effect was found for vocabulary learning, (g = 0.40; 95% CI = [0.10, 0.69]), especially in relation to expressive vocabulary (g = 0.54; 95% CI = [0.08, 1.00]). In addition, we found a significant positive correlation between multimedia e-books and the development of code-related skills. However, no significant differences were found between e-book and print book reading in relation to story comprehension.

Implications

Findings showed that digital features combined with adult scaffolding produced significant positive effects when compared to traditional print book reading with adult support. The findings have practical ramifications, since they can help researchers and educators identify which digital features have the greatest influence on improving children's language and literacy skills when engaging with e-books.

Keywords: e-books, multimedia e-books, interactive e-books, adult scaffolding, young children, meta-analysis.

The sale of e-books is a growing trend and its market share is steadily increasing (Korat & Falk, 2019). E-books can be instantly purchased online and they are available via apps, tablet or e-reader devices, and current digital sales are increasing across the board. In the present study, e-books are defined as a digital form of a print book and a number of terms are being used to refer to e-books, such as electronic storybooks, digital books, storybook apps, digital storybooks, e-readers. According to a report by the Association of American Publishers (AAP, 2021) e-book sales increased by 15.2%, in the first eleven months of 2020, generating $1.0 billion USD. Harper Collins has reported that in the first quarter of 2020, e-book sales were up 26% compared to the prior year (Kozlowski, 2020). The big genre sales within the digital division were children and general fiction e-books (Kozlowski, 2021). There are various formats available for the purchaser and consequently, the ease of access has paved the way for the application of e-books within the early years' curriculum.

Since the advent of tablet computers in 2010, young children tend to spend more and more of their time on on-screen activities (e.g., playing online games, watching online videos). During the COVID-19 pandemic, screen time has increased dramatically for everyone - including children, many of whom are receiving school instruction remotely (Hassinger-Das et al., 2020). Ofcom (2020) in the United Kingdom reported that 24% of 3-4 year old children have their own tablet and 42% of 5-7 years old own their own tablet or smartphone device. According to a US survey by Common Sense Media (Rideout & Robb, 2020) children among the ages of 0 to 8 years, spend an average of four minutes per day on e-book reading compared to nearly two minutes a day on watching television and videos. Ofcom (2020) reported similar findings with children aged 5–15 years increasingly likely to watch online videos, films and TV programming on mobile devices (43% of total media use). This fact only increases concerns many researchers have expressed previously over the effects of digital media on children's learning and development. The driving force behind these concerns is that young children today have their own digital devices and are more likely to be using them on a daily basis, which may potentially result in the replacement of printed storybooks by digital versions. Thus, e-books are a ubiquitous part of our society and may have a direct and immediate effect on the rate of young children's language development and literacy acquisition.

The first and utmost goal of this meta-analysis is to examine current e-book studies and evaluate the efficiency of e-books in facilitating language and literacy development in young children. Thus, the first question raised in this study is whether e-books offer any educational advantages when compared to print books and hence should be used to develop

young children's language and literacy skills. More specifically, the question is whether e-books can replace the benefits of an adult reading a story to young children for language (e.g., story comprehension, story recall, vocabulary learning) and literacy development (e.g., alphabet knowledge, phonological awareness, print awareness, word reading and writing). Their ability shall be assessed in terms of increasing a child's language and literacy skills without the support of an adult.

1.1 Storybook Reading

Storybook reading is well-established in the literature, and it is regarded as a leading avenue for building early academic skills (Bus et al., 1995; Bus et al., 2000; Dickinson & Tabors, 2001; Gonzalez et al., 2014; Whitehurst & Lonigan, 2003). The range of positive developmental outcomes gained from early exposure to books persist beyond early childhood and continue into adolescence and young adulthood (Mol & Bus, 2011; Rose et al., 2018). Early childhood education can provide children with opportunities to develop essential foundation skills in language and literacy that directly translate into later school success (Burchinal et al., 2002; McCardle et al., 2001). Storybook reading is a popular practice in preschool classrooms, and it can offer the reader/listener a number of educational benefits (Bus et al., 1995; Gonzalez et al., 2014). Early education provides children with opportunities to strengthen their communication and language skills, including the development of grammar, phonology, vocabulary, and pragmatics. Storybook reading activates the development of emergent literacy skills (Bus & Van IJzendoorn, 1988; Inoue et al., 2018), such as concepts of print (e.g., Nevo & Vaknin-Nusbaum, 2018; Justice & Ezell, 2000, 2004), phonological awareness (Chow et al., 2008; Lefebvre et al., 2011), and alphabet knowledge (Aram, 2006). These concepts can be targeted through high-quality adult-child book reading interactions (Justice & Ezell, 2002), which can support a range of early language skills, such as expressive and receptive vocabulary (e.g., Farrant & Zubrick, 2012; Flack et al., 2018; Lenhart et al., 2020), and decontextualized language (Beck & McKeown, 2001; Seven et al., 2020), which incorporates novel vocabulary (Marulis & Neuman, 2010; Montag et al., 2015).

Interactive (or dialogic) reading, for example, entails using a series of strategies to facilitate an interaction or dialogue between an adult and a child about the story at hand (Noble et al., 2019; Whitehurst et al., 1988). This common activity promotes conversation (Hoffman & Paciga, 2014) and appears to be a particularly rich source of verbal interaction between the adult and the child (e.g., Gilkerson et al., 2017; Mol et al., 2008; Whitehurst et al., 1988). Research has shown that during adult-child storybook reading, teachers are more

likely to engage children in discussions relating to the instruction of new vocabulary (Dickinson et al., 2014), and this is supported by sociocultural theory (Vygotsky, 1978). A recent study by Clemens and Kegel (2021) found that book reading is an effective language enhancing activity for children as young as 9 months old and that this activity elicits more language use than any other common language related parent-infant activity. The content of the storybooks appears to offer a valuable resource for parents, educators, and young children, stimulating rich language from both adults and children (Sosa, 2016). Furthermore, storybook reading allows adults to personalize story material by linking the text to the children's prior experience, enabling them to elicit conversations revolved around their own personal experiences, which improves story comprehension (Hoffman & Paciga, 2014), language exposure and the development of narrative and conversation skills (e.g., Grolig et al., 2019; Morrow, 1988).

Research results on storybook reading with children from low socioeconomic status (SES) families were found to be equally beneficial as results found in medium and high SES families (Shahaeian et al., 2018; Wasik & Bond, 2001). Low SES children enter the early years' classroom demonstrating a gap in their oral language production and weaker print and phonological awareness skills as compared to their middle-class peers (Dickinson & Snow, 1987; Justice & Ezell, 2002). For example, Lefebvre et al. (2011) studied low-income preschoolers' language and literacy development while undergoing a storybook-reading intervention programme. According to the findings, the experimental group outperformed the control group in phonological awareness. The results of the analysis were also compared with a group of higher-income preschoolers who did not receive the intervention. Children from low-income families outperformed their higher-income counterparts on phonological awareness, vocabulary and print awareness scores. Neuman and Kaefer (2018) worked in a year-long storybook intervention with low-income children on their oral language vocabulary and content knowledge. Results of their analysis showed that the young children learned significantly more words than the control group. These results indicate that storybook interventions have the potential to develop young children's language and literacy development regardless of their background.

1.2 Scaffolding and literacy development

Scaffolding involves education oriented support, discussions and interactions between a teacher and a learner. It is closely connected to Vygotsky's social constructivist view of learning and his concept of Zone of Proximal Development (ZPD, Vygotsky, 1978) as well as the constructivist learning theories of Bruner (1966), Dewey (1923), and Piaget (1973).

Constructivism's central idea is that learning is constructed and learners develop new knowledge by building on existing knowledge and experiences. According to Vygotsky (1978) learning takes place within the ZPD, that is, an area in which cognitive development is still in progress. The ZPD refers to the gap between what students can do by themselves and what they need assistance with in order to complete a learning task successfully. Students experience success in the ZPD when they receive instructional scaffolding, one of the most suggested, diverse, and powerful constructivist teaching strategies (Clack & Graves, 2005). Using Vygotsky's theory, the teacher can guide their students through instructional scaffolding by adjusting the support offered during a teaching session to fit the child's current level of performance (Verenikina, 2008). A constructivist approach promotes a learning environment in which teachers and students collaborate and share their knowledge (Nicaise & Barnes, 1996). During shared book-reading, which is a student-centered activity, both the child and adult are active participants in the construction of a dialogue surrounding the storybook (Whitehurst et al., 1988). Research greatly supports adult guidance while reading/listening to a storybook and the importance of adult scaffolding during storytelling to develop young children's literacy skills (Homer et al., 2014; Korat et al., 2011; Moody et al., 2010; Rvachew et al., 2017).

Scholars support adult scaffolding during e-book reading as research has demonstrated that young children learned more language from an e-book supported by adult scaffolding than from one read without scaffolding (Segal-Drori et al., 2010; Strouse et al., 2013). However, traditional adult storytelling scaffolding has inevitably changed over the last ten years due to the inclusion of e-books. Young children today are increasingly reading e-books without adult mediation. For instance, 80% of parents say their child aged 5 to 11 interact with a tablet computer or smartphone independently (Auxier et al., 2020). E-books include various digital features that may resemble the adult-child scaffolding process, making e-books a possible learning resource for young children (Moody, 2010). Thus, our focus has shifted to analysing the impact of these features on children's learning.

The constructivist approach to learning best supports this major change as children construct their knowledge through participation in the learning process of one's own initiative while reading/listening to e-books (Lasley et al., 2017). Children are able to actively engage and build new knowledge as they combine previous knowledge, experiences, skills and the use of digital features to comprehend the story's content and learn new vocabulary. For example, when engaging with an e-book the computer may narrate and highlight the text to support vocabulary and print awareness; it may provide animation to support comprehension

and use vibrant illustrations to engage the young reader both visually and audibly (Kayaoglu and Akbas, 2011). Rvachew et al. (2017) compared shared reading interactions with e-books versus paper books, with an adult reader for the development of emergent literacy skills. Their study examined twenty-eight children from kindergarten participating in an interactive reading style offered by an adult reader versus an animated e-book linking words from the text with animated illustrations. Written text combined with synchronized dynamic graphics and sounds may enhance story content and aid children's mental imaging of the story (Bus et al., 2015; Korat, 2010). E-books can facilitate information processing, support learning and offer children essential experiences which lead to constructive learning (Altun, 2018) and, by extension, children are able to scaffold their own learning (Bruner, 1966). A second goal of this meta-analysis is to evaluate the presence of scaffolding support in either the print condition, the e-book condition, or both conditions and its effects on language and literacy development, and whether outcome measures are better developed with the support of digital features in e-books in comparison to print book reading with and without adult support.

1.3 What is an e-book?

Storybooks delivered via digital devices have been referred to by a variety of terms (e.g., electronic storybooks, digital books, storybook apps, digital storybooks, e-readers; Reich et al., 2016). In the present study, the term *e-book* will be used when referring to the abovementioned terms. E-books are defined as a digital form of a book with features comparable to those of a traditional print book, such as “turning” pages, and digital features that can assist the reader, such as audio narration, word pronunciations, text highlighting, text-to speech options and gamification (Dore et al., 2018; Takacs et al., 2015; Yin & Hwang, 2018). E-books can incorporate a variety of digital features with little uniformity across currently available software (Korat & Falk, 2019; Papadakis et al., 2018). Innovative technological hypermedia, such as multimedia (e.g., animation, music and sound effects) and interactive features (e.g., games, hotspots, dictionary function) add complexity to the reading experience as e-books contain a variety of elements and functions that traditional reading on printed pages do not (Chen et al., 2020; Zhang et al., 2020). Thus, there is a need to research and evaluate the effectiveness of this educational medium, as it seems that the use of the e-book will continue to expand and make its way into the early year’s classroom.

Young children today can listen to storybooks not only when an adult reads to them from a printed version, but they can also “read” by themselves using e-books appearing on a computer, a tablet, a smartphone or some other electronic device (Korat & Falk, 2019). As a result of the growing awareness and concern of parents and teachers for the educational

quality of e-books, researchers in several countries have studied this issue (e.g., in The Netherlands: De Jong & Bus, 2003; Smeets & Bus, 2015; in the US: Ingram, 2020; Roskos et al., 2009; Schugar et al., 2013; in the UK: Karemaker et al., 2010; Kucirkova & Flewitt, 2020; Underwood & Underwood, 1998; and in Israel: Segal-Drori & Shabat, 2021; Shamir & Korat, 2015). Furthermore, e-book quality should also concern curriculum planers, e-book designers and software companies (Korat & Falk, 2019; van Daal et al., 2019). Of utmost concern is the potential mismatch between the goals of e-book developers and the developing child when creating new digital media. A third aim of this meta-analysis is to analyse experimental studies involving interventions with e-books in an effort to evaluate the specific features embedded in e-books that may simulate extraneous support (e.g., adult scaffolding) provided to children while listening/reading a story for language and literacy development.

1.4 Learning with e-books – the role of digital features

Investigating the quality of app and e-book content is a continuing concern of researchers as they argue that digital and media developers are prioritising marketing and digital sales rather than pursuing educational objectives and values (Hiniker et al., 2019). Commercial e-books available in app stores might be highly entertaining, but they may fall outside the scope of what researchers consider educational (Hirsh-Pasek et al., 2015). In order for children to learn, comprehend and develop their literacy and language skills while engaging with an e-book they have to show understanding that goes beyond words, focus on the content of the story, listen clearly to the dialogues, add their own perceptions and knowledge to foresee what will happen next, and preserve information they have already read as the story progresses (Newmann, 2020). The arguments regarding the design properties of e-books should be focused on the principles of Mayer's multimedia learning (Mayer, 2005), Paivio's dual coding theory (Paivio, 1986), and Sweller's cognitive load theory (Sweller, 1988; Sweller et al., 2011) and how words (printed or audible or both) and pictures (static or dynamic) should be presented to provide meaningful and effective learning.

Paivio's dual coding theory explains that the human mind simultaneously processes two types of information: visual information-images (nonverbal) and verbal information-logogens (Paivio, 1986; Sadoski & Paivio, 2013), both of which are represented within the content of e-books (Wong & Neuman, 2019). Mayer's (2005) cognitive theory of multimedia learning argues that multimedia narrations paired with images generate verbal and visual mental representations that are elaborated in working memory and can be combined with prior information to form new knowledge. Dual coding theory as applied in Takacs and Bus's (2016) study states that when two sources of information (such as narration and animation)

are compatible, they "can be processed simultaneously without causing cognitive overload" (Takacs & Bus, 2016, p.2). In line with Mayer's (2005) multimedia learning theory, it appears that narrative text accompanied by illustrations is beneficial to young children, just as images are beneficial when applied to insightful text. The multimodal features of e-books may facilitate simultaneous processing of verbal and nonverbal information, fostering story comprehension (Sadoski & Paivio, 2013). Reviews of apps for young children have shown that, in addition to static images, animated pictures, in particular, can be useful additions to stories (Van Daal & Sandvik, 2011; Zucker et al., 2009). Multimedia elements (e.g., extra images, animation) may be used to illustrate important events in a story or include details about the context of a word in e-books. For example, animation embedded in an e-book might better demonstrate the meaning of a verb than a static illustration.

The incorporation of engaging features (e.g., decorative illustrations) can improve student interest but may also adversely affect learning (Mayer, 2014). According to cognitive load theory (Sweller, 1988), the human cognitive system is limited and the amount of information that learners need to process affects learning new knowledge (Sweller et al., 2019). The auditory and visual channels have limited capacity in terms of working memory and too much information or unnecessary/distracting information might create a cognitive overload which interferes with learning (Sweller et al., 2011). Consequently, the limited capacity of young children's working memory and the various extraneous features embedded in e-books may lead to cognitive overload, and as a result this would interfere with children's understanding of the storyline and prevent them from absorbing important information related to the educational activity (Bus et al., 2015; Sweller, 2016). Thus, the design and the number of multimedia components in e-books are critical. In order to mitigate cognitive overload, e-book features need to be critically evaluated to determine their effect on language learning. Children can learn less when multimedia components of e-books are irrelevant to the overall educational goal as these components have the power to detract from or interfere with learning (Kelley & Kinney, 2017).

When comparing print books and e-books as a medium, multimedia and interactive features embedded in e-books might tax working memory compared to paper books or conversely paper books without any extra features might require a lot more adult input in order for new learning to pass from working memory to long-term memory. Furthermore, both formats incorporate active learning, as e-books offer various interactive features, such as hotspots and dictionaries and paper books usually go hand-in-hand with adult scaffolding. Finally, the success of any implementation of these concepts would be determined by the

cognitive load that the medium and story material place on young children with limited concentration span (Richter & Courage, 2017). The apparent inconsistencies between these viewpoints calls for further research into the disparities between how young children process e-books and print books.

In conclusion, factors found to impact children's learning from e-books and story apps have been explored in several experimental studies (e.g., Bus et al., 2020; Hassinger-Das et al., 2020; Lawrence & Choe, 2021; Neumann, 2020b). The array of studies published in the past decade offer mixed results as the e-books in question incorporate various and diverse features. To that end, the present meta-analysis investigates the embedded features within e-books, which may resemble adult scaffolding, and to what extent these digital features can promote learning when compared to traditional reading of print books.

2. Purpose

The aim of this meta-analysis is to analyse the efficacy of e-books in facilitating young children's language and literacy development when compared to more traditional presentations of stories, such as narrating a story aloud or reading a print storybook. Thus, only studies that compare e-book story presentations to more traditional presentations of the same or a similar story were included in the meta-analysis. The meta-analysis attempts to answer three research questions:

1. Do e-books foster language and literacy development compared to traditional print-like story presentations?

2. Which specific language and literacy outcomes are best developed from e-book reading with and without adult scaffolding?

3. Are interactive or multimedia features helpful in an e-book for the development of language and literacy skills?

2.1 Previous Meta-Analyses of the effects of e-books compared to print books

There are three meta-analyses currently available comparing e-books to print books. First, Zucker et al. (2009) focused on experimental studies published from January 1997 to January 2007 using e-books targeted at children aged 2 to 12 years old. Overall, seven experimental studies met their inclusion criteria. Findings explored the effectiveness of e-books in decoding and comprehension. For decoding (k = 2), an average, weighted effect of d = 0.09, (95% CI = [-0.35, 0.53]) was reported, which was statistically insignificant. For story comprehension (k = 7), a small positive significant effect of d = 0.31, (95% CI = [0.06, 0.55]) associated with e-books was found. Additional research in this area is required to determine

to what extent e-books effectively support children in language and literacy development. The small number of experimental studies available at the time, and the fact that most included studies date back more than a decade, suggests adding studies with newer types of digital e-books using current technology in a new meta-analysis is justified. Second, Takacs et al. (2014) evaluated multimedia e-books, television shows and films, in comparison to traditional print-like stories, for the years of 1980-2014, for comprehension and vocabulary development. Their analysis included 29 experimental and quasi-experimental studies. Multimedia-enhanced digital stories were found to be more beneficial than traditional print books for story comprehension (g = 0.40; 95% CI = [0.22, 0.58]) and vocabulary development (g = 0.30; 95% CI = [0.07, 0.53]). These findings are partially based on digital stories presented as animated films, children's television series, and video clips, which were not within the scope of this meta-analysis. Indeed, we excluded studies with video and television presentations given their technological differences to e-books. The current meta-analysis sought to evaluate the specific features included in e-books which may resemble adult scaffolding while reading a print book. There is more emphasis on the text itself in e-books compared to video-based story presentations as the text is foregrounded; there is no emphasis on text or interactivity in video-based stories. Finally, in a third meta-analysis Takacs et al. (2015) were interested in evaluating e-books with at-risk students. The participants consisted of a broad range of disadvantaged children with different risk factors, such as struggling readers, children with special needs, children with learning disabilities, severe language impairments and developmental delays. The present meta-analysis focuses on typically developing readers.

An important stage in any meta-analysis is the decision as to which types of studies are eligible for inclusion. A significant distinction between the above mentioned meta-analyses and the current study is the exclusion of studies which generally have a greater risk of allocation bias, i.e., non-random allocation to groups (Coolican, 2014). Risk of bias depends on how studies are carried out, including their design and their conduct (Higgins et al., 2013). Employing experimental designs with random allocation of participants into groups minimizes allocation bias and controls for differences between participants (Sullivan, 2011). When quasi-experimental studies are introduced in a meta-analysis, there is a risk for introducing allocation bias as quasi-experimental studies involve non-random assignment of participants to conditions or orders of conditions (Coolican, 2014). Thus, to avoid any design bias, the current meta-analysis included only experimental studies. The quality or rigor of the research methodology used in each study was assessed based on the quality codes proposed

by Troia (1999). The methodological strengths and limitations of each study included in the meta-analysis were identified using conventional evaluative criteria for quantitative research. The set of criteria for evaluating these studies with respect to internal and external validity are presented in Table 3.

Furthermore, findings from above mentioned research syntheses are not necessarily applicable to e-books available on the market today, as most of the primary studies included for analysis were published before 2008 and included e-books that are likely outdated today. Given the changes in technology, today's e-books are not easily comparable with the e-books available 20 years ago. For example, the study by De Jong and Bus (2004) used electronic CD-ROMs (From Het Spectrum Electronic Publishing) which are no longer available to purchase today. Due to the fact that CD-ROMs were not as technologically evolved as e-books are today, it is important to continue the analysis of e-books which are being used by young children today. Modern e-books include various features, such as dictionaries, hotspots, puzzles and questions, which need to be examined in comparison to traditional reading of print books.

3. Method

3.1 Inclusion and exclusion criteria

Several inclusion criteria were defined for systematically collecting and reviewing primary studies (Table 1). First, studies with experimental designs were included in the meta-analysis because experimental designs provide causal evidence of the effects of using e-books with children, and because there are fewer threats to validity in experimental compared to quasi-experimental designs (Shadish et al., 2002). For a study to be included its experimental design had to include a comparison condition in which the same or a similar story was presented using a print book. The comparison condition could also include presentations of static-illustrations with audio narration on an e-book.

Second, we also limited our search to studies that used e-books with children between the ages of 3 and 8 years, in a peer-reviewed journal or unpublished dissertation - conducted in any country, published in English, from January 2008 to January 2021. Given the rapid pace at which technology changes, we were interested in studies within the last decade as older technologies are likely obsolete.

Third, we included studies that evaluated the e-books' efficacy in facilitating language and literacy development. The studies included at least one outcome measure, such as the child's language and/or literacy skills including story comprehension and vocabulary, and

code related literacy skills, such as phonological awareness, letter knowledge, concepts of print, spelling, word reading, or general reading skills.

Fourth, the meta-analysis included studies with regular developing children and children from low/medium and high socioeconomic status (SES) families (e.g., Korat et al., 2014b). These children might have smaller vocabularies (Takacs et al., 2015) but in any given mainstream classroom, teachers are more likely to encounter children from various backgrounds as well as low/medium socioeconomic status. The current meta-analysis was undertaken with the aim to give insight to educators and school administrators into the use of e-books in a class environment, where teachers read a story to the children with language and literacy objectives. Thus, e-book efficiency is being evaluated with high/medium and low socioeconomic status families.

Hence, the following criteria were used to define the set of studies to be *excluded* from the meta-analysis:

1. Non-experimental studies (e.g., Kendeou et al., 2008) and quasi-experimental studies (e.g., Altun, 2018; Phadung et al., 2016).
2. Studies investigating children at risk for learning difficulties (e.g., Shamir et al., 2012), children with learning problems, such as struggling readers and/or special needs (e.g., Shamir et al., 2011), children with developmental delays or children with severe learning impairments (Smeets et al., 2014).
3. Studies undertaken in a home environment (e.g., Chiong et al., 2012; Korat & Shneor, 2019; Noel, 2013). These studies were excluded, because parents play a unique role in a child's life compared to teachers, and hence findings cannot easily be generalized to adult-facilitated learning in school.
4. Studies with a control group that followed the regular school program rather than reading or listening to a print book. These studies were not included (e.g., Korat, 2010; Korat & Blau, 2010; Korat et al., 2017) to ensure a clearly defined counterfactual condition.
5. Studies with films, video, and television shows were excluded (e.g., Neuman et al., 2020; Verhallen & Bus, 2009; 2010).

3.2 Literature search

We identified potential studies using electronic database searches, hand searches of key journals, and by searching the reference sections of identified studies. First, we searched for all articles involving e-books in the three major databases in the education and psychology fields: PsycINFO, ERIC, and Web of Science available from January 2008 to

January 2021. The search strategy included these key words and the Boolean operator "AND" for these combinations of words: *e-books* AND *literacy, e-books* AND *language, electronic book, computer, tablet, e-storybook, digital book, multimedia book, media book, interactive book, interactive storybook, e-literature, talking book, living book, living storybook, emergent literacy, reading, vocabulary, word learning, story comprehension, story retelling, phonics, phonological awareness, writing, comprehension, reading, spelling, adult scaffolding, adult support, dialogic reading, adult mediation, children, kindergartner, preschooler, elementary.* Next, we hand-searched the following relevant journals in order to obtain additional studies: *Journal of Computer Assisted Learning, Education and Information Technologies, Journal of Research on Technology in Education*, *Journal of Educational Psychology, Early Childhood Education Journal,* and *Reading Research Quarterly* for the dates January 2008 to January 2021. Furthermore, we searched the reference sections of review articles and the included articles that met our selection criteria. Finally, we searched for dissertations and theses reporting data that might be suitable for the present meta-analysis.

The database search produced 1235 reports, which were scanned based on the titles and the abstracts, of which 206 studies were reviewed in full and several were excluded due to study design (e.g., quasi-experimental) or sample characteristics that differed from the characteristics specified for this meta-analysis (e.g., participants' age range, atypically developing children) (Appendix A). Finally, 29 studies met the inclusion criteria. Of these, 18 articles reported on single studies, whereas eleven contained multiple treatments/experimental groups. The 29 studies that were submitted to the meta-analysis are marked with an asterisk (*) in the references section.

3.3 Study Coding

We selected the following research variables to examine more closely by assigning codes for the following aspects of each study: publication year, type of design (experimental between- subject design/within-subject design), characteristics of participants (e.g., age, ethnicity, SES, primary language), literacy outcomes measured (e.g., decoding, vocabulary or comprehension skills), software features (e.g., genre, game options embedded, hotspots, dictionary option, embedded prompts/lessons) and the length of the intervention. We also coded adult scaffolding/mediation: whether children received adult mediation while reading the paper book and/or the digital book. There were studies in which an adult guided the reading of both books; an adult guided the paper book reading but not the digital book and vice versa. All coding was completed by the first author and quality checked by the second and third authors (see Table 2 for a summary).

3.4 Methodological rigor of studies

The quality codes for establishing the methodological rigor of the studies included a selection of characteristics examined by Troia (1999) which can be found in Table 3. Twenty-one (72%) experimental studies met standards for high quality; the other eight studies (28%) were moderate in quality. All experimental studies used random assignment and dependent measures were described in enough detail.

Participant characteristics were not adequately described in half of the studies as children's ethnicity or primary language were typically not mentioned. Treatment conditions were not described in adequate detail to permit replication attempts in 23 out of 29 studies. Of course, word-count limitations in journals often dictate how much information can be provided by authors. Nonetheless, conditions need to be adequately described for replication purposes as well as enabling researchers and educators to employ innovative treatments with their students. In regard to treatment fidelity, according to Troia (1999), all research studies need to ensure that a procedure is used to ensure that treatment conditions are being implemented faithfully. As seen in Table 3, fidelity of treatment was not reported in eight studies, so it is unclear how reliably reported treatment results can be attributed to the intervention. Only five experiments reported effect sizes. The provision of effect sizes would facilitate an evaluation of the relative effectiveness of the experimental treatments used in these intervention studies.

3.5 Data Analysis

The index used to calculate effect sizes was Hedges's *g* statistic to correct for small sample size (Hedges & Olkin, 2014). Effect size is a standardized statistic that shows the direction (positive or negative) and magnitude of the intervention's effect. This effect size can be found by calculating the mean of the e-book intervention group minus the mean of the comparison group divided by the pooled standard deviation. The formula is:

$$g = \frac{y1 - y2}{sp}$$

with y1, y2, and sp denoting the mean of sample 1, the mean of sample 2, and the pooled standard deviation, respectively (Borenstein et al., 2009). To interpret this effect size (Hedges' *g* and Cohen's *d* are interpreted in the same way) Cohen recommended the following rule of thumb: a value of $d = 0.0$ represents a non-significant effect, $d = 0.20$ represents a small effect, $d = 0.50$ represents a moderate effect, and $d = 0.80$ represents a

large effect (Cohen, 1988). We report Hedges' *g* as an indicator of effect size, which is provided by the statistical software package Comprehensive Meta-Analysis (Version 3.3; Borenstein et al., 2013).

In order for all groups to be considered independent, Borenstein et al. (2009) suggests when dealing with multiple comparisons within a study to combine the data of the experimental groups and then compute the overall effect size for the control group versus the merged experimental groups. If studies included more than one treatment or more than one experimental group, the experimental groups were merged, however; they were treated as separate studies when examining outcome measures and interactive/multimedia e-books.

Moderator analyses were performed, using a random effects model, to contrast different categorical study variables: digital book features (interactive, multimedia, static, combinations); adult scaffolding (e-book condition, print book condition or both, or neither); study design (between/within study design); sample characteristics (SES, age range of participants); digital device (tablet vs computer); repetition of story reading (1 or 2 readings, more than two).

4. Results

4.1 Descriptive Statistics

We found 29 studies with 44 contrasts eligible for inclusion in this meta-analysis. Of the 29 studies, 27 appeared as journal articles, and two were published in the form of a dissertation. The majority of studies were conducted in a school setting (n = 27) and two at a university research lab. The majority of studies were conducted in English-speaking countries, USA (13), UK (1), and Canada (4). Four studies were conducted in Israel (Hebrew), three in Turkey (Turkish), two in The Netherlands (Dutch), one in Taiwan (Mandarin) and one in Jordan (Arabic). Four studies were published in 2020, two in 2019, seven studies were published in 2017, four in 2015 and another four in 2014, whilst the remaining publications were evenly spread across the other years (2021, 2018, 2016, 2013, 2011, 2010, 2009, 2008). Twenty-four studies were carried out with participants from preschool and kindergarten and five studies with first grade and second grade children. Ten studies used a standardised test to assess the learning outcomes, whereas 19 studies used new tests that were developed by the authors. Duration of the treatment varied from one to eight weeks, whereas the number of sessions varied from one to 16 with average session duration varying from 6 to 60 minutes. In total 2,317 children participated across all studies, 1,450 as experimental participants and 867 as control participants. All studies had an experimental

design (in line with the inclusion criteria). The majority of studies focused on story comprehension yielding 20 effect sizes. Eighteen studies were concerned with vocabulary learning (i.e., receptive, expressive); six studies with phonological awareness, five studies with print awareness, four studies with reading words, and another two studies were focused on spelling. The majority of studies included e-books with various digital features. Thirteen studies used e-books with multimedia features, two dealt with interactive e-books and eleven used interactive and multimedia e-books. Five studies dealt with basic 'unembellished' e-books which included oral narration.

4.2 Overall Effects

The associations between language and literacy outcomes and e-books in comparison to print books were examined. Estimates of the overall effect as well as five moderators can be found in Table 4 and 5. The available statistics were entered in the Comprehensive Meta-Analysis (Version 3.3) software (Borenstein et al., 2013) to calculate Hedges' *g* for each comparison to correct for small sample size studies. For all included comparisons, an effect size of $g = 0.25$ was found, which represents a small positive significant effect favouring the e-book condition ($k = 29$; SE = 0.08; 95% CI = [0.09, 0.42]; $p = 0.002$). This effect was heterogeneous, Q (28) = 92.88, $p = 0.00$, $I^2 = 70$ (Table 4).

4.3 Heterogeneity

The I-squared statistic (I^2) depicts the percentage of the total variability in effect estimates due to heterogeneity (between-study variability, Borenstein et al., 2009). A high percentage in the I-squared index suggests high heterogeneity. The forest plot (Appendix B) confirmed the high degree of heterogeneity. The I-squared value indicated that 70% of variation in effect size was due to heterogeneity (between-study variability) rather than chance (sampling error).

4.4 Publication Bias

Meta-analysis, like all research, has limitations which must be addressed. One of the main limitations of meta-analysis is publication bias. It should be noted that publication bias is not only a limitation to meta-analysis, but to all research in general (Borenstein et al., 2009). In a meta-analysis, a researcher searches the literature for studies dealing with the topic in question. After the meta-analysis is performed the researcher comes to conclusions dependent on the studies included in the meta-analysis. If the studies available for synthesis are not representative or exhaustive, the validity of the conclusions is threatened (Vevea & Woods, 2005). Given the potentially serious implications of publication bias, a number of

researchers have suggested statistical methods for detecting and correcting it in the context of meta-analysis.

4.4.1 Funnel Plot

For the investigation of publication and other biases in meta-analyses researchers may use funnel plots as a primary visual tool (Sterne et al., 2005). This can be done by visually inspecting the funnel plot to see if effect sizes are symmetrically distributed in a funnel shape.

Asymmetrical funnel plots may indicate publication bias. As seen in Figure 1, small scale studies appear towards the top of the plot and show a higher concentration on the left side of the mean than on the other. However, publication bias is only one of the possible reasons behind asymmetrical plots, there may be other reasons explaining funnel plot asymmetry. Poor methodological design in smaller studies may yield exaggerated estimates of intervention effects (Egger at al., 2003). Funnel plots can be useful for detecting bias, but their interpretation can be tricky, and they leave open the question of how to proceed if publication bias is suspected (Vevea & Woods, 2005). In the case of a small meta-analysis, such as the current one, Lipsey and Wilson (2001) argue that plots may be hard to interpret and caution reviewers against overanalysing funnel plots.

4.4.2 The Trim and Fill Method

The "trim and fill" method developed by Duval and Tweedie (2000), after observing an asymmetrical funnel plot, aims at both identifying publication bias and adjusting results for it (Duval, 2005). More specifically, it is used to estimate an average effect size that is corrected for publication bias (Vevea & Woods, 2005).

The number of studies missing from a biased funnel plot are estimated by reflecting on the negative side of the funnel plot, the largest effects, so studies with small size are added to the set (Vevea & Woods, 2005). A new mean effect size with the new small size studies is added in. The final estimate is interpreted as the average (weighted) effect size estimate corrected for publication bias. Duval (2005) suggests that this approach should be seen as a sensitivity analysis of the potential effect that missing studies have had on the observed result.

4.5 Effect sizes for each outcome

To answer the first and second research questions, effect sizes were inspected to evaluate the differences between e-books and traditional print book presentations in terms of children's language and literacy outcomes (Table 6, Table 7 and Figure 3).

4.5.1 Story Comprehension

We found 24 contrast in 20 articles/reports in which story comprehension was measured from a paper book in comparison to an e-book. The 20 studies assessing story comprehension were based on measures of children's retelling of the story, ten used questions, seven asked the children to retell the story and three utilized a mix of the two measures. For story comprehension, a zero effect of $g = 0.05$ was found when comparing e-books to traditional print books ($k = 20$; $SE = 0.08$; 95% CI = [-0.11, 0.21]; $p = 0.54$). This effect was heterogeneous, Q (19) = 41.62, $p = 0.002$, $I^2 = 54$.

4.5.2 Vocabulary learning

All comparisons assessing vocabulary focused on story-based word knowledge were analysed from 18 studies and 28 comparisons. Of the 18 studies interested in vocabulary development, 11 studies assessed expressive vocabulary and nine measured receptive vocabulary. For overall vocabulary learning, a positive significant effect of moderate size was found ($g = 0.40$; $k = 18$; $SE = 0.14$; 95% CI = [0.10, 0.69]; $p = 0.00$). This effect was heterogeneous, Q (17) = 135.82, $p = 0.00$, $I^2 = 87$. Specifically, a moderate positive and significant effect was found for expressive vocabulary ($g = 0.54$; $k = 11$; $SE = 0.23$; 95% CI = [0.08, 1.00]; $p = 0.02$; $I^2 = 91$), and a small positive and significant effect for receptive vocabulary ($g = 0.20$; $k = 9$; $SE = 0.09$; 95% CI = [0.01, 0.39]; $p = 0.03$; $I^2 = 45$).

4.5.3 Code-related literacy skills

Overall, of the 20 contrasts in 11 studies with code-related literacy skills as outcome measure, six studies targeted phonological awareness, five print awareness, four word reading skills, and two spelling. The overall effect for the 11 studies measuring the additional effect of technology was positive but small and non-significant ($g = 0.28$; $k = 11$; $SE = 0.16$; 95% CI = [-0.03, 0.59]; $p = 0.08$). The effect was heterogeneous, Q (10) = 41.18, $p = 0.00$; $I^2 = 75$. Results of code-related skills are presented separately below. Most effects were statistically non-significant suggesting that children in the e-book condition performed as well as children in the print condition. Specifically, six studies compared the effects of e-books to print books for *phonological awareness* with a small positive though non-significant effect ($g = 0.28$; $k = 6$; $SE = 0.19$; 95% CI = [-0.08, 0.66]; $p = 0.12$; $I^2 = 61$). Five studies including nine contrasts were under the category of *print knowledge* with a moderate positive significant effect: ($g = 0.63$; $k = 5$; $SE = 0.30$; 95% CI = [0.02, 1.23]; $p = 0.04$; $I^2 = 86$). Studies investigating the ability of children to *read words* following their intervention showed a non-significant effect ($g = 0.02$; $k = 4$; $SE = 0.28$; 95% CI = [-0.54, 0.59]; $p = 0.93$; $I^2 = 73$). Of the 29 studies, only two studies (with five contrasts) investigated *spelling* revealing a negative effect ($g = -0.02$; $k = 2$; $SE = 0.25$; 95% CI = [-0.52, 0.47]; $p = 0.93$; $I^2 = 60$).

4.6 Multimedia vs. Interactive E-books vs. 'Non-Embellished' E-books

To answer the third research question, the effects of multimedia and interactive features were compared to traditional print book reading. For a summary of the findings, see Table 8. As the effects of the different e-book features (e.g., hot-spots, dictionary, animation) on outcome measures were heterogeneous, the differences among stories including only multimedia, only interactive features, and those with both multimedia and interactive features were tested. There were 20 experimental interventions from 13 studies which investigated the effects of e-books with multimedia features (overall $g = 0.38$; $SE = 0.13$; 95% CI = [0.12, 0.63]; $p = 0.00$; $I^2 = 75$), two studies with interactive e-books ($g = 0.24$; $SE = 0.19$; 95% CI = [-0.14, 0.63]; $p = 0.21$; $I^2 = 00$), and eleven studies with 15 contrasts with e-books including both interactive and multimedia features (overall $g = 0.26$; $SE = 0.12$; 95% CI = [0.02, 0.49]; $p = 0.03$; $I^2 = 62$). Overall, the effects for e-books with multimedia features were found to be more beneficial when compared to print book reading. The other two categories were statistically non-significant as indicated by the confidence intervals. The meta-analysis also coded studies with non-embellished, basic e-books without any multimedia and interactive features ($k = 5$). For all included contrasts, an effect size of $g = -0.15$ was found, which represents a small negative but non-significant effect ($SE = 0.21$; 95% CI = [-0.56, 0.26]; $p = 0.47$; $I^2 = 59$).

4.6.1 Story comprehension

Stories including both multimedia and interactive features ($k = 7$) had a small positive but non-significant effect on story comprehension compared to print books, $g = 0.21$, (95% CI = [-0.07, 0.50]). The same non-significant effect for story comprehension was found in multimedia stories as well. Interactive stories ($k = 2$) and basic non-embellished stories ($k = 5$) yielded significant negative effects for story comprehension favouring the print condition.

4.6.2 Vocabulary learning

Multimedia-only stories for expressive and receptive vocabulary yielded a positive moderate but non-significant effect of $g = 0.46$ ($k = 9$; $SE = 0.24$; 95% CI = [-0.01, 0.94]; $p = 0.06$; $I^2 = 91$). For e-books including both multimedia and interactive features a small positive but non-significant effect of $g = 0.11$ ($k = 5$; $SE = 0.16$; 95% CI = [-0.20, 0.43]; $p = 0.47$) was observed. Specifically, for expressive vocabulary, which had the most contrasts in both groups, multimedia-only e-books yielded a moderate positive and significant effect of $g = 0.60$ ($k = 7$; 95% CI = [-0.03, 1.24]). An effectively zero effect was observed for multimedia-interactive e-books ($g = -0.01$; $k = 4$; 95% CI = [-0.32, 0.30]).

4.6.3 Code-related literacy skills

Multimedia-only stories showed an additional positive significant advantage for e-books over print books when code-related skills were concerned (specifically print knowledge $k = 3$, spelling $k = 1$, phonological awareness $k = 2$), $g = 0.63$, $SE = 0.18$, 95% CI = [0.28, 0.99], $p = .00$, $I^2 = 62$.

However, it was not possible to test the difference between interactive-only stories and multimedia-only stories, as there was only one contrast for interactive-only stories. E-book stories with both multimedia and interactive features yielded positive non-significant effects in all outcomes when compared to print books.

4.7 Animation and Hotspots

When comparing studies with only animation as an e-book feature from the list of studies with various multimedia features, ten studies evaluated the effects of animation in comparison to traditional print books. The overall effect was small in size ($g = 0.32$) and significant (95% CI = [0.01, 0.63]; $k = 11$; $SE = 0.15$; $p = 0.04$; $I^2 = 76$). In regard to vocabulary development ($k = 9$), when animation in e-books was compared to a print-like condition, a positive non-significant effect was found ($g = 0.49$; 95% CI = [-0.04, 1.03]; $SE = 0.27$; $p = 0.07$; $I^2 = 91$). Animation did not make a significant contribution to story comprehension as well, resulting in a small positive non-significant effect ($g = 0.15$; 95% CI = [-0.03, 0.35]; $k = 7$).

Only two studies evaluated hotspots in e-books without other digital features (Karemaker et al., 2017; Zipke, 2017), thus we were not able to evaluate the results of hotspots as a feature. However, we were able to evaluate ten studies which included hotspots combined with animation in their e-book condition and found an overall significant positive effect on language and literacy development ($k = 10$; $g = 0.20$; $SE = 0.10$; 95% CI = [0.00, 0.40]; $p = 0.04$; $I^2 = 45$). For separate outcome measures, the results were small and non-significant: Story comprehension ($g = 0.01$; 95% CI = [-0.15, 0.17]; $k = 7$); vocabulary development ($g = 0.49$; 95% CI = [-0.10, 1.08]; $k = 5$). For code-related skills, only four studies assessed the effects of hotspots in combination with animation ($g = 0.14$; 95% CI = [-0.39, 0.68]).

4.8 Adult scaffolding/mediation effects

We calculated the effects of adult support in either the print condition, the e-book condition or both conditions in order to find out the effects of adult scaffolding during storybook reading (Table 9). The calculated effect of adult scaffolding in any condition produced a positive non-significant effect ($g = 0.44$; $k = 9$; $SE = 0.23$; 95% CI = [-0.01, 0.89]; $p = 0.05$; $I^2 = 81$). In five out of 29 studies, e-books were assessed for language and

literacy outcomes when adult support was present in both the paper and e-book condition. In this small set of studies, we found a large positive effect favouring the e-book condition. However, the confidence interval crosses zero showing that this effect was not statistically different from zero, indicating that children in the e-book condition performed as well as children in the print book condition (g = 0.86, 95% CI = [-0.01, 1.73]). When comparing the effects of adult scaffolding in the print book condition with the independent use of e-books with various features, we found a negative effect favouring the print book condition (g = -0.07; k=4; SE = 0.16; 95% CI = [-0.40, 0.24]; p = 0.63; I^2 = 88), meaning that adult scaffolding in print books outperformed the digital features offered in e-books.

4.9 Adult Scaffolding for multimedia and interactive e-books

Due to the small number of studies, there was no way to control for adult scaffolding (multimedia e-books and adult support in both conditions k = 3, interactive e-books and adult support k = 1, interactive and multimedia e-book conditions and adult support k = 3).

5. Discussion

The aims of this meta-analysis were (1) to evaluate the effectiveness of e-books in comparison to traditional print books when they are being read by an adult either with scaffolding or handled independently; (2) to investigate whether outcome measures are better developed with the support of digital features in e-books in comparison to print book reading with and without adult support; and (3) to explore which type of digital features offer valuable and educational support to our young learners. The overall experimental data surrounding the efficiency of e-books are rather controversial, and there is no general agreement regarding their use for the development of language and literacy skills. Therefore, this meta-analysis offers the most recent data in an effort to better understand and evaluate e-books used by young children today. It has been hypothesized, that the specific features in e-books may mirror or resemble teacher/adult scaffolding when the adult is reading a traditional print book in an effort to develop young children's story comprehension, vocabulary knowledge and code-related skills. The overall impact of the 29 primary studies published between 2008 and 2021 appear modest as the results produced a small positive overall effect (g = 0.25; 95% CI = [0.09, 0.42]) favouring the e-book condition, however effect sizes vary across studies and subgroups.

The results differ when they are based on separate effects of language or literacy outcomes. It is apparent that various cognitive factors and content elements can influence how well young children learn from storybooks in any format (Nueman et al., 2021; Richter

& Courage, 2017). The variation among the procedures and outcome measures that have been reported in the literature further complicate the evaluation of effectiveness (Takacs et al., 2015). Therefore, we investigated the effect of story comprehension in e-books vs adult narration in print conditions and this result offers a unique contribution. When comparing our findings with those of the two existing meta-analyses (Takacs et al., 2014; Zucker et al., 2009), the most striking difference relates to the effect on story comprehension. Both prior meta-analyses found positive and significant effects on story comprehension, whereas this meta-analysis found a small positive but non-significant effect on story comprehension (g = 0.05; 95% CI = [-0.11, 0.21]), indicating that children in the e-book conditions performed as well as children in the print conditions. This finding is consistent with that of Liman Kaban and Karadeniz (2021) who evaluated the use of different digital reading media in 96 students. Despite the use of diverse reading media in the experimental and control groups, there was no significant difference in their reading comprehension levels.

Vocabulary development results are in line with results reported in Takacs et al.' (2014) meta-analysis as well as recent experimental studies (e.g., Korat et al., 2021a; Korat et al., 2017; Lee, 2020) supporting that digital books are more effective than print books especially for expressive vocabulary. Expressive vocabulary is one of the most difficult types of vocabulary for a child to develop. Children need to express the meaning of new words using definitions and by explaining the full meaning of a word. If an e-book is able to achieve this based on the digital features of storybooks, then this result is incredibly promising. Indeed, half of the studies with expressive vocabulary as an outcome had a medium to large positive effect size favouring the e-book condition. This might be explained by the type of features included within e-books. For example, the study by Korat et al. (2014b) produced large positive effect sizes in all four comparisons (see Table 7b) as their e-book included a dynamic and static dictionary. Regardless of digital design effects (static vs dynamic), the dictionary offered the opportunity to the students to observe unknown words in the form of an image by giving them an immediate answer to an unknown word. This example contradicts the effectiveness of audio narration of definitions and pronunciations as used in the study of Karemaker et al. (2017), which included an auditory dictionary, resulting in negative effects on expressive vocabulary (g = -0.23; 95% CI = [-0.85, 0.37]). The study by Korat et al. (2014b) is in line with Mayer's (2005) cognitive theory of multimedia learning which argues that multimedia narrations paired with images generate verbal and visual mental representations that are elaborated in working memory and can be combined with prior information to form new knowledge, such as expressive vocabulary development.

When comparing multimedia additions in e-books our findings revealed a small positive effect favouring the e-book condition, which showed that e-books are more beneficial than encounters with traditional print books with or without adult scaffolding. This effect was significant for code-related skills (g = 0.63; 95% CI = [0.28, 0.99]. However, previous experimental literature evaluating multimedia e-books in relation to the development of code-related skills (e.g., Arslan-Ari & Ari, 2021; Yow & Priyashri, 2019), supported that e-book reading may not be an activity that develops phonological awareness, print knowledge and reading words as children tent to pay more attention to the pictures rather than the text. A possible explanation for this might be that teacher mediation was evident in the studies included in this meta-analysis, indicating that teacher scaffolding with the use of multimedia e-books has a positive impact on the acquisition of code-related skills.

In regards to interactive features added to e-books, only two studies tested the difference between an interactive story and a non-interactive (print or static) story (Karemaker et al., 2017; Zipke, 2017). These studies showed no significant differences between interactive and non-interactive stories. A similar non-significant effect was also identified in e-book studies that included both interactive and multimedia features (k = 11). However, when analysing the results of e-books without any features, such as static e-books with basic oral narration, compared to children listening to print book narrations, results showed a small negative though non-significant effect (g = -0.15; 95% CI = [-0.56, 0.26]). This finding, although preliminary due to the small number of studies with 'unembellished' e-books (k = 5), might suggest that interactive and multimedia components, either separately or added together in an e-book, might serve as a scaffolding tool for young children, thus suggesting that e-books may have the potential to scaffold children's' literacy development.

When analysing the effects of digital features as scaffolding tools in comparison to print books without adult support the results reveal a small positive, non-significant effect indicating that unsupported e-books offer the same results as unsupported print book reading. However, in accordance with an earlier meta-analysis (Takacs et al., 2014), the same non-significant result was expected to be found when adult mediation was present during print book reading in comparison to independent use of e-books. This meta-analysis revealed that adult mediation during print book reading outperformed digital features when e-books were used independently. This result is based on only four studies, the positive effects of adult–child interactions during storytelling sessions cannot be replaced by digital features. In light of this finding, e-books with support were compared with print books with support, revealing that adult scaffolding combined with digital features offered in e-books facilitated children's

learning. It has been argued in past studies that adults may be less likely to scaffold children's understanding and elicit dialogic reading during e-book narrations in contrast to print book storytelling sessions (Eggleston et al., 2021; Munzer et al., 2019; Parish-Morris et al., 2013). However, the results of the current study are in agreement with Neumann (2020a) findings which showed that the teacher discussed more and read the e-book for a longer period of time than the print book. The current findings suggest that the combination of digital features and adult content-related discussions is significantly more effective in comparison to adult support offered during print book reading. This study supports evidence from recent observations (e.g., Korat et al., 2021b) which also found a considerable advantage for children who read the e-book with adult scaffolding in terms of story comprehension. Overall, the findings suggest that adult scaffolding in combination with an e-books' digital features may be important factors to consider during adult-child storybook reading.

6. Limitations

The main limitations of this study are the relatively small number of primary studies that were available and the range of outcomes that these studies included, as this means that the influence of a number of key features could not be evaluated robustly. First, the analysis was unable to test whether the quality of scaffolding affects learning and comprehension. It would be helpful to evaluate different types of scaffolding and review any differing effects. Second, discrete effects from different kinds of multimedia (such as animation, music and sound effects) as well as particular interactive features (such as games, hotspots, and the availability of a dictionary function) could not be assessed. The embedded features included in the e-books of the meta-analyzed studies did not address a particular feature in more than one or two studies, but were categorized as more broadly as multimedia and/or interactive. Third, a number of studies investigated the effects of e-books on reading words, phonological awareness or spelling, in contrast to other studies which focused on story comprehension and vocabulary learning, even though the acquisition of code-related skills are equally important acquire at this sensitive period of a child's educational development. Finally, adult scaffolding in both e-books and print books was limited. In the current study digital features in combination with adult scaffolding outperformed adult mediated print books, future studies could further explore this new finding in order to consolidate our findings. A further limitation is the relatively small samples in some studies which compounds the issues listed above. The meta-analysis may also be susceptible to publication bias, as, whilst every effort was made to identify relevant studies systematically, the scale of these studies may have

further compounded publication bias, as smaller studies would need larger effect sizes to reach a threshold for statistical significance. Finally, a number of the included studies have limitations in terms their methodological rigor or in the details of their reporting which may also have affected the findings from the overall synthesis.

7. Practical Implications

In this meta-analysis we have examined e-books and print books, the digital features of e-books as well as the support given by adults while reading a story for the promotion of language and literacy development. The findings of this study offer a number of important implications for future practice and the construction of e-books. Story comprehension is a major skill which young children need to acquire. Reading an e-book and expecting for children to understand the content and meaning of the story independently might be a little misguided. Most e-book studies in this meta-analysis involved e-books with the incorporation of hotspots. This means that while the children are listening to the story they have the opportunity to place their finger on the screen and listen to words shown on the specific page of the story. This feature could be assumed as an advantage as words are repeated and the child has the opportunity to listen to the pronunciation of the word and connect the word to the picture. However, this action might also be a source of interference while the narrator is reading the story and as a result, hotspots direct the child's attention towards the hotspots, and the child is unable to absorb important and necessary information in order to understand the content of the story. The distracting hotspots placed on the page of an e-book are considered extraneous information, which may have a negative impact on children's learning process resulting in cognitive load. The child's natural urge to press each hotspot numerous times might come from the notion that children expect interactivity because they are accustomed to game-like activities, which diverts their attention away from the storyline. There is, therefore, a definite need for digital book designers to assess the specifics incorporated in e-books and the timing of appearance of these features in order to maximize children's ability to learn.

Furthermore, our meta-analysis highlights the fact that when children are using an e-book without adult scaffolding their learning and development depends on the variety of features embedded in e-books which, more often than not, are contrasting one another. Each feature, depending on the frequency and timing included in an e-book, may harm or support children's learning. Looking closely at the studies included in this meta-analysis, the studies

that offered multiple interactive and multimedia support did not benefit children as well as the print book condition with adult support. In addition, children in the e-book conditions were responsible for their own learning whereas children that were supported in the print conditions were guided by an educated and experienced adult using instructional scaffolding to reach his/her educational goals. Teachers are extremely important in promoting children's e-book reading experiences (Christ et al., 2018; Reich et al., 2016). The teacher knows and understands the objectives of the educational activity and uses storytelling and scaffolding techniques to get the most out of every story. Most commercially available e-books do not include features that resembles external support (e.g., adult scaffolding) and as a result e-books may not be able to replace adult scaffolding. In order to reduce cognitive load designers should take into consideration Mayer's multimedia principles. Designing with the coherence principle in mind entails the exclusion of simultaneous presentation of words, sounds and animation, as text and animation together may overload the visual channel (Mayer, 2005). An implication of these findings is that both digital features and adult scaffolding should be taken into account by teachers and parents, as well as book designers. Our findings could be used to expand on existing designs of digital storybook apps for educational purposes.

8. Implications for future research

We recommend that future interventions investigate in more detail the effects of specific interactive features. The past decade has seen very few studies concerning interactivity in e-books. As technology evolves, interactive features evolve as well. In addition, future studies should include a wider spectrum of outcome variables. Most studies have focused on vocabulary development and story comprehension, thus we recommend that future studies include a wider range of outcome variables and could include network meta-analysis approaches. Indeed, outcomes, such as reading, spelling, phonological awareness, and print awareness, are equally important to children's literacy development. This meta-analysis is the first that included code-related skills in the analysis showing that code-related outcomes have the potential to be developed through e-book reading, even though the number of studies included was small (especially for spelling and reading words). It is furthermore suggested that future studies include follow-up testing, by re-administering their outcome measures, to investigate whether the effects of e-book and print book reading interventions extend beyond the period of the intervention and may have measurable long-term effects. It should be noted that none of the studies included in this meta-analysis performed a re-

administration of post tests to evaluate retention. We further recommend that future studies investigate the role of scaffolding and the type of scaffolding offered to young children during e-book reading sessions. We also recommend the investigation of separate digital effects with adult support in either the print condition, the e-book condition or both. It is important to evaluate each feature separately and to evaluate and make clear which of these features, if any, could lead to long-term benefits to learning.

9. Conclusion

In the present research synthesis, which included 29 studies and 2,317 young children, we found evidence to suggest that e-book story telling sessions are able to support language and literacy learning equally well as traditional print book storytelling sessions. For the development of children's vocabulary, e-books are more effective than print books, especially in expressive vocabulary. Small and non-significant effects were found for story comprehension. A key concern about e-books for preschoolers is that their multimedia and interactive features could be a distraction during reading and might interfere with children's learning. However, a small positive significant effect was found for multimedia e-books in contrast to e-books with minimal to no digital features. Our results confirmed that comprehension, vocabulary and code-related skills are facilitated as a result of e-book reading and were not affected negatively by e-books with both interactive and multimedia features.

The meta-analysis was also able to assess the effect of e-book reading in comparison to print book reading with and without the presence of an adult. Adult support was either in the print condition, the e-book condition or both conditions. Adult support was not instructional in the sense of providing guidance on how to use a tablet/computer or to keep a child on task. Instead, the adult asked questions regarding the story either during or after teaching, explained unknown words, discussed the content of the story based on children's own personal experiences and played games relating to comprehension of the story content, vocabulary and code related skills. The independent use of e-books showed a small positive non-significant effect in comparison to print book reading with and without the presence of an adult. The findings suggest that the specific digital features offered by the studies included in the meta-analysis are equal to adult scaffolding and appear to have the ability to scaffold children's learning. Moreover, adult support combined with e-book features outperformed all comparison conditions. The evidence from this study suggests that activities such as storybook reading accompanied with adult-child dialogic interactions offer a unique

experience and play an important role in language and literacy development - regardless of book type.

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9.2 Author Contributions

Information provided on separate document as requested.

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Table 1

Inclusion and Exclusion Criteria

Included	**Excluded**
Design	
Experimental random allocation studies	Quasi-experimental studies Qualitative or observational studies
Independent Variables	
Treatment condition: a digital presentation of a narrative story or informational text (tablet, desktop computer, personal computer or mobile phone) that: • Simulates a print book (e.g., pages that 'turn'); • Has written text on page; • Includes either some form of hypermedia (e.g., images, sounds, music, animation) or is a static e-book (only highlighted text and oral narration).	Treatment condition: Digital media such as video, television presentations, cartoons
Control condition: • Print book which has the same or similar content to treatment condition; • Static-illustrations with audio narration on an e-book.	Control condition: Following the regular school timetable
Dependent Variables	
Story comprehension Vocabulary Decoding-related skills	
Participants	
Grades Pre-K through 2 or Children ages 3- to 8-years Typical developing from high/medium/low SES	Children at risk for learning difficulties
Educational context	
School environment	Home environment
Publication	
Peer-reviewed journals Unpublished dissertations (conducted in any country - printed in English) Publication dates January 2008 to January 2021	

Table 2

Study Coding

Study and Year	Design of the study	Country - Language/ Ethnicity	SES	Age (years)	E-book Intervention (Device)	Material	Interactive features	Multimedia features	Comparison condition	Adult Scaffolding /Mediation – By whom	Number of Reading sessions	Outcome measures
Altun (2021)	Experimental Matched comparison group design	Turkey- Turkish		5	E-book (n = 97) (iPad)	*Kırmızı Kanatlı Baykuş ("Red-Winged Owl") Who Stole the Moon?*	-	Some animation, background music, character movements.	Print book (n = 99)	No	One reading of each story	Story Comprehension (1 measure) Vocabulary (Receptive) (1 measure)
Broemmel et al. (2015)	Experimental Between – subjects	United States English, Spanish and Chinese African-American, Hispanic, Chinese	High/ Low	4-5	E-books plus traditional picture books (n = 10) (Computer)	*The Alphabet Song Book (2006) Icky Sticky Frog (2000) Coral Reef Hide and Seek (2005)*	-	High quality animation, rich narration, sound effects and music.	Print book (n = 14)	Yes- By researcher (E-book +Print condition)	Three readings of each book.	Story Comprehension (1 measure)
Critelli (thesis) (2011)	Experimental Between – subjects	Northern New Jersey		4–6	E-book (n = 5) (Computer)	*Bubbles* CD-ROM story by Diane Foushee	-	-	Print book (n = 5)	No	3 sessions	Phonological awareness (1 measure) Word reading (1 measure) Story Comprehension (1 measure)
Eng et al. (2020) Experiment 1	Within subject design (randomized order)	United States		3-5	Contingent E-book (n = 17) (Tablet)	*Cat's Pajamas and Zoom City*	The contingent responsivity story included animations that activated contingently on the child's vocalizations.		Board Book (n = 18)	No	One reading of each story	Story Recall (1 measure)
Eng et al. (2020) Experiment 2	Within subject design (randomized order)	United States		3-5	Contingent E-book (n = 16) (Tablet)	*Cat's Pajamas and Zoom City*	The contingent responsivity story included animations that activated contingently on the child's vocalizations.		Static E-book (n = 17) (Tablet)	No	One reading of each story	Story Recall (1 measure)

(Continued)

Table 2

Study Coding

Study and Year	Design of the study	Country - Language/ Ethnicity	SES	Age (years)	E-book Intervention (Device)	Material	Interactive features	Multimedia features	Comparison condition	Adult Mediation/Scaffolding – By whom	Number of Reading sessions	Outcome measures
Gong and Levy (2009) Comparison 1	Experimental Between – subjects	Canada		4-5	E-book with 'Bouncing Ball' (n = 24) (Laptop)	6 stories including familiar topics.	-	A small ball bounced above each word in synchrony with the reader's voice.	Static e-book (n = 24) (Laptop)	No	10 days- 6 different storybook sessions	Print Knowledge (1 measure)
Gong and Levy (2009) Comparison 2	Experimental Between – subjects	Canada		4-5	E-book with 'Violation' (n = 24) (Laptop)	6 stories including familiar topics, such as animals, families, and friendship.	-	Bouncing ball condition + addition of two unreadable items per page of each book.	Static e-book (n = 24) (Laptop)	No	10 days	Print Knowledge (1 measure)
Gong and Levy (2009) Comparison 3	Experimental Between – subjects	Canada		4-5	E-book with 'Action' (n = 24) (Laptop)	6 stories including familiar topics, such as animals, families, and friendship.	Violation condition + child clicked on the violated item using the computer mouse.		Static e-book (n = 24) (Laptop)	No	10 days	Print Knowledge (1 measure)
Homer et al. (2014) Comparison 1	Experimental Between-subjects	USA-English		5-7	Kinect with activities (n = 12) (Microsoft's Xbox)	*Children Make Terrible Pets* by Microsoft Games Studio for the Kinect	Children were required to use movements to interact with the book.	On-screen animated character.	Book reading (n = 14)	Yes-By experimenter (Print condition)	1 reading	Reading Words (1 measure) Vocabulary (Expressive) (1 measure)
Homer et al. (2014) Comparison 2	Experimental Between-subjects	USA-English		5-7	Kinect without activities (n = 13) (Microsoft's Xbox)	*Children Make Terrible Pets* by Microsoft Games Studio for the Kinect	Kinect sensor detected the participant's image and displayed a live video-feed of the child on-screen.	On-screen animated character.	Book reading (n = 14)	Yes-By experimenter (Print condition)	1 reading	Reading Words (1 measure) Vocabulary (Expressive) (1 measure)

(Continued)

Table 2

Study Coding

Study and Year	Design of the study	Country - Language /Ethnicity	SES	Age (years)	E-book Intervention (Device)	Material	Interactive features	Multimedia features	Comparison condition	Adult Mediation/ Scaffolding – By whom	Number of Reading sessions	Outcome measures
Ihmeideh (2014)	Experimental Between-subjects	Jordan Amman Arabic	Middle and Low	4-5	E-book (n = 48) (Computer)	Arabic books: *The Conceited Ibex, Rami, The Dreams' King, The Three Goats*	-	Animated illustrations	Print Book (n = 44)	Yes- By teacher (Both conditions)	15 min each day for eight weeks.	Vocabulary (Expressive) (1 measure) Print awareness (1 measure) Phonological awareness (1 measure)
Karemaker et al. (2017) Comparison 1	Experimental Between-subjects	Oxfordshire – England	Mix	5.6-7	E-book with E-friend button (n = 32) (Computer)	*The Parachute*	E-friend button opens up a window with story questions.	-	'Flat e-book' (n = 30) (Computer)	No	1 reading session	Vocabulary (Expressive) (1 measure) Word Reading (1 measure) Story Comprehension (2 measures)
Karemaker et al. (2017) Comparison 2	Experimental Between-subjects	Oxfordshire – England	Diverse SES	5.6-7	E-book with Dictionary (n = 28) (Computer)	*The Parachute*	Dictionary button highlighted challenging words. By clicking on a word children could listen to pronunciation and definition.	-	'Flat e-book' (n = 30) (Computer)	No	1 reading session	Vocabulary (Expressive) (1 measure) Word Reading (1 measure) Story Comprehension (2 measures)
Kelley and Kinney (2017)	Experimental Between-subjects	US	Diverse SES	3-5	Interactive e-book (Learn) (n = 15) (Tablet)	*Hansel and Gretel* by Mindshapes Ltd	Six embedded questions related to the story and children can tap pictures to respond to the questions.	Animated characters.	E-book without interactive features (Watch) (n = 15) (Tablet)	No	Three sessions	Vocabulary (Expressive) (2 measures) Vocabulary (Receptive) (1 measure) Vocabulary (1 measure) Story comprehension (1 measure)

(Continued)

Table 2

Study Coding

Study and Year	Design of the study	Country - Language /Ethnicity	SES	Age (years)	E-book Intervention (Device)	Material	Interactive features	Multimedia features	Comparison condition	Adult Mediation/ Scaffolding – By whom	Number of Reading sessions	Outcome measures
Korat, Levin, Atishkin, Turgeman (2014a) Comparison 1	Experimental Between-subjects	Israel Hebrew	Middle	4-6	E-book with dynamic visual vocabulary support (Dictionary) (n = 38) (Computer)	*The Empty Pot* (1990)	-	Animated representations of target verbs in vocabulary support.	E-book without dictionary support (n = 37) (Computer)	No	Reading 3 times	Vocabulary (Expressive) (1 measure) Vocabulary (Receptive) (1 measure) Vocabulary (1 measure)
Korat, Levin, Atishkin, Turgeman (2014a) Comparison 2	Experimental Between-subjects	Israel Hebrew	Middle	4-6	E-book with static visuals dictionary support (n = 37) (Computer)	*The Empty Pot* (1990)	-	At the end of the narrators' reading of the screen, a large bubble appears with the target written form of the word and a figurative static presentation of a flower, with the narrator concomitantly saying a short explanation of the word	E-book without dictionary support (n = 37) (Computer)	No	Reading 3 times	Vocabulary (Expressive) (1 measure) Vocabulary (Receptive) (1 measure) Vocabulary (1 measure)
Korat, Levin, Atishkin, Turgeman (2014a) Comparison 3	Experimental Between-subjects	Israel Hebrew	Middle	4-6	E-book with adults vocabulary support (n = 37) (Computer)	*The Empty Pot* (1990)	-	At the end of the narrators' reading of the screen, a large bubble appears with the target written form of the word and a figurative static presentation of a flower, with the narrator concomitantly saying a short explanation of the word	E-book without dictionary support (n = 37) (Computer)	Yes-By researchers (E-book condition)	Reading 3 times	Vocabulary (Expressive) (1 measure) Vocabulary (Receptive) (1 measure) Vocabulary (1 measure)

(Continued)

Table 2

Study Coding

Study and Year	Design of the study	Country - Language /Ethnicity	SES	Age (years)	E-book Intervention (Device)	Material	Interactive features	Multimedia features	Comparison condition	Adult Mediation/ Scaffolding – By whom	Number of Reading sessions	Outcome measures
Korat, Levin, Ben-Shabt, Shneor and Bokovza (2014b) Comparison 1	Experimental Between-subjects	Israel Hebrew	Low	7-8	E-book with dictionary dynamic visuals (DVs) with the printed word (n = 41) (Computer)	*The Empty Pot* written and illustrated by Demi (1990)	-	Animated representations of target verbs in vocabulary support and printed words shown on screen.	Static E-book without a dictionary (control; n = 44) (Computer)	No	4 repetitions of e-book reading	Vocabulary (Expressive) (1 measure) Vocabulary (1 measure) Spelling (1 measure)
Korat, Levin, Ben-Shabt, Shneor and Bokovza (2014b) Comparison 2	Experimental Between-subjects	Israel Hebrew	Low	7-8	E-book with dictionary dynamic visuals (DVs) without printed words (n = 42) (Computer)	*The Empty Pot* (1990)	-	Animated representations of target words in the form of pictures.	Static E-book without a dictionary (control; n = 44) (Computer)	No	4 repetitions of e-book reading	Vocabulary (Expressive) (1 measure) Vocabulary (1 measure) Spelling (1 measure)
Korat, Levin, Ben-Shabt, Shneor and Bokovza (2014b) Comparison 3	Experimental Between-subjects	Israel Hebrew	Low	7-8	E-book with dictionary static visuals (SVs) with printed words (n = 43) (Computer)	*The Empty Pot* (1990)	-	Static representations of target verbs in vocabulary support e.g. a large bubble appears with the target written form of the word and a figurative static presentation of a flower.	Static E-book without a dictionary (control; n = 44) (Computer)	No	4 repetitions of e-book reading	Vocabulary (Expressive) (1 measure) Vocabulary (1 measure) Spelling (1 measure)
Korat, Levin, Ben-Shabt, Shneor and Bokovza (2014b) Comparison 4	Experimental Between-subjects	Israel Hebrew	Low	7-8	E-book with dictionary static visuals (SVs) without printed words (n = 45) Computer	*The Empty Pot* (1990)	-	Static representations of target verbs in vocabulary support e.g. a large bubble appears with a static presentation of a flower.	Static E-book without a dictionary (control; n = 44)	No	4 repetitions of e-book reading	Vocabulary (Expressive) (1 measure) Vocabulary (1 measure) Spelling (1 measure)

(Continued)

Table 2

Study Coding

Study and Year	Design of the study	Country - Language/ Ethnicity	SES	Age (years)	E-book Intervention (Device)	Material	Interactive features	Multimedia features	Comparison condition	Adult Scaffolding – By whom	Number of Reading sessions	Outcome measures
Kozminsky and Asher-Sadon (2013)	Experimental Between-subjects	Israel Hebrew	Mix	5-6	E-book (n = 25) (Computer)	*Pochzanim*	-	-	Print book (n = 25)	Yes- By experimenter (Print condition)	5 reading sessions	Story Comprehension (1 measure) Print Knowledge (1 measure) Vocabulary (1 measure) Phonological Awareness (1 measure) Spelling (1 measure)
Lee (2020)	Within subject design (randomized order)	US 54 Anglo, 35 African American, 1 Middle Eastern, 5 Hispanic, and 5 multiracial students	Low	6-7	E-book with recorded word explanation (n = 50) (iPad)	*Frederick and Swimmy*	-	Recorded word explanations	Static e-book (n = 50) (iPad)	No	2 readings	Vocabulary (Expressive) (1 measure)
Liao et al. (2020) Comparison 1	Experimental Between-subjects	Taiwan Mandarin Chinese		4-5	E-book highlight synchronization (implicit instruction) (n = 19) (Laptop)	*Six original Chinese storybooks*	-	Individual Chinese characters were highlighted in red when they were being pronounced, thus implicitly teaching the children which Chinese characters were associated with which sounds.	Static Read-only E-book (n = 20)	No	1 reading of each book	Print Awareness (1 measure)

(Continued)

Table 2

Study Coding

Study and Year	Design of the study	Country - Language/Ethnicity	SES	Age (years)	E-book Intervention (Device)	Material	Interactive features	Multimedia features	Comparison condition	Adult Scaffolding /Mediation – By whom	Number of Reading sessions	Outcome measures
Liao et al. (2020) Comparison 2	Experimental Between-subjects	Taiwan Mandarin Chinese		4-5	E-book print discussion (explicit instruction) (n = 20) (Laptop)	*Six original Chinese storybooks*	-	Verbal cues to or discussions of the print (references to the print) were explicitly added to the narration of the story. Also visual cues to synchronized with the verbal cues.	Static Read-only E-book (n = 20)	No	1 reading of each book	Print Awareness (1 measure)
Neuman et al. (2017)	Within subject design (randomized order)	US African American; Hispanic; 2% were of European descent	Low	3-4	E-book (n = 19) (iPad)	*Ish, Sid the Science Kid, Superkids: A sticky situation, The Valentine* all from Speakaboos	-	Animated characters	Print Book (n = 19)	No	2 sessions in each condition	Vocabulary (Expressive) (1 measure) Story Comprehension (2 measures)
O'Toole (2015) (thesis)	Experimental Between-subjects	Chicago 70 children were White; 2 Black; 4 Hispanic; 6 Asian; 14 children were biracial; and 4 parents did not respond	Middle/High	4	E-book read aloud by a live adult and narrated by an audio device (n = 50) (Tablet)	*Just in Passing* by Susan Bonners (1989)	-	-	Print book read aloud by a live adult and narrated by an audio device (n = 50)	No	1 session	Vocabulary (Receptive) (1 measure) Story Comprehension (1 measure)

(Continued)

Table 2

Study Coding

Study and Year	Design of the study	Country - Language/ Ethnicity	SES	Age (years)	E-book Intervention (Device)	Material	Interactive features	Multimedia features	Comparison condition	Adult Scaffolding /Mediation – By whom	Number of Reading sessions	Outcome measures
O'Toole and Kannass (2018) Comparison 1	Experimental Between-subjects	US 70 White, 2 Black, 4 Hispanic, 6 Asian, 14 biracial	Middle and high	4-5	Live E-book (n = 25) (Tablet)	*n/a*	-	-	Live Print Book (n = 25)	No	1 session	Vocabulary (Receptive) (1 measure) Story Comprehension (1 measure)
O'Toole and Kannass (2018) Comparison 2	Experimental Between-subjects	US 70 White, 2 Black, 4 Hispanic, 6 Asian, 14 biracial	Middle and high	4-5	Audio narrated e-book (n = 25) (Tablet)	*n/a*	-	-	Audio narrated Print book (n = 25)	No	1 session	Vocabulary (Receptive) (1 measure) Story Comprehension (1 measure)
Pearman (2008)	Within subject design (randomized order)	United States 32 white; 1 black; 21 Hispanic		7-8	E-book (n = 27) (Computer – CD-ROM)	*Heather Hits Her First Home Run* and *A Long Hard Day on the Ranch*	Hotspots for word pronunciations, graphics, sound effects, object labels, and definitions	Animation	Print book (n = 27)	No	20 days-two sessions	Story Comprehension (1 measure)
Reich et al. (2019)	Experimental design Between	USA - Southern California	Middle and high	3-5	E-book (n = 100) (iPad)	*Chris P. Bacon: My Life so Far*	6 hotspots per page, that when tapped repeated the word or provided some animation.		Print book (n = 100)	No	1 reading	Story Comprehension (3 measures) Vocabulary (Expressive) (1 measure)

(Continued)

Table 2

Study Coding

Study and Year	Design of the study	Country - Language /Ethnicity	SES	Age (years)	E-book Intervention (Device)	Material	Interactive features	Multimedia features	Comparison condition	Adult Scaffolding /Mediation – By whom	Number of Reading sessions	Outcome measures
Richter and Courage (2017)	Within subject design (randomized order)	Canada	Middle	3-5	E-book (n = 39) (iPad)	*Leo the Lightning Bug and A Frog Thing*	Hotspots to reactivate the multimedia features (e.g., thunder and lightning) or to produce word repetitions.	Multimedia features accompany the narration and provide additional visual or auditory information (e.g., sounds, animations)	Print Book (n = 40)	No	1 reading	Story Comprehension (1 measure)
Rvachew et al. (2017)	Within subject design (randomized order)	Canada (English)	Low	5-6	E-book (n = 14) (iPad)	*Caillou: What's That Funny Noise? and Caillou: My First Play*	-	Living words link animated text to animated illustrations. A prompt bar for the adult reader which suggests comments and questions.	Print Book (n = 14)	Yes-By teacher (Both conditions)	1 reading	Story Comprehension (1 measure) Phonological Awareness (1 measure)
Sapsaglam et al. (2020)	Experimental Between-subjects	Turkey		5-6	E-book (n = 10) (Computer to projector)	*Hungry Caterpillar, Brave Firfir, Tiny Seed, The Most Ordinary Tree of the Forest, The Dinosaur Came Out of My Seed*	-	-	Print book (n = 10)	No	1 reading of each story	Story Comprehension (1 measure)

(Continued)

Table 2

Study Coding

Study and Year	Design of the study	Country - Language /Ethnicity	SES	Age (years)	E-book Intervention (Device)	Material	Interactive features	Multimedia features	Comparison condition	Adult Instruction /Scaffolding – By whom	Number of Reading sessions	Outcome measures
Sari et al. (2019)	Experimental Between-subjects	Turkey Turkish	Diverse	4-6	E-book with animated illustrations with and without music/sounds (n = 41) (Laptop)	*Bear Is in Love with Butterfly, Little Kangaroo*	-	Animated characters and objects, sound effects, music	E-book with static illustrations with and without music/sounds (n = 42) (Laptop)	No	2 readings of each story	Story Comprehension (1 measure) Vocabulary (Receptive) (1 measure) Vocabulary (Expressive) (1 measure)
Segal-Drori et al. (2010) Comparison 1	Experimental Between-subjects	Israel Hebrew	Low	5-6	E-book without adult instruction (EB) (n = 32) (Computer)	*Confused Yuval and The Tractor in the Sandbox*	Hotspots	Automatic dynamic visuals that dramatize story details, sections and the complete story scene as well as extra music and film effects that may ‘‘bring the story content to life’’	Print book with adult instruction (PBI) (n = 32) (Computer)	Yes – By researchers (Print condition)	Four sessions	Phonological Awareness (1 measure) Reading Words (1 measure) Print Knowledge (1 measure)
Segal-Drori et al. (2010) Comparison 2	Experimental Between-subjects	Israel Hebrew	Low	5-6	E-book with adult instruction (EBI) (n = 32) (Computer)	*Confused Yuval and The Tractor in the Sandbox*	Hotspots	Automatic dynamic visuals that dramatize story details, sections and the complete story scene as well as extra music and film effects that may ‘‘bring the story content to life’’	Print book with adult instruction (PBI) (n = 32) (Computer)	Yes – By researchers (Both conditions)	Four sessions	Phonological Awareness (1 measure) Reading Words (1 measure) Print Knowledge (1 measure)

(Continued)

Table 2

Study Coding

Study and Year	**Design of the study**	**Country - Language /Ethnicity**	**SES**	**Age (years)**	**E-book Intervention (Device)**	**Material**	**Interactive features**	**Multimedia features**	**Comparison condition**	**Adult Instruction /Scaffolding – By whom**	**Number of Reading sessions**	**Outcome measures**
Smeets and Bus (2015) Comparison 1	Experimental Between-subjects	Netherlands 50% Dutch L1		4-6	Animated e-books (n = 36) (Computer)	*Pete on the Pavement, Bear Is in Love with Butterfly, Rokko the Crocodile, Bolder and the Boat, Cycling With Grandpa*	-	Animated characters and objects, sound effects, music	Static e-book (n=34) (Computer)	No	4 repetitions of each story	Vocabulary (Expressive) (1 measure) Vocabulary (Receptive) (1 measure) Vocabulary (1 measure) Story Comprehension (1 measure)
Smeets and Bus (2015) Comparison 2	Experimental Between-subjects	Netherlands 50% Dutch L1		4-6	Interactive animated e-books (n = 33) (Computer)	*Pete on the Pavement, Bear Is in Love with Butterfly, Rokko the Crocodile, Bolder and the Boat, Cycling With Grandpa*	Hotspots shape as a magnifying glass to search for unknown words	Animated characters and objects, sound effects, music	Static e-book (n = 34) (Computer)	No	4 repetitions of each story	Vocabulary (Expressive) (1 measure) Vocabulary (Receptive) (1 measure) Vocabulary (1 measure) Story Comprehension (1 measure)
Takacs and Bus (2016)	Within Subject design (randomized order)	Netherlands	Middle	4-6	Animated e-book (n = 20) (Computer)	*The Little Kangaroo, Imitators*	-	Animated scenes	Static e-book (n = 19) (Computer)	No	3 sessions	Vocabulary (Receptive) (1 measure) Story comprehension (1 measure)

((Continued)

Table 2

Study Coding

Study and Year	Design of the study	Country - Language/Ethnicity	SES	Age (years)	E-book Intervention (Device)	Material	Interactive features	Multimedia features	Comparison condition	Adult Instruction/ Scaffolding – By whom	Number of Reading sessions	Outcome measures
Willoughby et al. (2015)	Experimental Between-subjects	Ontario English		3-4	Alphabet e-books (n = 33) (iPad)	*A to Z Alphabet book, Letters A to Z, Interactive Alphabet, This place is a zoo, Alphabet Zoo, Z is for Zebra, ABC Magic, ABC Magic 2, ABC Funnimals, Animal ABC, Animal Alphabet*	Interactive games, audio hotspots	Animated hotspots	ABC Paper books (n = 30)	No	8 weeks – 16 sessions	Phonological Awareness (3 measures)
Zhou and Yadav (2017) Comparison 1	Experimental Between-subjects	United States All the participants speak English as the first language.		4-5	Multimedia e-book (n = 18) (iPad)	*The Polar Bear Horizon*	Hotspots to see and hear word labels when touching illustrations	Animated characters	Print book (n = 18)	No	2 reading sessions	Vocabulary (Receptive) (1 measure) Story Comprehension (1 measure)
Zhou and Yadav (2017) Comparison 2	Experimental Between-subjects	United States All the participants speak English as the first language.		4-5	Multimedia e-book with questioning (n = 18) (iPad)	*The Polar Bear Horizon*	Hotspots to see and hear word labels when touching illustrations	Animated characters	Print Book with questions (n = 18)	Yes- By researcher (Both conditions)	2 reading sessions	Vocabulary (Receptive) (1 measure) Story Comprehension (1 measure)
Zipke (2017) (Exp. 1)	Within subject design (randomized order)	New England State 15 Caucasian, 4 African American, 2 Latin American, 4 Asian American	Middle/ Low	4-5	E-book (n = 13) (Computer)	*Tacky Goes to Camp, Tacky in Trouble*	Hotspots on pictures to hear the object name	-	Print book (n = 12)	Yes By teacher (Print condition)	Two separate 30-min sessions	Story Comprehension (1 measure) Vocabulary (1 measure)

Table 3

Assessment of Methodological Quality Based on Selected Internal and External Validity Criteria from Troia (1999)

Study (alphabetically)	Random assignment (3) †	Control group intervention (3)	Sufficient participant description (3)	Treatment conditions explicitly described (2)	Operationalized measures (3)	Reliability of measures reported (2)	Treatment fidelity ensured (3)	Effect size reported (1)	Quality Rating
1. Altun (2021)	Y	Y	Y	Y	Y	Y	Y	N	High
2. Broemmel et al. (2015)	Y	Y	Y	Y	Y	N	Y	N	High
3. Critelli (2011)	Y	Y	N	Y	Y	N	N	N	Moderate
4. Eng, Tomasic & Thiessen (2020)	Y	Y	N	Y	Y	Y	Y	Y	High
5. Gong and Levy (2009)	Y	Y	N	Y	Y	Y	N	N	Moderate
6. Homer et al. (2014)	Y	Y	N	Y	Y	N	Y	N	Moderate
7. Ihmeideh (2014)	Y	Y	N	Y	Y	Y	N	N	Moderate
8. Karemaker et al. (2017)	Y	Y	N	N	Y	Y	Y	Y	High
9. Kelley & Kinney (2017)	Y	Y	N	N	Y	Y	Y	N	Moderate
10. Korat, Levin, Atishkin and Turgeman (2014)	Y	Y	Y	Y	Y	Y	N	N	High
11. Korat, Levin, Ben-Shabt, Shneor and Bokovza (2014)	Y	Y	Y	Y	Y	Y	N	N	High
12. Kozminsky & Asher-Sadon (2013)	Y	Y	N	Y	Y	Y	Y	N	High
13. Lee (2020)	Y	Y	Y	Y	Y	Y	Y	Y	High
14. Liao et al. (2020)	Y	Y	N	Y	Y	Y	Y	N	High
15. Neuman et al. (2017)	Y	Y	Y	Y	Y	Y	Y	N	High
16. O'Toole (2015)	Y	Y	Y	N	Y	Y	Y	N	High
17. O'Toole & Kannass (2018)	Y	Y	Y	N	Y	Y	Y	N	High
18. Pearman (2008)	Y	Y	Y	Y	Y	Y	Y	N	High
19. Reich et al. (2019)	Y	Y	Y	Y	Y	Y	Y	N	High
20. Richter and Courage (2017)	Y	Y	N	Y	Y	Y	Y	N	High

21. Rvachew et al. (2017)	Y	Y	Y	Y	Y	N	Y	N	High
22. Sapsaglam et al. (2020)	Y	Y	N	Y	Y	N	N	N	Moderate
23. Sarı, Basal, Takacs, Bus (2019)	Y	Y	Y	Y	Y	Y	Y	Y	High
24. Segal-Drori et al. (2010)	Y	Y	Y	Y	Y	Y	Y	N	High
25. Smeets and Bus (2015)	Y	Y	N	Y	Y	Y	N	N	Moderate
26. Takacs and Bus (2016)	Y	Y	N	N	Y	Y	Y	N	Moderate
27. Willoughby et al. (2015)	Y	Y	Y	N	Y	Y	Y	N	High
28. Zhou and Yadav (2017)	Y	Y	Y	Y	Y	Y	Y	N	High
29. Zipke (2017)	Y	Y	Y	Y	Y	Y	N	Y	High
Ratio of studies meeting criterion	29/29	29/29	16/29	23/29	29/29	24/29	21/29	5/29	
Percentage	100%	100%	55%	79%	100%	82%	72%	17%	

Note: †Each quality variable is weighted based on its importance for ensuring internal or external validity (adapted from Troia, 1999). Quality variables weighted: 3–indicate strong importance and it is considered a fatal flaw if one of these variables are missing, 2–indicate moderate importance, and 1–indicate some importance. A score was assigned of the full weight if all aspects of the variable were present in the study and a 0 if any single aspect of the variable was missing. Based on this adapted system, a sum score of 15-20 and no fatal flaws indicates High Quality, 8-14 indicates Moderate Quality, 0-7 indicates Low Quality.

Table 4

Statistics for each study

Study	Outcome(s)†	Hedges's g	Standard error	95% confidence interval	Z-Value	p-value	Study Design	Publication Status	SES	Device	Adult Support
Altun (2021)	SC, RV	-0.00	0.14	[-0.28, 0.27]	-0.02	0.980	Between	Journal	-	iPad	
Broemmel (2015)	SC	-0.53	0.40	[-1.32, 0.26]	-1.30	0.192	Between	Journal	High & Low	Computer	Both conditions
Critelli (2011)	SC, PA, RW	-0.06	0.57	[-1.19, 1.05]	-0.11	0.907	Between	Dissertation	-	Computer	
Eng (2020)	SC	1.00	0.25	[0.50, 1.50]	3.95	0.000	Within	Journal	-	Tablet	
Gong (2009)	PK	0.42	0.23	[-0.03, 0.88]	1.79	0.072	Between	Journal	-	Laptop	
Homer (2014)	RW, EV	0.08	0.32	[-0.56, 0.72]	0.24	0.804	Between	Journal	-	Microsoft's Xbox	Print condition
Ihmeideh (2014)	EV, PA, PK	1.53	0.24	[1.05, 2.02]	6.26	0.000	Between	Journal	Middle & Low	Computer	Both conditions
Karemaker (2017)	SC, EV, RW	0.20	0.22	[-0.24, 0.65]	0.90	0.367	Between	Journal	Diverse SES	Computer	
Kelley (2017)	SC, V, RV, EV	0.06	0.35	[-0.63, 0.77]	0.19	0.848	Between	Journal	Diverse SES	Tablet	
Korat (2014a)	EV, RV, V	0.58	0.19	[0.20, 0.96]	3.04	0.002	Between	Journal	Middle	Computer	E-book condition
Korat (2014b)	EV, V, S	0.43	0.17	[0.10, 0.77]	2.57	0.010	Between	Journal	Low	Computer	
Kozminsky (2013)	SC, V, PA, PK, S	-0.44	0.28	[-1.00, 0.10]	-1.58	0.113	Between	Journal	-	Computer	Print condition
Lee (2020)	EV	0.42	0.20	[0.03, 0.81]	2.11	0.034	Within	Journal	Low	iPad	
Liao (2020)	PK	1.01	0.28	[0.45, 1.58]	3.54	0.000	Between	Journal	-	Laptop	
Neuman (2017)	SC, V	-0.04	0.31	[-0.66, 0.58]	-0.12	0.900	Within	Journal	Low	iPad	
O'Toole (2015)	SC, RV	0.28	0.20	[-0.11, 0.67]	1.40	0.159	Between	Dissertation	-	Tablet	
O'Toole (2018)	SC, RV	0.07	0.19	[-0.31, 0.46]	0.35	0.723	Between	Journal	-	Tablet	
Pearman (2008)	SC	0.42	0.27	[-0.11, 0.95]	1.55	0.12	Within	Journal	-	Computer	
Reich (2019)	SC, EV	-0.18	0.14	[-0.46, 0.09]	-1.31	0.189	Between	Journal	High	iPad	
Richter (2017)	SC	0.04	0.22	[-0.39, 0.48]	0.20	0.837	Within	Journal	Middle	iPad	
Rvachew (2017)	SC, PA	0.60	0.37	[-0.13, 1.35]	1.60	0.108	Within	Journal	Low	iPad	Both conditions

Sapsaglam (2020)	SC	-1.09	0.46	[-2.01, -0.17]	-2.32	0.020	Between	Journal	-	Computer to projector	
Sari (2019)	SC, EV, RV	0.16	0.21	[-0.26, 0.59]	0.74	0.457	Between	Journal	Diverse SES	Laptop	
Segal-Drori (2010)	PA, RW, PK	0.72	0.22	[0.29, 1.16]	3.26	0.001	Between	Journal	Low	Computer	Both conditions
Smeets (2015)	SC, RV, EV, V	-0.00	0.20	[-0.41, 0.40]	-0.01	0.988	Between	Journal	-	Computer	
Takacs (2016)	SC, RV	0.21	0.31	[-0.40, 0.83]	0.67	0.498	Within	Journal	Middle	Computer	
Willoughby (2015)	PA	-0.09	0.24	[-0.58, 0.39]	-0.38	0.700	Between	Journal	-	iPad	
Zhou (2017)	SC, RV	0.36	0.23	[-0.09, 0.82]	1.55	0.121	Between	Journal	-	iPad	Both conditions
Zipke (2017)	SC, V	0.36	0.40	[-0.42, 1.16]	0.90	0.364	Within	Journal	Middle and Low	Computer	Print condition
Random		**0.25**	**0.08**	**[0.09, 0.42]**	**3.11**	**0.002**					

Note: †SC= story comprehension, V=Vocabulary, RV= receptive vocabulary, EV=expressive vocabulary, PA=phonological awareness, PK=print knowledge, RW=reading words, S=spelling.

Table 5

Overall results of the 29 studies and moderator analyses†

		Effect Size and 95% confidence interval				Test of null (2-Tail)		Heterogeneity	
	k	*g*	SE	Lower Limit	Upper Limit	Z-value	P-value	*Q*	I^2
Overall	29	0.259	0.083	0.096	0.422	3.119	0.00	92.88	70
High/Middle SES	18	0.17	0.09	-0.00	0.36	1.86	0.06	49.58	65
Low or diverse SES	11	0.39	0.14	0.11	0.68	2.72	0.00	33.61	70
Tablet/iPad studies	12	0.18	0.09	-0.00	0.37	1.90	0.05	24.43	55
Computer/Laptop	17	0.29	0.12	0.04	0.54	2.34	0.01	60.98	73
High quality rating studies	21	0.26	0.08	0.98	0.42	3.15	0.00	54.14	63
Moderate quality rating studies	8	0.20	0.25	-0.29	0.70	0.79	0.42	37.82	81
1 or 2 repetitions of story reading	18	0.24	0.08	0.06	0.41	2.74	0.00	41.66	59
More than 3 repetitions of story reading	11	0.26	0.17	-0.07	0.60	1.53	0.12	48.10	79
Studies with children aged 3-6	24	0.24	0.10	0.04	0.43	2.38	0.01	89.90	74
Studies with children over 6 years old	5	0.35	0.09	0.16	0.55	3.58	0.00	1.54	00

† Moderator analyses for digital features and adult support are described on separate tables.

Table 6

Overall results for outcome measures

Outcome Measure	Number of comparisons included†	Effect size (Hedges's g)	Standard error	95% confidence interval	*p*
Story Comprehension	20	0.05	0.08	[-0.11, 0.21]	.54
All Vocabulary	18	0.40	0.14	[0.10, 0.69]	.00
Expressive Vocabulary	11	0.54	0.23	[0.08, 1.00]	.02
Receptive Vocabulary	9	0.20	0.09	[0.01, 0.39]	.03
All code related	11	0.28	0.16	[-0.03, 0.59]	.08
Phonological Awareness	6	0.28	0.19	[-0.08, 0.66]	.12
Print Knowledge	5	0.63	0.30	[0.02, 1.23]	.04
Reading Words	4	0.02	0.28	[-0.54, 0.59]	.93
Spelling	2	-0.02	0.25	[-0.52, 0.47]	.93

†Combined e-book interventions against print books in same studies.

Table 7a

Statistics of each study for Comprehension and Outcome Measures descriptions

Study	Age	N_{total} ($n_{e\text{-}book} + n_{print}$)	Intervention Group	Comparison Group	Measured Outcomes	Effect size for treatments	95% CI for treatment
Comprehension-Related Outcomes							
Altun (2021)	5	196 (97 + 99)	E-book	Print Book	Five story comprehension questions	0.09	[-0.18, 0.37]
Broemmel (2015)	4-5	24 (10 + 14)	E-book and print book	Print Book	Audiotaped book retellings	-0.53	[-1.32, 0.26]
Critelli (2011)	4-6	10 (5 + 5)	E-book	Print Book	10-item comprehension subtest	0.00	[-1.12, 1.12]
Eng (2020) Exper. 1	3-5	35	Contingent E-book	Board Book	10 Story recall questions	0.70	[0.03, 1.36]
Eng (2020) Exper. 2	3-5	33	Contingent E-book	Static E-book	10 Story recall questions	1.46	[0.71, 2.21]
Karemaker (2017) Comparison 1	5.6-7	47 (32 + 15)	E-friend group	Flat E-book	Story comprehension tasks and recall test	0.07	[-0.53, 0.67]
Karemaker (2017) Comparison 2	5.6-7	43 (28 + 15)	Dictionary group	Flat E-book	Story comprehension tasks and recall test	-0.32	[-0.94, 0.29]
Kelley (2017)	3-5	30 (15 + 15)	Interactive e-book (Learn)	E-book without interactive features (Watch)	Story retell measure	-0.10	[-0.80, 0.58]
Kozminsky (2013)	5-6	50 (25 + 25)	E-book	Print Book	Plot understanding test	-0.71	[-1.27, -0.14]
Neuman (2017)	3-4	38	E-book	Print Book	Free recall and Story sequencing	-0.07	[-0.69, 0.55]
O'Toole (2015)	4	100 (50 + 50)	E-book	Print Book	Story comprehension test	0.14	[-0.24, 0.53]
O'Toole (2018) Comparison 1	4	50 (25 + 25)	Live E-book	Live Print Book	7 Open-ended 'wh' questions	0.03	[-0.51, 0.57]
O'Toole (2018) Comparison 2	4	50 (25 + 25)	Audio narrated e-book	Audio narrated print book	7 Open-ended 'wh' questions	-0.13	[-0.68, 0.41]
Pearman (2008)	7-8	54	E-book	Print Book	Oral retelling	0.42	[-0.11, 0.95]
Reich (2019)	3-5	200 (100 + 100)	E-book	Print Book	➢ 14 Free recall questions	-0.10	[-0.38, 0.16]

					➢ Story Sequence ➢ 8 questions on story events and characters		
Richter (2017)	3-5	79	E-book	Print book	9 Recall questions	0.04	[-0.39, 0.48]
Rvachew (2017)	5-6	28	E-book	Print Book	Recall of story	0.35	[-0.37, 1.07]
Sapsaglam (2020)	5-6	20 (10 + 10)	E-book	Print book	5 Story comprehension questions	-1.09	[-2.01, -0.17]
Sari (2019)	4-6	83 (41 + 42)	E-book with animated illustrations with and without music/sounds	E-book with static illustrations with and without music/sounds	Story comprehension questions	0.52	[0.08, 0.95]
Smeets (2015) Comparison 1	4-6	53 (36 + 17)	Animated e-book	Static e-book	Retelling story	0.12	[-0.44, 0.68]
Smeets (2015) Comparison 2	4-6	50 (33 + 17)	Interactive e-book	Static e-book	Retelling story	0.05	[-0.52, 0.63]
Takacs (2016)	4-6	39	Animated e-book	Static e-book	Story retelling	0.24	[-0.37, 0.86]
Zhou (2017) Comparison 1	5	36 (18 + 18)	Multimedia e-book	Print book	Story comprehension test	0.06	[-0.57, 0.70]
Zhou (2017) Comparison 2	5	36 (18 + 18)	Multimedia e-book with questioning	Print book with questions	Story comprehension test	0.44	[-0.20, 1.08]
Zipke (2017)	4-5	25	E-book	Print Book	Story comprehension test	-0.42	[-1.19, 0.34]

Table 7b

Statistics of each study for Vocabulary and Outcome Measures descriptions

Study	Age	N_{total} ($n_{e\text{-}book} + n_{print}$)	Intervention Group	Comparison Group	Measured Outcomes	Effect size for treatments	95% CI for treatment
Vocabulary-Related Outcomes							
Altun (2021)	5	196 (97 + 99)	E-book	Print Book	The Turkish Receptive Language Test	-0.10	[-0.38, 0.17]
Homer (2014) Comparison 1	5-7	19 (12 + 7)	Kinect with activities	Book reading	Expressive vocabulary: 10 Words from Active Decoding Words	0.28	[-0.59, 1.17]
Homer (2014) Comparison 2	5-7	20 (13 + 7)	Kinect without activities	Book reading	Expressive vocabulary: 10 Words from Active Decoding Words	0.37	[-0.52, 1.27]
Ihmeideh (2014)	4.7-5.2	92 (48 + 44)	E-book	Print Book	Target vocabulary: Ten words were selected from the e-books' text Children were shown ten pictures of objects and were asked to say the word of the object.	2.82	[2.25, 3.40]
Karemaker (2017) Comparison 1	5.6-7	47 (32 + 15)	E-friend E-book	Flat e-book	Expressive vocabulary: Target definitions	-0.43	[-1.04, 0.17]
Karemaker (2017) Comparison 2	5.6-7	43 (28 + 15)	Dictionary E-book	Flat e-book	Expressive vocabulary: Target definitions	-0.23	[-0.85, 0.37]
Kelley (2017)	3-5	30 (15 + 15)	Interactive e-book (Learn)	E-book without interactive features (Watch)	➢ Expressive vocabulary: Definitional expressive vocabulary test Decontextual expressive vocabulary test ➢ Receptive vocabulary test ➢ Target vocabulary test Target vocabulary used in story retell	0.40 0.31 -0.33	[-0.29, 1.10] [-0.38, 1.01] [-1.03, 0.36]
Korat (2014a) Comparison 1	4-6	50 (38 + 12)	E-book with dynamic visual vocabulary	E-book without dictionary	➢ Expressive vocabulary: Word meaning expressive test ➢ Receptive vocabulary test ➢ Target words test Target vocabulary used in story retell	0.60 0.56 0.38	[-0.04, 1.25] [-0.08, 1.20] [-0.25, 1.02]
Korat (2014a) Comparison 2	4-6	49 (37 + 12)	E-book with static visual vocabulary	E-book without dictionary	➢ Expressive vocabulary: Word meaning expressive test ➢ Receptive vocabulary test ➢ Target words test Target vocabulary used in story retell	0.47 0.36 0.00	[-0.17, 1.12] [-0.27, 1.01] [-0.64, 0.64]
Korat (2014a) Comparison 3	4-6	49 (37 + 12)	E-book with adult vocabulary support	E-book without dictionary	➢ Expressive vocabulary: Word meaning expressive test ➢ Receptive vocabulary test	1.26 0.85	[0.57, 1.95] [0.19, 1.51]

					➢ Target words test Target vocabulary used in story retell	0.72	[0.06, 1.38]
Korat (2014b) Comparison 1	7-8	52 (41 + 11)	E-book with dictionary dynamic visuals (DVs) with the printed word	E-book without dictionary	➢ Expressive vocabulary: Word Meaning: Expressive test	1.02	[0.34, 1.71]
					➢ Target words test Target vocabulary used in story retell	0.65	[-0.01, 1.32]
Korat (2014b) Comparison 2	7-8	53 (42 + 11)	E-book with dictionary dynamic visuals (DVs) without printed words	E-book without dictionary	➢ Expressive vocabulary: Word Meaning: Expressive test	0.55	[-0.11, 1.21]
					➢ Target words test Target vocabulary used in story retell	0.34	[-0.30, 1.00]
Korat (2014b) Comparison 3	7-8	54 (43 + 11)	E-book with dictionary static visuals (SVs) with printed words	E-book without dictionary	➢ Expressive vocabulary: Word Meaning: Expressive test	0.69	[0.03, 1.36]
					➢ Target words test Target vocabulary used in story retell	0.37	[-0.28, 1.03]
Korat (2014b) Comparison 4	7-8	56 (45 + 11)	E-book with dictionary static visuals (SVs) without printed words	E-book without dictionary	➢ Expressive vocabulary: Word Meaning: Expressive test	0.67	[0.00, 1.33]
					➢ Target words test Target vocabulary used in story retell	0.19	[-0.45, 0.84]
Kozminsky (2013)	5-6	50 (25 + 25)	E-book	Print Book	Target Vocabulary test Target vocabulary used in story retell	-0.51	[-1.07, 0.04]
Lee (2020)	6-7	100	E-book with recorded word explanation	Static e-book	Target Vocabulary Express meaning test	0.42	[0.03, 0.81]
Neuman (2017)	3-4	38	E-book	Print Book	Vocabulary target test	-0.00	[-0.63, 0.61]
O'Toole (2015)	4	100 (50 + 50)	E-book	Print Book	➢ The Peabody Picture Receptive Vocabulary Test (PPVT-4) (Dunn & Dunn, 2007)	0.41	[0.02, 0.80]
O'Toole (2018) 1	4	50 (25 + 25)	Live E-book	Live Print Book	Receptive word learning test	0.24	[-0.30, 0.79]
O'Toole (2018) 2	4	50 (25 + 25)	Audio narrated e-book	Audio narrated print book	Receptive word learning test	0.17	[-0.37, 0.71]
Reich (2019)	3-5	200 (100 + 100)	E-book	Print Book	The vocabulary related questions	-0.26	[-0.54, 0.01]
Sari (2019)	4-6	83 (41 + 42)	E-book with animated illustrations with music/sounds	E-book with static illustrations with music/sounds	➢ Receptive target vocabulary test ➢ Expressive target vocabulary test	0.05 -0.08	[-0.37, 0.48] [-0.51, 0.33]
Smeets (2015) Comparison 1	4-6	53 (36 + 17)	Animated E-book	Static e-book	➢ Expressive vocabulary: TvK Expressive vocabulary test	-0.37	[-0.94, 0.19]
					➢ Receptive: PPVT standardized test	-0.23	[-0.80, 0.33]
					➢ Target vocabulary test sentence completion task	0.06	[-0.50, 0.63]
Smeets (2015) Comparison 2	4-6	50 (33 + 17)	Interactive e-book	Static e-book	➢ Expressive vocabulary: TvK Expressive vocabulary test	-0.08	[-0.66, 0.49]
					➢ Receptive: PPVT standardized test	-0.07	[-0.65, 0.49]
					➢ Target vocabulary test sentence completion task	0.55	[-0.03, 1.13]

Takacs (2016)	4-6	39	Animated e-book	Static e-book	Vocabulary receptive test	0.18	[-0.43, 0.80]
Zhou (2017)	5	36 (18 + 18)	Multimedia-book	Print book	Target Receptive vocabulary test	0.65	[-0.00, 1.30]
Zhou (2017) Comparison 2	5	36 (18 + 18)	Multimedia e-book with questioning	Print book with questions	Target Receptive vocabulary test	0.30	[-0.34, 0.94]
Zipke (2017)	4-5	25	E-book	Print Book	Word Recognition test	1.16	[0.33, 1.98]

Table 7c

Statistics of each study for Decoding and Outcome Measures descriptions

Study	Age	N_{total} ($n_{e\text{-}book}$ + n_{print})	Intervention Group	Comparison Group	Measured Outcomes	Effect sizes for treatments	95% CI for treatment
Code-Related Outcomes							
Critelli (2011)	4-6	10 (5 + 5)	E-book	Print book	➢ 10 questions for Phonological awareness ➢ 10 reading words	-0.33 0.13	[-1.46, 0.79] [-0.98, 1.25]
Gong (2009) Comparison 1	4-4.9	32 (24 + 8)	E-book with 'Bouncing Ball'	Static e-book	Print discrimination task - Reading subtest of Wilkinson's (1993) the WRAT-3	0.61	[-0.17, 1.41]
Gong (2009) Comparison 2	4-4.9	32 (24 + 8)	E-book with 'Violation'	Static e-book	Print discrimination task - Reading subtest of Wilkinson's (1993) the WRAT-3	0.26	[-0.52, 1.04]
Gong (2009) Comparison 3	4-4.9	32 (24 + 8)	E-book with 'Action'	Static e-book	Print discrimination task - Reading subtest of Wilkinson's (1993) the WRAT-3	0.39	[-0.39, 1.17]
Homer (2014) Comparison 1	5-7	19 (12 + 7)	Kinect with activities	Book reading	Reading words: 20 Sight Words Active Decoding Words High Frequency Words	-0.25	[-1.14, 0.64]
Homer (2014) Comparison 2	5-7	20 (13 + 7)	Kinect without activities	Book reading	Reading words: 20 Sight Words Active Decoding Words High Frequency Words	-0.14	[-1.02, 0.73]
Ihmeideh (2014)	4.7-5.2	92 (48 + 44)	E-book	Print Book	➢ Ten questions were developed to measure phonological awareness skills ➢ Print Awareness: Clay's (1979) test	0.78 1.00	[0.36, 1.20] [0.57, 1.43]
Karemaker (2017) Comparison 1	5.6-7	47 (32 + 15)	E-friend E-book	Flat e-book	Target word reading test	-0.47	[-1.08, 0.13]
Karemaker (2017) Comparison 2	5.6-7	43 (28 + 15)	Dictionary E-book	Flat e-book	Target word reading test	-0.35	[-0.97, 0.26]
Korat (2014b) Comparison 1	7-8	52 (41 + 11)	E-book with dictionary dynamic visuals (DVs) with the printed word	E-book without dictionary	Word Spelling test	0.19	[-0.46, 0.85]
Korat (2014b) Comparison 2	7-8	53 (42 + 11)	E-book with dictionary dynamic visuals (DVs) without printed words	E-book without dictionary	Word Spelling test	0.17	[-0.48, 0.82]
Korat (2014b) Comparison 3	7-8	54 (43 + 11)	E-book with dictionary static visuals (SVs) with	E-book without dictionary	Word Spelling test	0.28	[-0.37, 0.93]

			printed words				
Korat (2014b) Comparison 4	7-8	56 (45 + 11)	E-book with dictionary static visuals (SVs) without printed words	E-book without dictionary	Word Spelling test	0.10	[-0.54, 0.75]
Kozminsky (2013)	5-6	50 (25 + 25)	E-book	Print Book	➢ Phonological Awareness test ➢ Print Knowledge test ➢ Orthographic Awareness test All based on existing tests (Blum, 2001; Drori, 1998; Tuvaland Zeiler, 1995)	-0.10 -0.58 -0.33	[-0.64, 0.44] [-1.14, -0.02] [-0.87, 0.22]
Liao (2020) Comparison 1	4-5	29 (19 + 10)	E-book highlight synchronization	Static Read-only E-book	Preschool Word and Print Awareness (PWPA) test	0.43	[-0.32, 1.18]
Liao (2020) Comparison 2	4-5	30 (20 + 10)	E-book print discussion	Static Read-only E-book	Preschool Word and Print Awareness (PWPA) test	1.91	[1.03, 2.79]
Rvachew (2017)	5-6	28	E-book	Print Book	➢ Letter – sound Phonological tests: matching a spoken sound to the appropriate printed letter, matching pictures of words that share a common rime or onset, identifying a frequently occurring word from a list of three, and identifying a new word on the basis of a familiar first letter.	0.86	[0.10, 1.62]
Segal-Drori (2010) Comparison 1	5-6	48 (32 + 16)	E-book without adult instruction	Print Book with adult instruction	➢ Phonological Awareness test ➢ Reading 9 words ➢ 16 questions dealing with print awareness (Shatil, 2001)	-0.05 -0.64 0.55	[-0.64, 0.53] [-1.24, -0.04] [-0.04, 1.15]
Segal-Drori (2010) Comparison 2	5-6	48 (32 + 16)	E-book with adult instruction	Print Book with adult instruction	➢ Phonological Awareness test ➢ Reading 9 words ➢ 16 questions dealing with print awareness (Shatil, 2001)	0.95 2.76 3.04	[0.33, 1.57] [1.95, 3.57] [2.19, 3.88]
Willoughby (2015)	3-4	63 (33 + 30)	Alphabet e-books	ABC Paper books	Letter-naming task Letter-sound task Test of phonological awareness kindergarten version (TOPA-K; Torgesen & Bryant, 1994)	-0.09	[-0.58, 0.39]

Table 8

E-books with and without Multimedia and Interactive features on language and literacy outcomes

Type of technology story	Number of comparisons included	Effect size (g)	Standard error	95% confidence interval	*p*
Multimedia E-books only	**13†**	**0.38**	**0.13**	**[0.12, 0.63]**	**.00**
Story Comprehension	7	0.15	0.09	[-0.03, 0.35]	.11
Vocabulary	9†	0.46	0.24	[-0.01, 0.94]	.06
Receptive vocabulary	5	0.09	0.15	[-0.20, 0.39]	.54
Expressive vocabulary	7	0.60	0.32	[-0.03, 1.24]	.06
Code related	5†	0.63	0.18	[0.28, 0.99]	.00
Phonological Awareness	2	0.80	0.18	[0.43, 1.17]	.00
Print Knowledge	3	0.81	0.19	[0.44, 1.19]	.00
Reading Words	0	-	-	-	-
Spelling	1	0.18	0.16	[-0.14, 0.52]	.26
E-books with both Interactive and Multimedia features	**11†**	**0.26**	**0.12**	**[0.02, 0.49]**	**.03**
Story Comprehension	7	0.21	0.14	[-0.07, 0.50]	.14
Vocabulary	5†	0.11	0.16	[-0.20, 0.43]	.47
Receptive vocabulary	3	0.22	0.18	[-0.13, 0.58]	.21
Expressive vocabulary	4	-0.01	0.16	[-0.32, 0.30]	.94
Code related	4	0.23	0.22	[-0.20, 0.67]	.29
Phonological Awareness	2	0.14	0.22	[-0.29, 0.57]	.51
Print Knowledge	2	0.83	0.42	[0.00, 1.66]	.04
Reading Words	2	0.24	0.38	[-0.50, 0.98]	.52
Spelling	0	-	-	-	-
Interactive E-books only	**2†**	**0.24**	**0.19**	**[-0.14, 0.63]**	**.21**
Story Comprehension	2	-0.19	0.19	[-0.57, 0.18]	.31
Receptive Vocabulary	0	-	-	-	-
Expressive Vocabulary	1	1.16	0.23	[0.70, 1.63]	.00
Phonological Awareness	0	-	-	-	-
Print Knowledge	0	-	-	-	-
Reading Words	1	-0.43	0.22	[-0.87, 0.00]	.05
Spelling	0	-	-	-	-
E-books without Multimedia and Interactive features (static/basic)	**5†**	**-0.15**	**0.21**	**[-0.56, 0.26]**	**.47**
Story Comprehension	5	-0.27	0.21	[-0.69, 0.14]	.19
Receptive Vocabulary	2	0.31	0.14	[0.03, 0.58]	.02
Expressive Vocabulary	0	-	-	-	-
Phonological Awareness	2	-0.14	0.25	[-0.63, 0.34]	.56
Print Knowledge	1	-0.58	0.28	[-1.14, -0.02]	.03
Reading Words	1	0.13	0.57	[-0.98, 1.25]	.81
Spelling	1	-0.33	0.28	[-0.87, 0.22]	.24

†Combined e-book interventions against print books in same studies with same (or without) technological features.

Table 9

Studies with and without adult scaffolding / mediation in print and e-books

	Number of studies	Effect size (g)	Standard error	95% confidence interval	*p*
Studies with adult support either in e-book condition, or in print condition or both conditions	9†	0.44	0.23	[-0.01, 0.89]	.05
Studies with adult support in both conditions (e-book and print are supported)	5†	0.86	0.44	[-0.01, 1.73]	.05
Story Comprehension	3	0.12	0.29	[-0.45, 0.70]	.68
Vocabulary	2	1.57	1.26	[-0.90, 4.06]	.21
Code related	3	1.30	0.42	[0.48, 2.13]	.00
Studies with adult support in print condition only	4†	-0.07	0.16	[-0.40, 0.24]	.63
Story Comprehension	2	-0.61	0.23	[-1.06, -0.15]	.00
Vocabulary	3	0.29	0.47	[-0.63, 1.21]	.54
Code related	3	-0.19	0.17	[-0.54, 0.14]	.25
Studies with adult support in e-book condition only (not in print book)	1	1.00	0.24	[0.52, 1.49]	.00
Studies without adult support in e-book condition (independent use) and all included comparisons in print condition (with and without support print)	26†	0.18	0.06	[0.04, 0.31]	.00
Story Comprehension	18†	0.04	0.08	[-0.12, 0.22]	.59
Vocabulary	17†	0.25	0.10	[0.04, 0.45]	.01
Code related	9†	0.06	0.14	[-0.23, 0.35]	.68
Studies without adult support in both conditions (independent use of e-book vs only narration of print book – no scaffolding)	22†	0.21	0.07	[0.06, 0.35]	.00
Story Comprehension	16†	0.10	0.08	[-0.05, 0.27]	.19
Vocabulary	14†	0.25	0.10	[0.04, 0.46]	.01
Code related	6†	0.17	0.20	[-0.21, 0.57]	.37

†Combined e-book interventions against print books in same studies.

Figures

Figure 1

Funnel Plot of Standard Error by Hedge's g

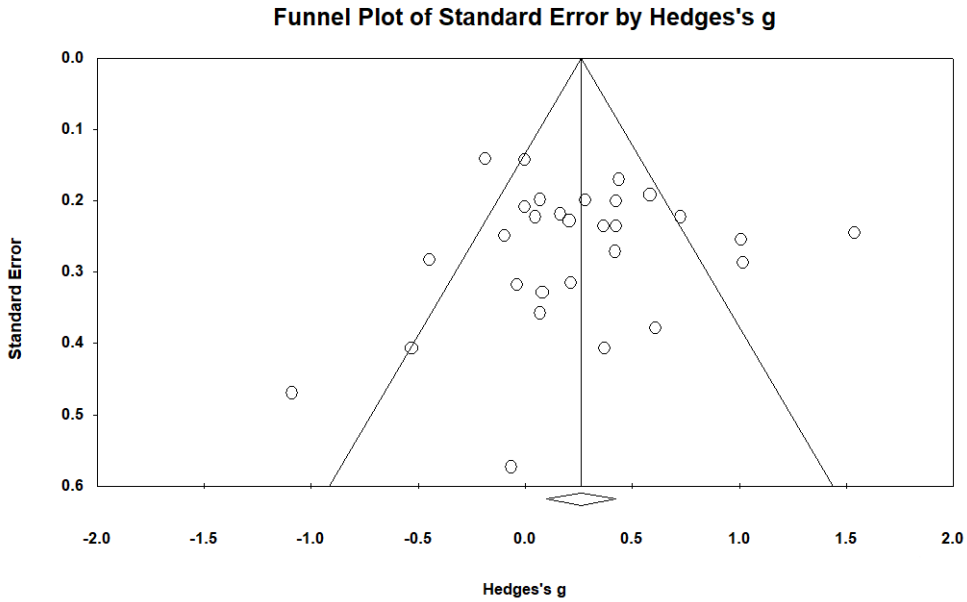


Figure 2

Trim and Fill Funnel Plot Hedges's g and Standard Error

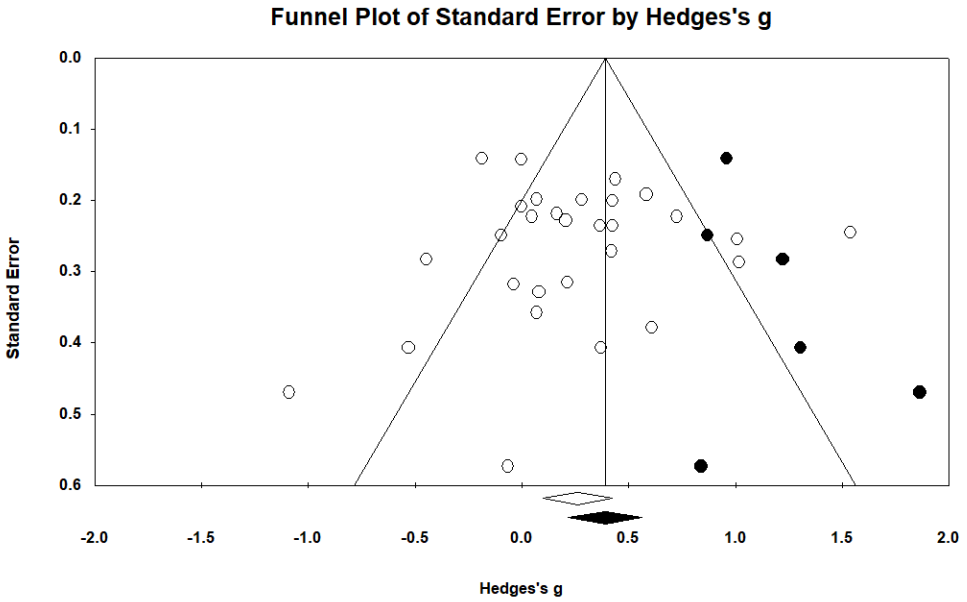
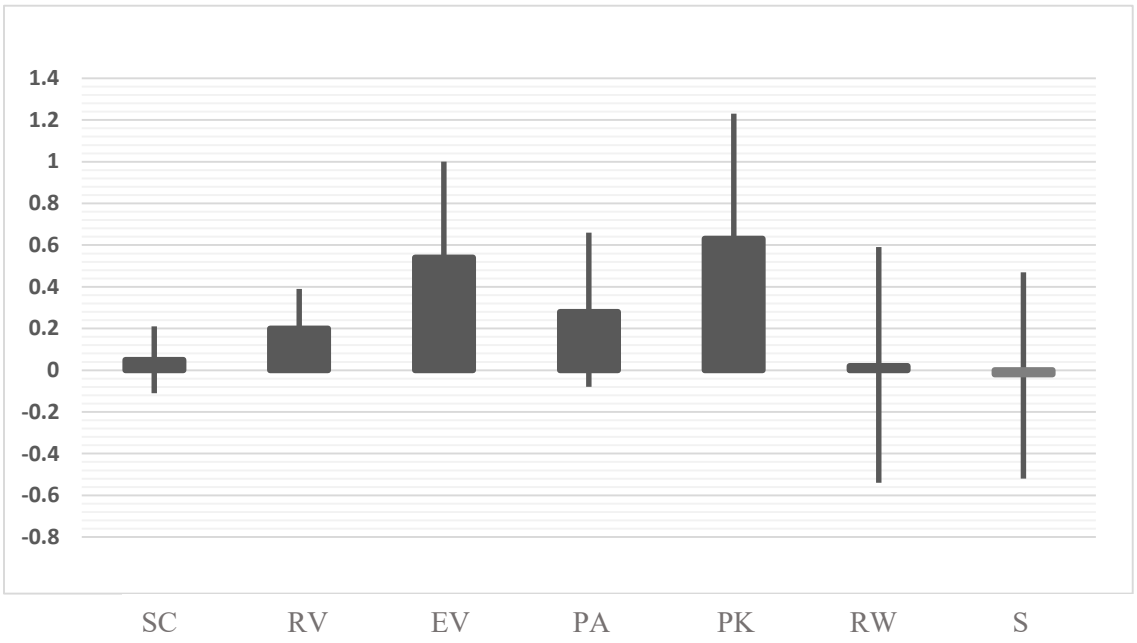


Figure 3

Effect sizes and 95% CIs of outcome measures



Note: SC= story comprehension, RV= receptive vocabulary, EV=expressive vocabulary, PA=phonological awareness, PK=print knowledge, RW=reading words, S=spelling.