KU LEUVEN

FACULTY OF PSYCHOLOGY AND
EDUCATIONAL SCIENCES

STIMULATING PRESCHOOLERS' EARLY LITERACY DEVELOPMENT USING EDUCATIONAL TECHNOLOGY:

A SYSTEMATIC LITERATURE REVIEW

Master's thesis submitted for the
degree of Master of Science in
Educational Studies by
Genica Fae Bautista

Supervisor: Prof. Dr. Joke Torbeyns
Co-supervisor: Prof. Dr. Pol Ghesquière

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Summary

Learning to read is an important aspect of life. Prior to formal schooling, young children develop elements of early literacy that are critical for them to become successful readers. Despite the importance of early literacy development, instruction in this domain is confronted with challenges as it tends to be narrow and insufficient. While there is growing interest in the potential of educational technology to address these challenges and facilitate children's learning, a recent systematic literature review taking into account findings from both media comparison and value-added studies that focused on preschoolers' early literacy development was still missing. Therefore, the present Master's thesis aims to address this gap by providing a systematic analysis of the available empirical research on the effectiveness of educational technology for stimulating preschoolers' early literacy development.

Specifically, three research questions were investigated: (1) Is educational technology effective in stimulating preschoolers' early literacy development? (2) Which features of educational technology and its implementation are associated with its effectiveness? (3) Which child characteristics are associated with its effectiveness? To answer these questions, a systematic search was conducted by consulting four electronic databases – i.e., ERIC (Ovid), PsycArticles, PubMed, and Web of Science. Using the inclusion and exclusion criteria, 58 articles reporting on 60 empirical studies were selected for the review. The analysis of data involved the methodical extraction and narrative synthesis of information from the findings of the primary studies.

The systematic review has found that media comparison studies provide some evidence of the benefits of using educational technology in early literacy instruction. Additionally, code-focused games are suggested to be a promising type of educational technology for improving phonological awareness. Another important finding is that value-added studies indicate certain features of educational technology and its implementation to be associated with its effectiveness. These include augmented reality, metacognitive guidance, fading pictorial cues, and scaffolding. In terms of child characteristics, this review has found that existing studies suggest the association of collaborative talk, phonological working memory, and error rate with the effectiveness of educational technology. Due to limitations in the data from the primary studies, there is a strong need for further research to allow for unambiguous conclusions regarding the features and characteristics that impact the effectiveness of educational technology to be drawn in the future. Despite its weaknesses, this study provides insights into the use of learning technologies in view of enhancing the early literacy development of young children. Overall, the findings of this review can benefit educators, designers, and researchers of educational technology in shaping, evaluating, and improving the design of more effective technologies for early literacy learning.

Acknowledgements

This endeavor would not have been possible without the dedicated support and guidance of the following people. First, I would like to express my sincerest gratitude to my supervisor Prof. Dr. Joke Torbeyns and co-supervisor Prof. Dr. Pol Ghesquière for their invaluable feedback, insights, and patience. Additionally, I would like to thank my professors and lecturers throughout the preparatory program as well as this Master's program for sharing their knowledge and inspiring me. Special thanks to Ms. Veerle Tuerlinckx for assisting me in the early stage of the literature search. Lastly, I am grateful to my family, including my partner and his parents, for their constant support and encouragement.

Clarification of Approach and Contribution

This Master's thesis was written in collaboration with my supervisor Prof. Dr. Joke Torbeyns and co-supervisor Prof. Dr. Pol Ghesquière. It was based on the research topic proposed by Prof. Dr. Torbeyns, which I adopted as it greatly overlaps with my interest in the early literacy development of young children.

Before starting the research project, Prof. Dr. Torbeyns and Prof. Dr. Ghesquière provided me with some literature to enhance my understanding of the matter at hand. After my first meeting with Prof. Dr. Torbeyns, I started to search for additional references, formulated the research questions, and designed an action plan to begin the literature search. Prof. Dr. Torbeyns suggested some changes, which I took into account as I finalized the plan. After Prof. Dr. Torbeyns, Prof. Dr. Ghesquière, and I agreed on the plan, I proceeded with the literature search and systematic review. Aside from helping me design and conduct the research by offering their insights, Prof. Dr. Torbeyns and Prof. Dr. Ghesquière also guided me during the writing of this thesis by providing constructive feedback.

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Introduction

Learning to read is a crucial aspect of education and daily life (Gillen & Hall, 2013; White & Grieder, 2016). Young children acquire much knowledge of the function and process of reading prior to formal schooling (Teale & Sulzby, 1986; Teale et al., 2020; Whitehurst & Lonigan, 1998). This early literacy development is critical for children to become successful readers (Hulme & Snowling, 2013; National Early Literacy Panel [NELP], 2008; Shapiro et al., 2013; Snow et al., 1998; Storch & Whitehurst, 2002). In the process of early literacy development, four components are identified as core elements that strongly predict reading success – i.e., phonological awareness, letter-sound knowledge, rapid automatized naming, and print awareness (Hulme & Snowling, 2013; Shapiro et al., 2013). Despite the well-established importance of these core elements, instruction in the domain of early literacy is confronted with numerous challenges as it tends to be narrow and insufficient (Early et al., 2010; Pelatti et al., 2014; Pentimonti & Justice, 2009). Throughout the years, there has been an increasing research interest in the potential of educational technology to aid in early literacy instruction and stimulate the development of early literacy in preschoolers (National Reading Panel [NRP], 2000; Rohlfing & Müller-Brauers, 2020). In comparison with non-digital educational tools, educational technology offers "affordances" (National Academies of Sciences, Engineering, and Medicine [NASEM], 2018), such as interactivity, adaptivity, and linked representations, which could provide additional learning opportunities and help in addressing common barriers in early literacy instruction. While there are some reviews of empirical studies on the potential of educational technology to serve as tools for learning, there are currently no recent systematic reviews focusing on its effectiveness for the stimulation of early literacy development. Therefore, the aim of the current study is to provide a systematic analysis of the available empirical research on the effectiveness of educational technology in facilitating preschoolers' early literacy development.

In the following sections, the theoretical framework of this review will be presented. First, early literacy, including its core components and common challenges in instruction, will be discussed. Then, educational technology, together with its affordances, will be described to understand how it can address the challenges in early literacy instruction. Finally, the research questions that guided the current systematic review will be explained.

Early Literacy

Early literacy consists of young children's precursor knowledge, abilities, and attitudes related to conventional reading and writing (NELP, 2008). Also referred to as *emergent literacy* – a term attributed to Marie Clay – these competencies are presumed to develop in the early years before children start formal instruction (Teale & Sulzby, 1986; Teale et al., 2020; Whitehurst & Lonigan, 1998). While they are contrasted with conventional literacy skills, which are considered as later and more sophisticated manifestations of reading and writing, these early competencies are recognized as strong

and consistent predictors of reading achievement and therefore academic success (Hulme & Snowling, 2013; NELP, 2008; Shapiro et al., 2013; Snow et al., 1998; Storch & Whitehurst, 2002).

Several authors have proposed different models to conceptualize the component knowledge, skills, and attitudes involved in the domain of early literacy. Whitehurst and Lonigan (1998) proposed a model with two interdependent sets of competencies and processes: outside-in components, which are associated with children's understanding of what is read (e.g., language, conceptual knowledge), and inside-out components, which are related to decoding print (e.g., letter-sound correspondences, phonological awareness). In line with theories of information processing, the two main components are also linked to top-down and bottom-up processes, respectively (Carrell & Eisterhold, 1983; Helland et al., 2011). Similar categorizations of early literacy components have been made by other authors – for example, meaning-related and code-related (Lonigan et al., 2011), word recognition and language comprehension (Gough & Tunmer, 1986), and simple lower-order and complex higher-order (van de Ven et al., 2017). Another model, which was proposed by Rohde (2015), views early literacy with three overlapping components of print awareness, phonological awareness, and language.

Although there is considerable debate on the early literacy models and specific components included (Sénéchal et al., 2001), recent research has identified the following "cognitive foundations" for learning to read: phonological awareness, letter-sound knowledge, and rapid automatized naming (Caravolas et al., 2012; Hulme & Snowling, 2013; Lervåg et al., 2009). *Phonological awareness* involves the ability to identify and manipulate units of sounds that compose spoken words, including syllables, sub-syllables, and phonemes (Rohde, 2015; Whitehurst & Lonigan, 1998). It can be assessed through tasks such as: rhyme matching (e.g., selecting the word that rhymes with "cat" from response alternatives "hat", "bar", and "man"), syllable blending (e.g., "What do you get when you say 'can'… 'dy' together?"), syllable deletion, (e.g., saying "candy" without /dee/), phoneme isolation (e.g., "What is the first sound in 'hat'?"), and phoneme deletion (e.g., "hat" without /h/). Research has shown that children follow the same developmental hierarchy in achieving sensitivity to linguistic units. For example, children tend to develop sensitivity to larger units in the syllable level earlier than they acquire sensitivity to smaller units in the phoneme level (Vloedgraven & Verhoeven, 2009; Whitehurst & Lonigan, 1998). While phonemic awareness is rather complex for young children, findings from numerous studies support its pivotal role in predicting individual differences in literacy development (see the meta-analysis of Melby-Lervåg et al., 2012). Research comparing children with dyslexia and typically developing children (e.g., Elbro & Jensen, 2005) clearly shows that children with dyslexia perform less favorably in measures of phonemic awareness. Longitudinal studies (e.g., Lervåg et al., 2009; Muter et al., 2004) also show strong correlations between phonemic awareness measured in preschool and word recognition measured in the first years of formal reading instruction. As a strong predictor for learning to read, children's phonological awareness establishes the foundation for efficient grapheme-phoneme mapping (Hulme et al., 2002).

Letter-sound knowledge refers to the understanding that letters in printed words (i.e., graphemes) map on to the smallest unit of sounds in spoken words (i.e., phonemes; Rohde, 2015; Whitehurst & Lonigan, 1998). Research indicates that children's development of letter-sound knowledge (e.g., letter A can have the sound /æ/ as in "cat") comes later than the learning of letter-names (e.g., letter A has the name "ay"; Blaiklock, 2004; Treiman et al., 1996). However, this may also be related to the emphasis given to either letter-name or letter-sound instruction in the classrooms (Blaiklock, 2004). Nevertheless, similar to phonological awareness, letter-sound knowledge has been shown to be a strong predictor of children's progress in learning to read (Caravolas et al., 2012). Additionally, studies involving children at risk for reading difficulties (e.g., Bowyer-Crane et al., 2008; Hulme et al., 2012) reveal that interventions targeting both phonological awareness and letter-sound knowledge improved the children's word reading skills. According to Hulme and Snowling (2013), the relationship between letter-sound knowledge and reading may be due to the fact that a good knowledge of letter-sound correspondences provides children with the foundation to decode unfamiliar words by themselves on a letter-by-letter basis and demonstrates their visual-phonological learning (i.e., associating abstract shapes or letters with corresponding sounds), both of which are essential when learning to read. Thus, early literacy development is critically dependent on letter-sound knowledge as well.

Rapid automatized naming is the ability to rapidly and accurately name familiar pictures, colors, letters, or numbers (Hulme et al., 2012). It involves the retrieval of phonological codes from long-term memory, which is a similar process that is needed to read successfully (Vanden Bempt et al., 2021; Whitehurst & Lonigan, 1998). Although phonological awareness, letter knowledge, and rapid naming may be influenced by a common phonological factor, previous studies have shown that rapid naming could also be independent from the former components (Kirby et al., 2003; Lervåg et al., 2009; Vander Stappen & Reybroeck, 2018). Therefore, rapid automatized naming is also considered as an important predictor of differences in reading development.

Aside from the three components already mentioned, literacy research has also identified another potentially important element in predicting reading skills. *Print awareness* refers to young children's sense of written language and its function even without the ability to read (Rohde, 2015; Whitehurst & Lonigan, 1998). For example, in English, children's print awareness involves understanding that print has meaning, recognizing the difference between print and pictures, knowing the order in which the pages of a book are read, and knowing that reading must be done from left to right and from top to bottom of the page (Justice & Ezell, 2001). Lomax and McGee (1987) suggest that print awareness lays the foundation for understanding letter-sound correspondences. Whereas earlier research has recognized print awareness to be moderately correlated with measures of decoding and spelling (National Early Literacy Panel, 2008), a more recent study by Piasta et al. (2012) identifies the same competency as a predictor of growth in children's reading skills.

Given the importance of the different components of early literacy identified in the research literature, developmentally appropriate practice has to be employed to support their enhancement. This entails overcoming practical barriers such as difficulties in maintaining young children's interest for long periods and ensuring appropriate teacher-to-child ratios that allow for individualized learning opportunities (Whitehurst & Lonigan, 1998). Unfortunately, instruction in the domain of early literacy tend to be insufficient and ineffective, with many preschool programs failing to provide quality language and literacy experiences to young children. For example, in a study involving over 2000 preschoolers, Early et al. (2010) found that children spent only 17% of their typical day in the classroom engaged in literacy-related activities and 44% of the time not engaged in any learning activity. Although Pelatti et al. (2014) reported slightly better results with 20% of the average day dedicated to literacy, literacy experiences were limited, as learning opportunities related to phonological awareness and letter knowledge were confined to rhyming tasks and letter names, respectively. Similar findings on the scarcity of learning opportunities targeting phonological awareness were also reported by Hawken et al. (2005), adding that syllable and phoneme blending activities were generally neglected. Moreover, implementing individualized instruction to meet the different learning needs of children is a daunting task, as early childhood educators tend to make little use of support strategies to assist struggling children in the classroom (Pentimonti & Justice, 2009). In order to foster the early literacy development of young children, it is essential that these challenges are addressed.

Educational Technology

Recent studies increasingly focus on the potential of educational technology to promote the development of early literacy in young children (Rohlfing & Müller-Brauers, 2020). The use of educational technology in early childhood classrooms for stimulating learning in other domains, including science, mathematics, music, and arts, is also the subject of numerous studies, with many of them reporting its benefits (e.g., Lee & Tu, 2016; Moyer-Packenham et al., 2015; Paule-Ruiz et al., 2017; Price et al., 2015). *Educational technology*, which refers to "a variety of electronic tools and applications that help deliver learning materials and support learning process" (Cheung & Slavin, 2012, p. 201), offers affordances that may not be possible with non-digital educational tools. These affordances, such as adaptivity, choice, collaboration, linked representations or modality, and personalization, are characteristics and possibilities of technology that facilitate important learning opportunities for users (Barzillai et al., 2017; NASEM, 2018; Wouters & van Oostendorp, 2013). For example, the digital environment of an educational game on a tablet may have features of interactivity and feedback as it requires the learners to tap the picture that corresponds to the audio recording of the word in parts (e.g., phoneme segments) and provides immediate feedback (i.e., correct versus incorrect, with a short explanation of why the learner's input was correct or incorrect). According to Moreno and Mayer (2007), this can promote meaningful knowledge construction in students by creating a multimodal learning environment that aims to maximize their active processing of the education

materials and minimize their cognitive load. This is also in line with different theories of learning suggesting that children learn best in experiences that are active or "minds-on", engaging, meaningful, and socially interactive (Hirsh-Pasek et al., 2015). More concretely, while keeping in mind the weaknesses in the instruction of early literacy in preschool programs, educational technology has the potential to facilitate young children's exposure to educational materials through carefully designed environments. These digital learning environments may accommodate children's diverse needs and abilities by providing repetitive yet diverse and individualized exercises that target their core competencies; scaffold their learning by including multimodal and adaptive features; and sustain their interest by incorporating educational concepts in the context of play. Indeed, as emphasized by Tobias et al. (2015, p. 9), the "educational value of these affordances depends on whether and how they are applied and the degree to which they stimulate deeper, or more frequent cognitive processing of instructional input". Therefore, it would be beneficial to conduct research that determine whether these affordances can indeed be used for instruction and enhance learning in the domain of early literacy.

To investigate instructional effectiveness, empirical research on educational technology typically adopts a particular approach, which is related to the distinction between the media comparison approach and the value-added approach (Mayer, 2011). Studies using a media comparison approach compare learning with one medium (e.g., touchscreen mobile device) against learning with another medium (e.g., printed book). While research on learning and technology usually adheres to a media comparison approach, it is argued that differences in learning outcomes cannot be attributed to the medium as such. Instead, it is the design and instructional method within the medium that will determine learning (Clark, 2001; Mayer, 2011). Thus, shifting the focus from media comparison to value-added research is needed. Studies employing a value-added approach compare learning with the standard version of educational technology (e.g., non-adaptive tablet game) against the enhanced version with added instructional features or affordances of the same technology (e.g., adaptive tablet game). Aside from the specific features of educational technology, several other elements have been identified to affect the impact of an educational technology especially when implemented in large-scale school settings, including the characteristics of the learners (e.g., prior knowledge, language) and the level of support provided to learners in using the technology (NASEM, 2018). Consequently, studies are increasingly analyzing different implementation types of educational technology as well (e.g., Verbruggen et al., 2021), for example, by comparing a condition of implementation without teacher scaffolding versus with additional teacher scaffolding.

As educational technology becomes more widely used, the number of studies investigating its potential to stimulate the development of young children's early literacy grows as well (Rohlfing & Müller-Brauers, 2020). Although there is general enthusiasm for using educational technology in instruction, there is still a lack of systematic reviews on the demonstrated effects of educational technology for early literacy. Several literature reviews on the effectiveness of educational technology

included older children and other aspects of literacy, and thus, did not focus on the early literacy development of younger preschool children (e.g., Booton et al., 2021; Cheung & Slavin, 2012; Eutsler et al., 2020; Ramdoss et al., 2011). There were also review studies that focused solely on the literacy of specific groups of children such as children with autism (e.g., Ramdoss et al., 2011) and with learning difficulties (e.g., Loo et al., 2010). The few reviews currently available on the use of educational technology in the domain of early literacy remain limited and inconclusive due to theoretical and methodological weaknesses. For example, some of these reviews were not systematically conducted, included only a small part of the available studies on the matter at hand, and are now outdated considering the continuous and fast-paced evolutions in technology (e.g., Drigas & Kokkalia, 2014; Lieberman et al., 2009; Neumann & Neumann, 2014). The recent systematic literature reviews of Herodotou (2018) and Griffith et al. (2020) on the effectiveness of technology on young children's learning both remain limited with reference to scope, as they only included research on tablet applications and a small number of studies on early literacy. Moreover, none of these reviews made the important distinction between media comparison studies and value-added studies. This is not to say that the contributions made by previous reviews are unimportant and should be neglected. Instead, the gap in research on the potential of educational technology in stimulating the early literacy development of preschoolers needs to be recognized and filled. Therefore, the present study set to conduct a systematic review which addresses the abovementioned concerns by including available recent studies and making the distinction between media comparison and value-added research.

Current Study

It is well-established that the early literacy competencies of young children are necessary for their reading achievement and academic success (Hulme & Snowling, 2013; NELP, 2008; Shapiro et al., 2013; Snow et al., 1998; Storch & Whitehurst, 2002). However, early literacy instruction in preschool programs tends to be narrow and insufficient (Early et al., 2010; Pelatti et al., 2014; Pentimonti & Justice, 2009). While there is growing interest in the potential of educational technology to address the problems in early literacy instruction and facilitate young children's learning in this domain, previous reviews are limited, inconclusive, and failed to focus on preschoolers' early literacy development. Taking these points together, the current study intends to provide a systematic analysis of the available empirical research on the effectiveness of educational technology for stimulating preschoolers' early literacy development. Specifically, three research questions were investigated: (1) Is educational technology effective in stimulating preschoolers' early literacy development? (2) Which features of educational technology and its implementation are associated with its effectiveness? (3) Which child characteristics are associated with its effectiveness?

The first research question inquires about the overall effectiveness of educational technology and focuses on findings of empirical studies following a media comparison approach. As argued by

Girard et al. (2013), studies on educational technology suffer from the "control group problem", which highlights the heterogeneity of conditions and ambiguity of the concept of "control group" applied by the authors on their studies. Following the suggestion of Verbruggen et al. (2021) that a fine-grained approach of dividing the large number of studies into smaller subgroups could help to address the heterogeneity of control groups among the included studies, the current review classifies media comparison studies into subgroups based on the comparison treatment received by the control group.

To move beyond focusing exclusively on media comparisons, the second research question inquires about the characteristics of educational technology which may be associated with its effectiveness and considers findings of empirical studies that make value-added comparisons. In evaluating the effectiveness of a base version of educational technology to an enhanced version, attention is given to its design and implementation, and how they potentially affect learning.

The third research question focuses on both media comparison and value-added studies while considering possible correlations between child characteristics and effectiveness of the educational technology.

Method

The Systematic Review Approach

A systematic literature review was conducted to examine the available empirical studies on the effectiveness of educational technology in stimulating young children's early literacy development. Defined as "a review of existing research using explicit, accountable rigorous research methods" (Gough et al., 2017, p. 4), systematic reviews aim to select and assess all relevant studies to answer a specific research question, for example, on the effectiveness of an educational intervention. Given the serious increase in the amount of research available in the past years, this particular type of review can be helpful in finding relevant and reliable information by synthesizing existing evidence related to the question (Petticrew & Roberts, 2007). Moreover, its adherence to a systematic and explicit methodology serves to limit bias when reaching conclusions.

Literature Search and Selection Process

To identify studies of interest for the current review, a systematic search was conducted by consulting four electronic databases – i.e., ERIC (Ovid), PsycArticles, PubMed, and Web of Science. These databases were chosen based on the suggestion of the Cochrane Library Handbook (Lefebvre et al., 2022), their relevance to the subject area of this review, and their availability to the author as a student of KU Leuven. The following search string was entered to browse each database: *[(preschool* OR kindergarten* OR ''early childhood'') AND (''education* technology'' OR digital* OR computer* OR electronic* OR "education* media" OR "digital media" OR ICT OR technology OR "information and communication* technology") AND (reading OR literacy OR "early literacy" OR "emergent*

literacy")]. This search was completed in December 2021 and obtained a total of 2131 journal articles written in the English language.

In the first phase, 2131 records were obtained from the four databases and saved in Endnote 20 reference management tool. The list of records was checked for duplicates, with 303 duplicates automatically removed by the software and 105 duplicates manually removed by the author. This resulted in 1723 unique records. In the second phase, the title and abstract of these records were screened for relevance using the following criteria (see Table 1): (a) intervention study, (b) focus on the domain of early literacy, (c) use of educational technology, (d) formal organization context, and (e) preschool level. Those studies that did not meet these criteria were excluded, which resulted in 112 reports sought for full-text retrieval. Eleven of these reports were not accessible to the author. In the final phase, 101 full-text reports were read and assessed for eligibility on the basis of the same inclusion criteria, which resulted in a set of 58 reports. Two of these articles reported on more than one study, which resulted in the final total of 60 studies included in the current review. An overview of the literature selection process is shown in Figure 1.

Data Analysis

This systematic review adhered to a narrative approach to analyze the data, which involved the methodical extraction and narrative synthesis of information from the findings of the primary studies. This approach is recommended when the studies are characterized by a large heterogeneity and variability in populations, interventions, outcomes, and study designs (Griffith et al., 2020; Petticrew & Roberts, 2007; Ryan, 2019). First, the description of the primary studies was organized into logical categories. Second, a within-study analysis was conducted which focused on identifying and summarizing the relevant findings for each study. Finally, a cross-study synthesis was completed to provide an overall summary of the findings that consider issues in variability between studies. An overview of the included studies is presented in Appendices A and B. This overview contains the following categories:

Number

This refers to the assigned number of the report as it was presented in the current review. For reports consisting of multiple studies, the number of the report combined with a different letter was assigned to each study, for example, 23a and 23b.

Author (Year)

This refers to the name of the author/s of the report and the year in which the report was published.

Language (Country, Continent)

This refers to the language used in the intervention reported in the article, and the country and continent wherein the study was conducted.

Study design

This refers to the type of research design used in the study. In line with Ross and Morrison (2008), distinctions were made among the included studies for the review: true experimental, quasi-experimental, and single-subject research. A true experimental research design compares two or more groups that are subjected to standardized procedures and exposed to different treatments wherein participants are randomly assigned. A quasi-experimental design, however, does not assign participants randomly to treatments. Instead, it uses intact or pre-existing groups, e.g., groups according to class sections of preschool. Finally, a single-subject design, which is a variation of the time series design, involves one or multiple participants who serve as their own control in the study.

Table 1

Inclusion and Exclusion Criteria

Criterion	Included	Excluded
Intervention study	The article reports on an intervention study with the following features: (1) use of an intervention by experimental manipulation and standardization of procedures, *and* (2) comparison of the experimental and control conditions, i.e., a study based on true experimental design (randomized controlled trials), quasi-experimental design, or single-subject design (i.e., multiple-baseline or multiple-probe design).	The article is not based on an intervention study, i.e., a study without an intervention involving an experimental manipulation or without a comparison between experimental and control conditions, e.g., review, meta-analysis, correlational study, descriptive study, and case study.
Domain of early literacy	The article focuses on the stimulation of the proximal aspects of reading development in early literacy through the use of educational technology, i.e., print awareness, phonological awareness, rapid automatized naming, and/or letter-sound knowledge.	The article focuses on the distant general aspects of reading development, e.g., oral language and vocabulary; or does not focus on the domain of early literacy, e.g., focuses on the stimulation of development in another content domain with early literacy intervention in the control condition.
Use of educational technology	The article involves: (1) the actual use of digital educational technology *and* (2) with the aim to stimulate and support the learning process of the child in the domain of early literacy during the intervention.	The article does not involve the use of educational technology to stimulate the learning process of the child, e.g., using educational technology in the pre- and post-tests but not as part of the intervention.
In formal organization context	The article focuses on an intervention conducted in a formal organization context outside the family, and is mediated by professionals, e.g., in school or nursery.	The study is not conducted in a formal organization context and/or the intervention is not mediated by professionals, e.g., intervention conducted at home and/or mediated by the parents.
Preschool level	The article focuses on children at the preschool and/or kindergarten level, i.e., intervention is delivered (1) to children before the age of 7 *and* (2) before the start of formal reading instruction.	The article focuses on children at other education levels, e.g., primary school, secondary school, or university level, and/or their teachers.

Study participants

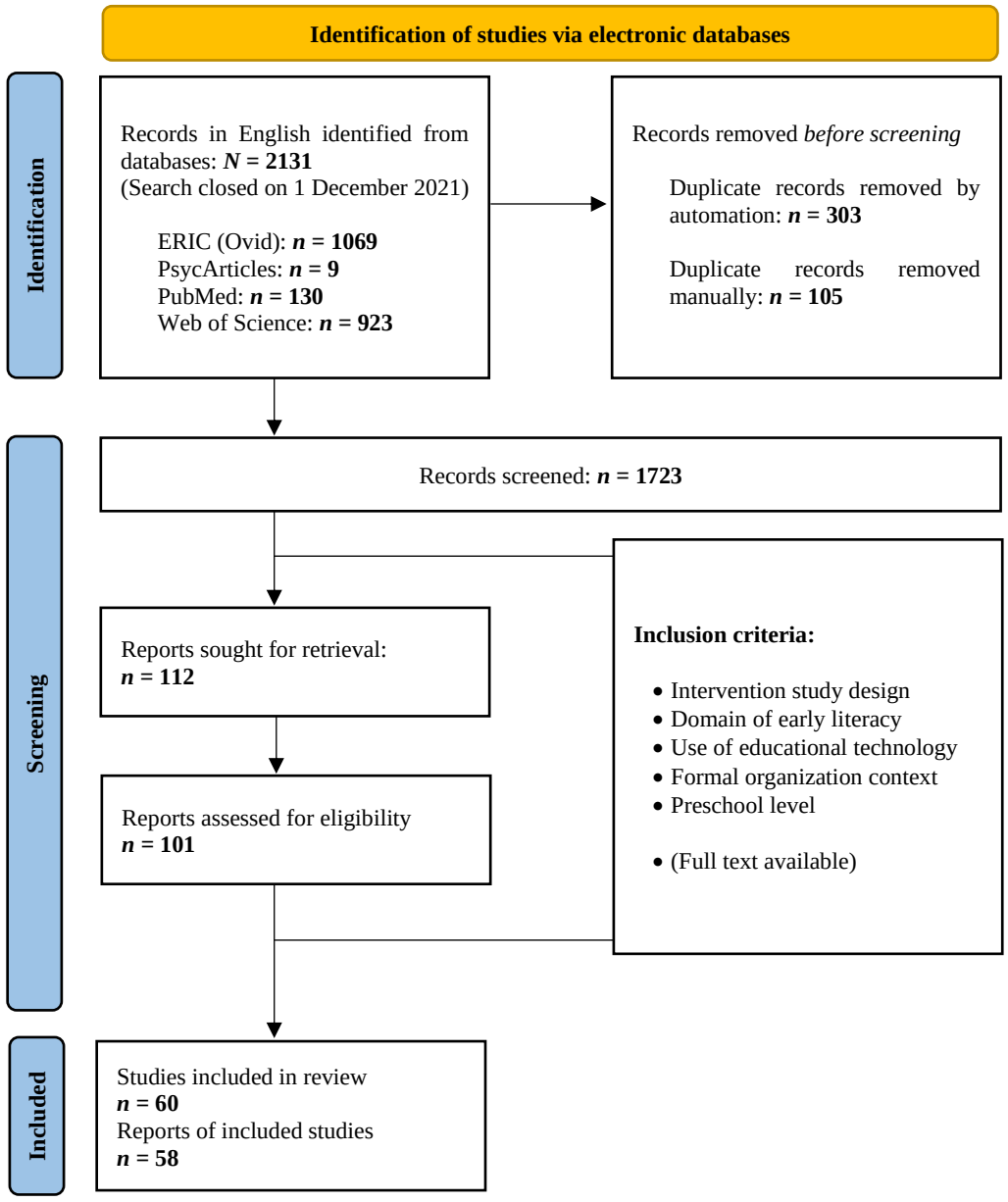
This refers to the descriptions regarding the participants of the study, including the sample size, their age range, and specific characteristics of the sample mentioned in the article. For example, some studies particularly included students from schools serving mainly children from families of low socio-economic status (SES) or students with disabilities.

Study approach

This refers to the two genres of research on educational technology as categorized by Mayer (2011): media comparison approach and value-added approach. Following the suggestion of Verbruggen et al. (2021), studies adhering to the media comparison approach were further partitioned

Figure 1

Flowchart of the Literature Search and Selection Process



into subcategories based on the comparison treatment applied to the control group. These subcategories were assigned either *A* to signify the use of an active control group which received an alternative treatment or *I-BAU* for an inactive/passive control group which did not receive an alternative treatment, i.e., studies describing the control condition involving regular program or business as usual. Next, subcategories with active control group were assigned either *ET* to refer to the use of educational technology in the alternative treatment or *NET* to signify the use of non-technology as an alternative treatment. The active control group subcategories were also assigned either *EL* to denote that the alternative treatment was applied for the stimulation of early literacy or *NEL* to signify that the alternative treatment did not focus on the stimulation of early literacy. Thus, five subcategories were identified: A-ET/EL, A-ET/NEL, A-NET/EL, A-NET/NEL, and I-BAU. Moreover, as some of the primary studies included more than one control group, one study may be coded as following both media comparison and value-added approaches. Furthermore, those studies following a media comparison approach may be assigned in multiple subcategories.

Early literacy component (Measure)

This refers to the component or subdomain of early literacy that is relevant to the research questions of the current review and measured as an outcome in the primary studies included in the review: *PA* or phonological awareness, *LSK* or letter-sound knowledge, *RAN* or rapid automatized naming, and *PRAW* or print awareness. A study may investigate either a single early literacy component or multiple early literacy components.

Grouping structure of intervention

This refers to the grouping structure used in the intervention, i.e., individual, pair, small-group, or whole-class.

Duration of intervention (Session length)

This refers to the total amount of time (weeks and/or number of sessions) of the intervention, including the typical length of each session.

Educational technology and early literacy condition

This refers to the materials and/or activities using educational technology and focusing on early literacy that were applied in the intervention condition.

Activities in the control condition

This refers to the comparison treatment applied in the control condition, i.e., the specification of materials and activities offered to the control group.

Main findings

This refers to the findings of the primary studies that are relevant to the current review. Thus, the relevant findings were analyzed per research question focusing on the effectiveness of educational technology (i.e., whether there was a significant difference in outcomes between the conditions and the reported effect size), features of educational technology and its implementation associated with the effectiveness of the intervention, and child characteristics associated with the effectiveness of the intervention.

Results

Description of the Primary Studies

In total, 60 relevant studies reported in 58 different articles were included in the review. Appendix A provides an overview of these studies and their key characteristics.

Twenty-four studies were published from 2016 to 2021, sixteen from 2010 to 2015, fifteen from 2004 to 2009, and five were published before 2004. The oldest study included in the review was published in 1998. Since then, there has been a noticeable increase in the number of studies published every six years.

Twenty-three studies were conducted in North America, 22 in Asia, 10 in Europe, four in Oceania, and one in South America. Eight languages were included: half of the studies focused on the English language, 16 on Hebrew, and three on Turkish. Other languages included in the studies were Italian, Arabic, Norwegian, and Portuguese.

Regarding study design, 25 of the 60 studies adopted a true experimental design, 31 followed a quasi-experimental design and four used a single-subject design.

The total number of participants across studies is 8341. Nineteen studies included fewer than 51 participants, 20 studies between 51 and 100, 10 studies between 101 and 150, two between 151 and 200, three between 201 and 250, and six included more than 250 participants. More than half (65%) of the studies had fewer than 101 participants. Moreover, the primary studies varied in terms of the age range of their participants. Following the current review's inclusion criteria, the oldest participants of the primary studies were 7-year-olds. The youngest participants were 3-year-olds.

Regarding study approach in terms of media comparison or value-added approach, 40 of the 60 studies were exclusively media comparative (i.e., compared the learning outcomes of children who learned from one type of media or educational technology to those who learned from another type of media), five followed exclusively a value-added approach (i.e., compared the learning outcomes of children who learned from one version of an educational technology to those who learned from another version of the same educational technology), and 15 used both approaches in their study. Therefore, 55

studies were considered below in addressing the first research question and 20 studies were taken into account in addressing the second research question.

Thirty-seven studies focused on the effect of educational technology on one particular early literacy component, whereas 23 investigated multiple components. Most of the studies (n = 52) addressed phonological awareness, 20 focused on letter-sound knowledge, 14 addressed print awareness, and one study investigated rapid automatized naming.

Regarding the grouping structure used in the intervention, most studies (n = 44) had the participants work individually, five studies instructed the participants to work in pairs, three studies divided participants into small groups with 3-4 members, and two studies followed the whole-class approach. In six studies, a combination of two or more grouping structures was used (e.g., participants worked individually and in small groups during the intervention).

Finally, the duration of the intervention in the included studies varied widely, ranging from only three sessions for the whole intervention to daily sessions for one school year. Similarly, the length of intervention sessions was diverse, ranging from 10 minutes to 45 minutes.

Narrative Synthesis of the Primary Studies

Effectiveness of educational technology

Overall, 55 of the 60 studies followed the media comparison approach. To address the first research question, the reported findings on the effectiveness of educational technology for early literacy development in these studies were analyzed. Of the 55 studies, nearly half (n = 25) found a positive intervention effect, indicating that the intervention with educational technology in the domain of early literacy was more effective in increasing participants' early literacy outcomes than the control condition. Of these studies with positive effects, 16 reported effect sizes that ranged from medium to large, one noted effect sizes from small to medium, and nine did not report the effect size of the intervention. Sixteen of the 55 studies reported mixed findings: 15 studies found positive effects for some early literacy outcomes and no effects for other outcomes, and one study observed negative and no effects for different early literacy outcomes. Twelve of the 55 studies reported no significant differences between conditions, while two studies found that the intervention with educational technology was less effective than the control condition.

To address the "control group problem" (Girard et al., 2013), the media comparison studies in this review were divided into subcategories based on the types of control condition. As previously mentioned, some media comparison studies included more than one control condition. Thus, it should be noted that a study may be assigned in more than one subcategory and consequently be mentioned multiple times in the discussion below.

A first subcategory of studies, A-ET/EL (n = 8), consisted of an active control group given an alternative treatment using educational technology on early literacy. The majority of these studies compared code-focused computer games with meaning-focused computer games [14, 17, 40, 43, 54], two compared code-focused computer games with narrative e-books [13, 55], and one compared synthetic phonics activities with analytic phonics activities from the same computer program [10]. All studies examined educational technology's effect on phonological awareness, while three of these studies additionally looked at the effect on letter-sound knowledge [13, 54, 55]. Of all the studies in this subcategory, five reported a positive effect [13, 14, 17, 40, 43], indicating that code-focused computer activities were more effective than meaning-focused applications in improving preschoolers' phonological awareness. Effect sizes ranged from medium to large. However, two studies reported mixed findings [10, 55], noting that one application or set of digital activities was more favorable for some early literacy outcomes but not for other outcomes. For example, Study 55 found that the code-focused computer program "Living Letters" had a significant positive effect on children's phonological awareness but its effect on letter-sound knowledge was non-significant when compared to the narrative e-book condition. Furthermore, one study reported no significant difference in effects of digital letter games and meaning-focused games on both letter-sound knowledge and phonological awareness [54].

A second subcategory, A-ET/NEL (n = 5), consisted of an active control group that received a different treatment using educational technology but did not focus on early literacy (e.g., comparing "Earobics Step 1" early literacy software with "Building Blocks" math software). Instead, the computer programs in the control condition of these studies addressed math (n = 2), science (n = 1), and a combination of early literacy and math (n = 2). Only one of the studies found a positive effect with a moderate effect size [3], which suggested the more favorable effect of early literacy computer games on both print awareness and phonological awareness compared to a combination of literacy and math computer programs. Three studies reported mixed findings with positive effects for some outcomes and no effects for other outcomes [21, 29, 38]. For example, children who used the computer software "JerenAli" which embedded early literacy exercises within stories were found by Study 21 to have greater improvements in letter-sound knowledge but not overall phonological awareness when compared to children who used math games. Similarly, Study 38 observed greater improvements in the letter-sound knowledge of the group that received a curriculum supplement with literacy-focused media elements (e.g., episodes and games from "Sesame Street" and "Super Why!") than the group that received science-focused media supplements, but found no significant differences in their phonological awareness gains. In contrast, Study 29 found that children benefitted more from computer program "Lexia Early Reading" in terms of phonological awareness but not print awareness when compared to the use of a combination of literacy and math computer activities. Finally, one study did not find any significant differences in phonological awareness gains between the intervention group that used an early literacy software and the comparison group that used a math software [2].

A third subcategory, A-NET/EL (n = 16), comprised an active control group that received a non-technology treatment that also focused on early literacy. Instead of using educational technology, the control condition in these studies utilized printed books (n = 8), oral storytelling (n = 1), pen-and-paper exercises (n = 1), and other non-digital activities targeting early literacy (n = 6). Of these studies, six reported a positive intervention effect in favor of the educational technology condition [7, 19, 20, 31, 32, 33]. Effect sizes ranged from medium to large. Four studies reported mixed findings: three studies found positive effects for some early literacy outcomes and no effects for others [23b, 28, 48], while one study found negative effects and no effects for different early literacy outcomes [27]. Whereas four studies found no significant differences between conditions [11, 24, 56, 57], two studies reported that the intervention condition with educational technology was less effective in improving outcomes than the control condition [4, 35]. Overall, results from this subcategory were contradictory. For example, in terms of facilitating print awareness, Studies 19 and 32 suggested greater benefits from e-books than printed books and oral storytelling, while Studies 23b and 48 observed no significant differences between e-books and printed books, and Study 27 found that printed books were more effective than e-books. In terms of raising phonological awareness, some studies found educational technology such as the computer program "Lexia Early Reading" [31] and researcher-developed computer exercises embedded within a story [20] to be more effective than non-digital class activities, while other studies [e.g., 56] did not observe significant differences in effectiveness between an adaptive tablet game and pen-and-paper exercises.

A fourth subcategory, A-NET/NEL (n = 0), involved an active control group that received a non-technology treatment and did not focus on early literacy. None of the included media comparison studies used this type of control group.

Finally, a fifth subcategory, I-BAU (n = 32), included an inactive control group that did not receive a comparison treatment during the study. These studies, which comprise the largest subcategory, described the control condition as the regular preschool program or business as usual. Seventeen studies reported a positive effect [5, 6, 8, 9, 15, 20, 23a, 30a, 32, 33, 41, 42, 45, 48, 49, 50, 58], indicating that the intervention with educational technology was more beneficial than the instruction offered to the inactive control condition. Eight studies reported mixed findings with positive effects for some early literacy outcomes and no effects for others [23b, 26, 34, 36, 39, 47, 51, 52]. Another seven studies found no effects for any of the examined outcomes [1, 22, 24, 25, 30b, 44, 53]. Similar to previous subcategories, results in the I-BAU subgroup were also varied. For example, when comparing e-books with regular preschool activities, Studies 23a, 45, 49, and 50 found these technological tools to be more favorable in supporting phonological awareness, while Studies 22, 24, 25, and 44 did not observe significant differences between conditions.

Features of educational technology and its implementation associated with effectiveness

For the second research question, the findings of the studies following a value-added approach were analyzed while taking into account the features of the educational technology and its implementation that are associated with the effectiveness of the intervention. Overall, 20 of the 60 studies adhered to this particular approach. Of these 20 studies, 12 studies investigated different features of the educational technology [12, 13, 16, 18, 25, 35, 37, 42, 43, 45, 49, 56]. One study focused on the feature of realism [37] by comparing a 2D version of an educational book (i.e., printed book) with a version that uses augmented reality (AR), and found that the AR condition was more effective in promoting preschoolers' rapid letter naming skills compared to the 2D condition. Addressing the feature of metacognitive guidance, two studies compared a base version of an e-book without metacognitive guidance with an enhanced version that includes metacognitive guidance [45, 49]. Both studies found that participants who used the enhanced version of the e-book made more progress in phonological awareness. Speech manipulation was another feature that was examined by one study, which compared a manipulated version (i.e., slowed down speech rate by 150%) of a computer program offering rhyming and synthesis games with a standard version of the same program [43]: it found that the standard version was more effective in increasing phonological awareness than the version with slowed down speech. Turning to the added value of pictorial cues, two studies analyzed the benefit of using integrated pictorial cues in digital alphabet applications on letter-sound: Study 35 found no significant difference in effectiveness when compared to a version with form-taking pictorial cues, while Study 12 found that a version with fading integrated pictorial cues is more effective than another version with non-fading integrated cues or one without pictorial cues at all. Regarding modality, one study reported mixed findings [13]: both conditions with auditory-only and auditory-and-visual support are more beneficial for stimulating phonological awareness than conditions without any support, although the conditions with versus without support did not differ in terms of improvement in letter-sound knowledge. Two studies that investigated the feature of adaptivity had different results: whereas Study 18 reported more gains in both letter-sound knowledge and phonological awareness for children who played an adaptive version of the tablet game compared to those who were in the non-adaptive condition, Study 56 did not observe significant differences between the base and enhanced versions of the game in stimulating the same early literacy components. In two more studies that focused on features of sound categorization [42], dictionary support and hotspots [25], no differences in effectiveness were found as well. Finally, one study focused on features of interactivity, readability, and attention [16] by comparing four versions of a computer e-book and their effectiveness in promoting print awareness: (1) the base version that only includes the story and its pages, (2) an enhanced version that features a small bouncing ball above each word as the narrator's voice reads, (3) another enhanced version that shows unreadable items (e.g., scribbles or digits instead of letter/words) for each page of the book, and (4) another enhanced version where the child is required to click on the unreadable items to move on to the next page. In terms of attention and readability, only the third and fourth conditions showed significant improvements in print awareness, indicating that directing preschoolers' attention to the print did not increase their

understanding of print, but making them aware that not all displays are readable promoted their print awareness. In terms of interactivity, the study compared the third and fourth conditions and reported that the fourth group performed better in the measure for print awareness.

The remaining eight value-added studies investigated features of the implementation of the educational technology [4, 22, 23a, 23b, 26, 46, 47, 54]. Of these studies, two focused on scaffolding by comparing e-book reading with adult support to that without adult support [23b, 26]. Results of both studies showed significant differences between the two groups in improvement in phonological awareness, in favor of e-book reading with adult support. In one study that addressed the teacher's instructional focus when implementing the use of educational technology [4], results revealed that emphasizing phonemes was more beneficial for increasing phonological awareness than focusing on vocabulary. Addressing the contribution of grouping structure, two studies showed different results: Study 46 did not find differences in e-book reading when done individually or with a partner, while Study 47 observed greater gains in phonological awareness for children who read the e-book with a peer. Moreover, children who took the role of tutor within the pair made the most progress. With respect to the number of sessions, two studies again showed different results when comparing the benefit of having five sessions as opposed to only three: Study 22 did not observe differences between the two conditions, whereas Study 23a found five sessions to be more favorable in increasing phonological awareness. Finally, when investigating the potential contribution of an executive functioning support through a stop-and-think procedure implemented using a stuffed animal to which children had to explain their thoughts, one study did not find any significant differences between the conditions in terms of improvements in phonological awareness and letter-sound knowledge [54].

Child characteristics associated with effectiveness of educational technology

For the third research question, findings from both media comparison and value-added studies were analyzed with respect to the child characteristics associated with the effectiveness of the educational technology. Sixteen of the media comparison studies examined various child characteristics. One of the characteristics, gender, was addressed by two studies [19, 36]. Both studies did not find an association between gender and effectiveness of the intervention, indicating that using e-books to stimulate phonological awareness and print awareness were equally successful for boys and girls. Another characteristic, children's at-risk status for learning disabilities (LD), was investigated by two studies [17, 50]: The first study did not observe significant differences in the effect of the computer-based training program "Fast ForWord" which uses a bottom-up approach in facilitating the phonological awareness of children who are at risk of developing LD and those who are not at risk, suggesting the effectiveness of the bottom-up computer program for phonological awareness regardless of children's at-risk status for LD [17]. Similarly, the second study did not find differences in phonological awareness gains between the two status groups after intervention and instead, it provided evidence for the greatest improvement in another component, print awareness, by the at-risk group that

used an e-book. This was in comparison to the improvements made by (a) those without risk of learning disabilities using the same e-book, and (b) those with and without risk of LD who did not use the e-book [50]. Regarding phonological working memory, one study found phonological working memory scores to be positively associated with improvements in the phonological awareness (particularly, blending sounds) scores of the intervention group after using "Lexia Reading Core5" [36]. Focusing on children's prior knowledge or pretest scores, seven studies noted different results. One study did not find an association of pretest score with the effectiveness of educational technology [56], while six studies observed a relationship between these two variables [2, 14, 23b, 28, 30b, 31]. Of the six studies, four found that children with lower pretest scores benefited more from the intervention [2, 23b, 30b, 31]. For example, Study 31 identified greater improvements on phonological awareness of initial low performers who used the computer program "Lexia Early Reading" than the initial low performers who received an alternative non-digital intervention, indicating that educational technology may be particularly beneficial for low-performing children. However, in two studies, children with higher pretest scores had better outcomes after the intervention [14, 28]. For example, Study 14 noted that children who had already mastered their rhyme-level skills before the intervention attained greater gains in phonological awareness (particularly, phoneme-level) scores after receiving tablet activities with explicit phonological instruction, compared to those without rhyme-level skill mastery before starting the same intervention. Regarding the total amount of time children spent on the intervention, two studies addressed its potential association with the effectiveness of educational technology and showed mixed findings [28, 36]. The first study found total intervention time (i.e., time spent using the computer programs) to be associated with growth on phonological awareness, while the second did not observe an association between these two variables. With respect to children's collaborative talk which was investigated by one study, it was noted that the more children engaged in meaningful (unprompted and spontaneously occurring) discussion with each other during their joint activity with an e-book, the better was their performance in measures of sub-syllabic phonological awareness [44]. Regarding error rate, one study observed that as children made more errors while playing adaptive computer games, they performed weaker on phonological awareness measures after the intervention [55]. Finally, other characteristics of children that were also considered but found not to be associated with the effectiveness of educational technology were: ethnicity [52], SES [38, 56], home language [56], English language learner status [36, 52], special education status [52], non-verbal cognitive abilities [28], amount of time spent oriented to the book [57], and children's rating of the intervention [28].

Turning now to the value-added studies, five of them examined the potential association of different child characteristics with the effectiveness of the educational technology. Similar to some media comparison studies, SES was also investigated by two value-added research [22, 25], but this time with mixed findings: Study 22 found no association between children's SES and the effectiveness of an e-book; whereas Study 25 observed significantly greater gains in phonological awareness for

children with low SES after either 3 or 5 e-book intervention sessions, compared to (a) mid-SES children who are also in the intervention groups and (b) low- and mid-SES children in the business-as-usual group. Four studies investigated age as another potential variable associated with the effectiveness of educational technology [12, 22, 23, 46]. Of these studies, three did not find such an association [12, 23a, 46], while one observed that the younger group (4- to 5-year-olds) improved their scores in phonological awareness more than the older group (5- to 6-year-olds) after either 3 or 5 e-book intervention sessions [22]. Finally, one study examined the association between children's segmentation ability at the phoneme level and the effectiveness of educational technology [12]. In the embedded and without-pictorial-cues conditions, children with good first-sound isolation ability performed better in letter-sound knowledge measures after the intervention; however, in the fading condition, there was no difference between children with good and poor first-sound isolation ability.

Discussion

The aim of the current study was to provide a systematic analysis of the available empirical research on the effectiveness of educational technology for stimulating preschoolers' early literacy development. A systematic search was conducted in four databases which resulted in 58 articles with 60 studies. Three research questions, stated at the beginning, were used to guide the review process and analysis. The first research question centered on the findings of the selected studies following a media comparison approach in investigating the overall effectiveness of educational technology on early literacy outcomes. The second research question considered findings from those studies following a value-added approach by taking into account the features of educational technology and its implementation in improving early literacy outcomes. The third research question focused on child characteristics associated with the effectiveness of educational technology in the domain of early literacy. In the following sections, the limitations of the selected primary studies are first taken into account, the main findings concerning each research question are discussed, as well as the limitations of the current systematic review and the findings' implications for practice.

Limitations of the Primary Studies

The findings of the current review are subject to certain limitations of the primary studies that were analyzed. First, despite being in line with the inclusion criteria of this review, several of the primary studies had small numbers of participants and interventions that lasted for short periods of time. This may reduce the reliability of their findings. Second, despite the importance of different early literacy competencies, a vast majority of the primary studies focused on phonological awareness while little attention was given to letter-sound knowledge, print awareness, and rapid automatized naming. Likewise, there is a high concentration of studies conducted in North America and Asia, and on the English and Hebrew languages. Third, although a wide range of features of educational technology and its implementation has been investigated in relation to the effectiveness of learning technology, these

value-added studies remain scarce. As such, findings on which features have an added benefit to learning remain inconclusive. Moreover, research on educational technology tend to focus on various populations, interventions, outcomes, and study designs, which often makes it difficult to generalize results and make definite conclusions from their findings. Therefore, given these weaknesses, the results need to be discussed and interpreted with caution.

RQ 1: Is educational technology effective in stimulating preschoolers' early literacy development?

The first research question entailed the analysis of the effectiveness of educational technology in general according to the findings of the included media comparison studies. Overall, only about half of the media comparison studies reported that the educational technology condition was more effective than the control condition, while more than a fifth indicated that the educational technology condition was as effective as the control/comparison condition. This suggests that although educational technology tends to be effective for stimulating young children's early literacy development, evidence of its superior effectiveness compared to other conditions remains mixed and unclear.

Integrating the findings from the subcategories of media comparison studies, different kinds of educational technology may be effective for specific components of early literacy. However, as previously noted, the majority of the media comparison studies investigated phonological awareness. Consequently, there was relatively more evidence gathered for the effectiveness of educational technology on phonological awareness than effects on the other elements of early literacy. For supporting letter-sound knowledge, digital applications with spelling and letter-related activities/games tend to be favorable. For facilitating print awareness, while e-books and integrated learning systems (ILS) were commonly used in the studies, no clear evidence or trend of effectiveness was found. For promoting phonological awareness, digital applications, e-books, and ILS with rhyming, blending, and spelling activities/games tend to be beneficial. Moreover, educational technology with content that is focused on code tends to be more effective in increasing phonological awareness than those focused on meaning and vocabulary. This can be seen as an interesting finding. First, it corroborates the finding of the National Early Literacy Panel (2008) that code-focused interventions had the greatest effect on phonological awareness. Furthermore, it is consistent with the strong agreement on the importance of code-focused instruction in the beginning stages of learning to read (Castles et al., 2018). Second, it shows that two conditions both using educational technology focused on early literacy can have differences in learning outcomes. As such, differences in learning outcomes cannot be simply attributed to the medium, and instead, factors such as the design, instructional method, and focus within the medium influence changes in learning (Clark, 2001; Mayer, 2011). While the first three subcategories of media comparison studies helped in highlighting this important insight, the fifth subcategory which comprised majority of the media comparison studies provided unclear descriptions of the control condition employed in their studies. As implied by the identification of the "control group problem"

(Girard et al., 2013), it is important to adequately describe and clarify the control employed in a study to allow for a common baseline when comparing the results of the effectiveness of educational technology in different studies.

RQ 2: Which features of educational technology and its implementation are associated with its effectiveness in stimulating preschoolers' early literacy development?

The second research question is about the features of educational technology and its implementation that were investigated in assessing the effectiveness of educational technology in the domain of early literacy. While most studies included in the current review were media comparative, exactly one-third followed the value-added approach and focused on the features that increased the effectiveness of educational technology. As previously noted, the existing value-added studies were much fewer compared to the media comparison studies. Moreover, the investigated features were scattered with only one or two studies focusing on a given feature. Thus, the current review suggests features that may be influencing the effectiveness of educational technology but it cannot provide the final word on the matter.

The review found that several features of educational technology targeting early literacy development have recently attracted research attention. These include level of realism, metacognitive guidance, speech manipulation, pictorial cues, modality, adaptivity, interactivity, dictionary support and hotspots, and sound categorization. Augmented reality, metacognitive guidance, and fading pictorial cues were found by at least one primary study to contribute to the effectiveness of educational technology in facilitating the early literacy development of preschoolers, indicating that these features are promising but further research is needed in the area. Regarding the contribution of the level of realism, the results of the existing study included in this review were in line with the findings of another review by Booton et al. (2021), which suggested that AR is beneficial for students who are learning English as a second language. In contrast, Mayer (2019), similar to Wouters et al. (2013), concluded that realism is not a promising feature when used primarily for aesthetics, citing reports that found higher learning gains in favor of games rendered on desktop computers and with cartoon-like representations than immersive virtual reality and photo realistic representations. However, the positive contribution of realism, particularly AR, may be partially explained by the interaction that happens when engaging with the AR application – that is, children's motor movements when aligning the device and picture book to activate the animation could help them to efficiently make associations and recognize letters (Pan et al., 2021). Another possible explanation is the immersion principle (Makransky, 2021) – the higher psychological presence that children experience due to the level of realism offered by AR facilitates enjoyment which can lead to higher attention and generative processing. Regarding metacognitive guidance embedded in e-books, the results of the review suggest that this feature helps in stimulating the phonological awareness of children at risk for learning disabilities. Guiding learners to plan their

response to the task and evaluate their performance afterwards seemed to address previous findings that weak readers have difficulties regulating their own learning while reading (Shamir, 2017). Regarding the use of fading pictorial cues, it may be that preschoolers benefitted from stimulus fading as it helped them pay attention to the visual features of the letters (de Graaff et al., 2007). Speech manipulation, phonological hotspots, and sound categorization were features found without added value to the effectiveness of educational technology. Regarding the use of slowed down speech in rhyming and synthesis games for preschoolers with language impairment, the review's finding was in contrast to an earlier study in 1996 which involved slightly older children and longer duration of intervention, and thus, the difference in age and design of intervention might be responsible for the different results (Segers & Verhoeven, 2004). Moreover, while an enhanced version of a game might be expected to facilitate added learning compared to its standard version, this finding may be due to the distraction caused by the manipulated speech for the young learners. According to the cognitive theory of multimedia learning, poor instructional design of multimedia causes extraneous cognitive processing and overload in learners (Mayer, 2021). The same explanation may also be given regarding hotspots related to phonological awareness which did not demonstrate an added benefit. These unfavorable findings highlight the problematic features of educational technology, such as causing distraction, in addition to those affordances that can facilitate learning (NASEM, 2018).

The review also found that some research attention has been directed to the implementation features of educational technology, including scaffolding, support for executive functioning, grouping structure, and number of sessions. Scaffolding, which involved adult assistance, was found by a few studies to contribute to the effectiveness of educational technology. Executive functioning support, wherein young players are asked to provide explanation for their answers before deciding, was found to have an added benefit to the use of educational technology. This is in line with previous reviews which focused on a wider age range of learners (e.g., Mayer, 2019; Wouters & van Oostendorp, 2013) and found self-explanation and reflection to be promising instructional support features of educational technology. The beneficial effect of embedding these activities may be explained by the passive dissipation model (Simpson et al., 2012) – the short delay allots time for an impulsive response to fade and helps children replace it with a more self-regulated response. Regarding the grouping structure, the results of the review show mixed findings, with existing studies reporting contradictory outcomes. One existing study indicated that working in pairs with the educational technology was neither more or less effective than working individually, similar to the conclusion of Mayer's (2019) review. However, another study indicated that working in pairs has an added benefit to learning especially when taking the role of a peer tutor. A possible explanation was that, in this context, paired peer learners regulated their peer's behavior which also helped them to regulate their own behavior and thinking (Shamir et al., 2008).

RQ 3: Which child characteristics are associated with the effectiveness of educational technology stimulating preschoolers' early literacy development?

The third research question is about child characteristics which may be related to the effectiveness of educational technology in stimulating children's early literacy development. Similar to the above case concerning features of educational technology and its implementation, various child characteristics were investigated in media comparison and value-added studies. However, as previously stated, there is not enough data from the primary studies to obtain unequivocal conclusions on the role of children's characteristics.

In general, the current review found no evidence that English language learner status, special education status, ethnicity, and home language were associated with the effectiveness of educational technology. Furthermore, contradictory findings were revealed regarding the relevance of age, gender, SES, time spent on the intervention, at-risk status for learning disabilities, and prior knowledge in investigating the effectiveness of educational technology. However, some child characteristics such as collaborative talk, phonological working memory, and error rate were found to be associated with the effectiveness of educational technology in stimulating the different components of early literacy. Interestingly, prior knowledge was investigated by several studies with varying results – while most studies found it associated with the effectiveness of educational technology, at least one value-added study focusing on the feature of adaptivity did not find it relevant. In considering the studies which found prior knowledge relevant, findings remain unclear whether children with high or low prior knowledge benefit more from the use of educational technology. Further research is needed to confirm which and in what direction learner characteristics affect the impact of educational technology.

Limitations of the Current Review

The current systematic review has a number of limitations that need to be acknowledged. One limitation of this study is that it only focused on intervention studies targeting the four abovementioned early literacy components. While these components were selected due to scientific evidence indicating their central role in early reading development, this is not to imply that other early literacy components (e.g., related to vocabulary, meaning, and oral language) are not worthy of research attention and should be ignored. Similarly, this review was limited to cognitive learning outcomes related to early literacy. It should be noted that affective and motivational outcomes are also worth considering in the investigation of the effectiveness of educational technology. Finally, due to limited time and resources, it was not possible to include an assessment of the risk of bias of the primary studies. As such, in an effort to increase the quality of this systematic literature review, only published journal articles were included. Unpublished and/or gray literature was excluded, which may also increase selection bias. In spite of its limitations, the current review adds to the understanding of the effectiveness of educational technology in the domain of early literacy.

Implications

The current systematic review synthesizes and analyzes available empirical research on the effectiveness of educational technology for stimulating young preschoolers' early literacy development. By directing attention to the findings of both media comparison and value-added studies, this review addressed not only whether young preschoolers can learn effectively using educational technology in the early literacy domain, but also whether certain features of educational technology, its implementation, and learner characteristics are associated with its effectiveness. Consequently, this review provides insights into certain instructional and contextual features which may enhance the benefits of using educational technology to facilitate early literacy learning in young children (e.g., augmented reality, metacognitive guidance, fading pictorial cues, and scaffolding). It also sheds light on certain child characteristics which are associated with an increased positive impact from educational technology (e.g., collaborative talk, phonological working memory, and error rate). Therefore, this review has a number of important implications for future practice. First, designers and developers of educational technology would benefit from taking current research evidence into consideration. By using learning theories and principles as their guide, they can construct technological tools within a framework supported by a strong research base. Second, while the use of educational technology is becoming common in early childhood classrooms, educators need to carefully select which tools would be meaningful and appropriate to the needs of their learners. One should not expect that the mere application of technology in the classroom would be an easy solution to the challenges of early literacy instruction. Instead, the answer to whether educational technology can be effective or not is determined by many factors such as its content, design, instructional methods used, and characteristics of the learners. Lastly, this review is a reminder that collaboration among educators, designers, and researchers is important in shaping, evaluating, and improving the design of more effective technologies for learning.

Directions for Future Research

Notwithstanding its limitations, the present study offers valuable insights on the effectiveness of educational technology for supporting the early literacy development of preschoolers. Based on these findings, some recommendations for future research are raised. First, although media comparison research can be useful in determining whether a particular media can be as effective or more effective than conventional media, there is a need to shift research attention toward value-added studies which are relevant to identify design features that can enhance the instructional effectiveness of educational technology. Additionally, research is needed to determine the contextual conditions under which specific features are most beneficial. This includes the investigation of educational technology's implementation features and learners' characteristics. In doing so, the careful design of educational technology may also be used for closing ability gaps. Second, in adding studies to the research base,

rigorous and well-designed experimental research is needed. Among many things, this includes ensuring that control conditions are adequate and vary only in one dimension from the intervention condition. Moreover, it is important that a clear and detailed description of the control condition is provided in the report. Third, it would be useful to conduct longitudinal studies to identify the long-term effects of using educational technology. This could also investigate whether learning gains from educational technology persist beyond possible novelty effects.

Conclusion

Although there is growing interest in the investigation of educational technology's potential to address challenges in early literacy instruction and facilitate young children's learning in this domain, a recent systematic literature review taking into account the findings from media comparison and value-added studies that focused on preschoolers was still missing. Therefore, this study aimed to address this issue by providing a systematic analysis of the available empirical research on the effectiveness of educational technology for stimulating preschoolers' early literacy development while also considering design features and contextual conditions, i.e., implementation features and learner characteristics, that may be associated to its usefulness. The systematic review has found that media comparison studies provide some evidence of the benefits of using educational technology in early literacy instruction, and code-focused games are a promising type of educational technology for improving phonological awareness. Another important finding is that value-added studies indicate certain features of educational technology and its implementation to be associated with its effectiveness. These include augmented reality, metacognitive guidance, fading pictorial cues, and scaffolding. In terms of child characteristics, the review has found that existing studies suggest the association of collaborative talk, phonological working memory, and error rate with the effectiveness of educational technology. Due to limitations in the data from the primary studies, there is a strong need for further research to allow for unambiguous conclusions regarding the features and characteristics that impact the effectiveness of educational technology to be drawn in the future. Despite its weaknesses, this study provides insights into the use of learning technologies in view of enhancing the early literacy development of young children. Overall, the findings of this review can benefit educators, designers, and researchers of educational technology in shaping, evaluating, and improving the design of more effective technologies for early literacy learning.

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Appendices

Appendix A

Table 2

Overview of Primary Studies (Description)

No.	Author (Year)	Language (Country, Continent)	Study design	Study participants	Study approach (Subcategory[a])	Early literacy component (Measure)	Grouping structure of intervention	Duration of intervention (Session length)
1	Amorim et al. (2020)	Portuguese (Brazil, South America	Quasi-experimental	*N* = 737 4-5 y No other specifications	Media comparison (I-BAU)	PA (PAT-OP by Seabra et al., 2013)	Pair	20 sessions in 10 weeks (45 mins, including 25 mins with the mobile application)
2	Anthony (2016)	English (US, North America)	True experimental	*N* = 247 5-6 y From low SES	Media comparison (A-ET/NEL)	PA (non-standardized test with tasks created for the study)	Individual	21 weeks (30 or 45 mins)
3	Bauserman et al. (2005)	English (US, North America)	Quasi-experimental	*N* = 88 5-7 y From low SES	Media comparison (A-ET/NEL)	PRAW (CAP test by Clay, 1979); PA (PAT by Cassady et al., 2002)	Individual	8 weeks (30 mins)
4	Brabham et al. (2006)	English (US, North America)	Quasi-experimental	*N* = 152 5-7 y No other specifications	1: Value-added 2-3: Media comparison (A-NET/EL)	PA (TPI by Murray et al., 2000)	Varied (individual, pair, and small-group)	6 sessions in 4 weeks (10-15 mins)
5	Campbell and Mechling (2009)	English (US, North America)	Single-subject (Multiple-probe)	*N* = 3 5-6 y With learning disabilities	Media comparison (I-BAU)	LSK (task created for the study)	Varied (individual and small-group)	24 sessions in 5-6 weeks (10-20 mins)
6	Carson (2020)	English, (Australia, Oceania)	Quasi-experimental	*N* = 24 4-5 y At-risk for reading difficulties due to developmental language disorder	Media comparison (I-BAU)	LSK (tasks from online PA probes); PA (subtests from PIPA by Dodd et al., 2000, and tasks from online PA probes)	Individual	16 sessions in 8 weeks (20-25 mins)
7	Cassady and Smith (2003)	English (US, North America)	Quasi-experimental	*N* = 88 5-7 y No other specifications	Media comparison (A-NET/EL)	PRAW (CAP test); PA (PAT by Cassady et al., 2002)	Individual	1 school year of daily sessions (20 mins)

No.	Author (Year)	Language (Country, Continent)	Study design	Study participants	Study approach (Subcategory[a])	Early literacy component (Measure)	Grouping structure of intervention	Duration of intervention (Session length)
8	Chai et al. (2015)	English (US, North America)	Single-subject (Multiple-probe)	*N* = 2 5-6 y With developmental delays	Media comparison (I-BAU)	PA (in-game scores)	Individual	61-68 sessions in 6-7 weeks (10 mins)
9	Chera and Wood (2003)	English (UK, Europe)	Quasi-experimental	*N* = 30 3-6 y No other specifications	Media comparison (I-BAU)	PA (subtests from PA Training by Wilson, 1993)	Individual	10 sessions in 4 weeks (10 mins)
10	Comaskey et al. (2009)	English (Canada, North America)	True experimental	*N* = 53 5-6 y From low SES; English language learners (ELLs)	Media comparison (A-ET/EL)	PA (tasks created for the study)	Small-group	40 sessions in 13-16 weeks (10-15 mins)
11	Davidson et al. (2009)	English (US, North America)	Quasi-experimental	*N* = 254 4-5 y From low SES	Media comparison (A-NET/EL)	PA (ISF subtest from DIBELS 2002, rhyming subtest from WJ III, and blending subtest from CTOPP)	Small-group (4) in rotating center	1 school year (Varied)
12	de Graaff et al. (2007)	Dutch (Netherlands, Europe)	True experimental	*N* = 39 5-7 y No other specifications	1-2: Value-added	LSK (receptive and productive tasks created for the study)	Individual	6 sessions in 2 weeks (25 minutes)
13	Elimelech and Aram (2020)	Hebrew (Israel, Asia)	True experimental	*N* = 129 4-6 y From low SES	1-2: Value-added 3: Media comparison (A-ET/EL)	LSK (task in Hebrew created for the study); PA (test created by Levin & Aram, 2013)	Individual	8 sessions in 4 weeks (20 mins)
14	Gilliver et al. (2016)	English, (Australia, Oceania)	Quasi-experimental	*N* = 30 3-5 y With physical disabilities (deaf and hard-of-hearing)	Media comparison (A-ET/EL)	PA (test created for the study with items based on word set used in the intervention)	Individual	6 sessions in 6 weeks (20-30 mins)
15	Goffredo et al. (2016)	Italian (Italy, Europe)	True experimental	*N* = 16 3-6 y Typically-developing	Media comparison (I-BAU)	PA (CMF by Marotta et al., 2008)	Individual	5 sessions in 5 weeks (20 mins)
16	Gong and Levy (2009)	English (Canada, North America)	True experimental	*N* = 96 4-5 y Typically-developing	1-3: Value-added	PRAW (print discrimination task by Levy et al., 2006)	Individual	6 sessions in 4 weeks (10-15 mins)

No.	Author (Year)	Language (Country, Continent)	Study design	Study participants	Study approach (Subcategory[a])	Early literacy component (Measure)	Grouping structure of intervention	Duration of intervention (Session length)
17	Helland et al. (2011)	Norwegian (Norway, Europe)	Quasi-experimental	*N* = 49 5 y At-risk for dyslexia; Typically-developing children	Media comparison (A-ET/EL)	PA (rhyme, same initial phoneme, and phoneme deletion subtests from Ringerik Material by Lyster et al., 2002)	Individual	40 sessions in 8 weeks (20 mins)
18	Hooshyar et al. (2018)	English (South Korea, Asia)	True experimental	*N* = 102 4-6 y No other specifications	Value-added	LSK (in-game scores); PA (in-game scores)	Individual	Unclear
19	Ihmeideh (2014)	Arabic (Jordan, Asia)	Quasi-experimental	*N* = 92 4-5 y From low and middle SES; Typically-developing	Media comparison (A-NET/EL)	PRAW (CAP test by Clay, 1979, adapted to Hebrew); LSK (task created for the study); PA (items created for the study)	Individual	40 sessions in 8 weeks (15 mins)
20	Kartal et al. (2016)	Turkish (Turkey, Asia)	Quasi-experimental	*N* = 53 4-6 y No other specifications	1: Media comparison (A-NET/EL) 2: Media comparison (I-BAU)	PA (PASS-T)	Individual	8-12 sessions in 4-6 weeks (17 mins)
21	Kartal and Terziyan (2016)	Turkish (Turkey, Asia)	True experimental	*N* = 20 4-6 y From low SES	Media comparison (A-ET/NEL)	LSK (task created for the study); PA (PASS-T)	Individual	27 sessions in 9 weeks (12 mins)
22	Korat and Blau (2010)	Hebrew (Israel, Asia)	True experimental	*N* = 247 4-6 y From low and middle SES	1: Value-added 2: Media comparison (I-BAU)	PA (sub-syllabic segmentation task created for the study with target words from the storybook)	Small-group (3; without adult support)	3 or 5 sessions (20-25 mins)
23a	Korat and Segal-Drori (2016) (Study 1)	Hebrew (Israel, Asia)	True experimental	*N* = 214 4-6 y From low SES	1: Value-added 2: Media comparison (I-BAU)	PA (test created for the study)	Individual	3 or 5 sessions (20-25 mins)
23b	Korat and Segal-Drori (2016) (Study 3)	Hebrew (Israel, Asia)	True experimental	*N* = 128 5-6 y From low SES	1: Value-added 2: Media comparison (A-NET/EL) 3: Media comparison (I-BAU)	PRAW (CAP test by Clay, 1979, adapted to Hebrew); LSK (task created for the study); PA (test created for the study)	Individual	4 sessions (15-20 mins)

No.	Author (Year)	Language (Country, Continent)	Study design	Study participants	Study approach (Subcategory[a])	Early literacy component (Measure)	Grouping structure of intervention	Duration of intervention (Session length)
24	Korat and Shamir (2007)	Hebrew (Israel, Asia)	True experimental	*N* = 128 5-6 y From low and middle SES	1: Media comparison (A-NET/EL) 2: Media comparison (I-BAU)	PA (sub-syllabic segmentation task created for the study)	Individual	3 sessions (20-35 mins)
25	Korat and Shamir (2008)	Hebrew (Israel, Asia)	True experimental	*N* = 149 5-6 y From low and middle SES	1-2: Value-added 3: Media comparison (I-BAU)	PA (sub-syllabic segmentation task created for the study)	Individual	3 sessions (20-35 mins)
26	Korat et al. (2011)	Hebrew (Israel, Asia)	True experimental	*N* = 96 5-6 y From low SES	1: Value-added 2: Media comparison (I-BAU)	PA (opening and closing phoneme tasks by Aviram, 2004, and syllabic and sub-syllabic segmentation tasks created for the study)	Pair	4 sessions (15-20 mins)
27	Kozminsky and Asher-Sadon (2013)	Hebrew (Israel, Asia)	Quasi-experimental	*N* = 50 5-7 y Typically-developing	Media comparison (A-NET/EL)	PRAW; PA (measures adapted from existing tests by Blum, 2001; Drori, 1998; and Tuval and Zeiler, 1995)	Individual	5 sessions (10-31 mins)
28	Lonigan et al. (2003).	English (US, North America)	True experimental	*N* = 41 3-5 y At-risk for reading difficulties	Media comparison (A-NET/EL)	PA (rhyme oddity, rhyme matching, word blending, syllable and phoneme blending, word elision, syllable and phoneme elision tasks created for the study)	Individual	32-40 sessions in 8 weeks (15-20 mins)
29	Macaruso and Rodman (2011a)	English (US, North America)	Quasi-experimental	*N* = 66 3-5 y English language learners (ELLs)	Media comparison (A-ET/NEL)	PRAW; PA (print awareness, sound matching, and rhyming subtests from GRADE Level K by Williams, 2001)	Individual	55 sessions in 32 weeks (15-20 mins)
30a	Macaruso and Rodman (2011b)	English (US, North America)	Quasi-experimental	*N* = 38 4-5 y Typically-developing	Media comparison (I-BAU)	PA (sound matching and rhyming subtests from GRADE Level K by Williams, 2001)	Individual	16 weeks (10-15 mins)
30b	Macaruso and Rodman (2011b) (Study 2)	English (US, North America)	Quasi-experimental	*N* = 66 5-6 y No other specifications	Media comparison (I-BAU)	PRAW; PA (print awareness, sound matching, and rhyming subtests from GRADE Level K by Williams, 2001)	Individual	7 months (15-20 mins)

No.	Author (Year)	Language (Country, Continent)	Study design	Study participants	Study approach (Subcategory[a])	Early literacy component (Measure)	Grouping structure of intervention	Duration of intervention (Session length)
31	Macaruso and Walker (2008)	English (US, North America)	Quasi-experimental	*N* = 71 5-6 y No other specifications	Media comparison (A-NET/EL)	PA (ISF and PSF subtests from DIBELS, and oral language concepts subtest from GMRT 2000)	Individual	48 sessions in 24 weeks (15-20 mins)
32	Maureen et al. (2018)	Unclear (Indonesia, Asia)	Quasi-experimental	*N* = 37 5-6 y No other specifications	1: Media comparison (A-NET/EL) 2: Media comparison (I-BAU)	PRAW; LSK; PA (tests created for the study)	Whole-class	3 sessions in 3 weeks (30 mins)
33	Mioduser et al. (2000)	Hebrew (Israel, Asia)	Quasi-experimental	*N* = 46 5-6 y At-risk for reading disabilities	1: Media comparison (A-NET/EL) 2: Media comparison (I-BAU)	PA (PAT by Lapidot et al., 1995)	Individual	1 school year (Unclear)
34	Neumann (2018)	English, (Australia, Oceania)	True experimental	*N* = 48 5-6 y With learning disabilities; At-risk for learning and reading disabilities	Media comparison (I-BAU)	PRAW (CAP test by Clay, 2005); LSK (test created for the study)	Individual	9 sessions in 9 weeks (30 mins)
35	Nicholas et al. (2016)	English, (Australia, Oceania)	Quasi-experimental	*N* = 48 5-6 y From low SES	1: Value-added 2: Media comparison (A-NET/EL)	LSK (test created for the study)	Varied (individual, pair, and small-group)	10 sessions in 10 weeks (20 mins)
36	O'Callaghan et al. (2016)	English (UK, Europe)	True experimental	*N* = 98 4-6 y Below-average students	Media comparison (I-BAU)	PA (blending and phoneme segmentation subtests from PhAB-2)	Individual	40 sessions in 8 weeks (20-30 mins)
37	Pan et al. (2021)	English (US, North America)	Quasi-experimental	*N* = 76 3-6 y No other specifications	Value-added	RAN (task created for the study)	Individual	6 weeks (10-30 mins)
38	Penuel et al. (2012)	English (US, North America)	Quasi-experimental	*N* = 436 3-4 y From low SES	Media comparison (A-ET/NEL)	LSK; PA (letter sounds and beginning sound subtests from PALS-PreK)	Whole-class	10 weeks = 25 hours (Varied)

No.	Author (Year)	Language (Country, Continent)	Study design	Study participants	Study approach (Subcategory[a])	Early literacy component (Measure)	Grouping structure of intervention	Duration of intervention (Session length)
39	Putman (2017)	English (US, North America)	Quasi-experimental	*N* = 72 5-7 y No other specifications	Media comparison (I-BAU)	PRAW; LSK; PA (CAP, letter sounds, and hearing/recording sounds subtest from OSELA 2002)	Individual	20-24 weeks (Unclear)
40	Reitsma and Wesseling (1998)	Dutch (Netherlands, Europe)	Quasi-experimental	*N* = 98 4-5 y No other specifications	1: Media comparison (A-ET/EL)	PA (blending and phoneme segmentation tasks created for the study)	Individual	24 sessions in 12 weeks (10 mins)
41	Ross and Joseph (2021)	English (US, North America)	Single-subject (Multiple-probe)	*N* = 5 5-6 y English language learners (ELLs)	Media comparison (I-BAU)	LSK (task created for the study with trained and untrained words)	Individual	16 weeks (15 mins)
42	Samur (2019)	Turkish (Turkey, Asia)	Quasi-experimental	*N* = 87 4-5 y No other specifications	1: Value-added 2: Media comparison (I-BAU)	LSK (test created for the study)	Individual	12 sessions in 12 weeks (10 mins)
43	Segers and Verhoeven (2004)	Dutch (Netherlands, Europe)	Quasi-experimental	*N* = 36 4-6 y With specific language impairment	1: Value-added 2: Media comparison (A-ET/EL)	PA (tasks from existing tests)	Individual	5 weeks (15 mins)
44	Shamir (2009)	Hebrew (Israel, Asia)	True experimental	*N* = 96 5-6 y From low SES	Media comparison (I-BAU)	PA (syllabic and sub-syllabic segmentation tasks in Hebrew by Shamir et al., 2008)	Pair	3 sessions (35 mins)
45	Shamir (2017)	Hebrew (Israel, Asia)	True experimental	*N* = 78 4-7 y At-risk for learning disabilities	1: Value-added 2: Media comparison (I-BAU)	PA (rhyming measure created for the study)	Individual	6 sessions (20 mins)
46	Shamir and Korat (2007)	Hebrew (Israel, Asia)	True experimental	*N* = 72 5-6 y From low SES; Typically-developing	Value-added	PA (sub-syllabic segmentation task created for the study)	Varied (individual or pair)	3 sessions (30 mins)
47	Shamir et al. (2008).	Hebrew (Israel, Asia)	True experimental	*N* = 110 5-6 y From low SES; Typically-developing	1: Value-added 2: Media comparison (I-BAU)	PA (syllabic and sub-syllabic segmentation tasks created for the study, and initial and final phoneme tasks by Aram & Levin, 2001)	Pair: Tutor/tutee	2-3 sessions (30 mins)

No.	Author (Year)	Language (Country, Continent)	Study design	Study participants	Study approach (Subcategory[a])	Early literacy component (Measure)	Grouping structure of intervention	Duration of intervention (Session length)
48	Shamir et al. (2012)	Hebrew (Israel, Asia)	Quasi-experimental	*N* = 110 5-7 y At-risk for learning disabilities	1: Media comparison (A-NET/EL) 2: Media comparison (I-BAU)	PRAW (CAP test adapted to Hebrew); PA (sub-syllabic awareness task created for the study)	Varied (Individual for e-book; small groups for printed book)	6 sessions (20-35 mins)
49	Shamir and Lifshitz (2013)	Hebrew (Israel, Asia)	True experimental	*N* = 77 4-7 y At-risk for learning disabilities	1: Value-added 2: Media comparison (I-BAU)	PA (rhyming measure created for the study)	Individual	5 or 6 sessions (20 mins)
50	Shamir and Shlafer (2011)	Hebrew (Israel, Asia)	True experimental	*N* = 136 5-7 y At-risk for learning disabilities	Media comparison (I-BAU)	PRAW (CAP test adapted to Hebrew by Shatil, 2001); PA (sub-syllabic awareness measure created for the study)	Individual	6 sessions (20-35 mins)
51	Shamir et al. (2017)	English (US, North America)	Quasi-experimental	*N* = 516 5-7 y No other specifications	Media comparison (I-BAU)	PRAW; PA (concept of word and phonemic awareness subtests from STAR EL Assessments, and PSF subtest from DIBELS)	Individual	1 school year of daily sessions (15 mins)
52	Shamir et al. (2018)	English (US, North America)	Quasi-experimental	*N* = 1696 5-7 y No other specifications	Media comparison (I-BAU)	LSK; PA (subtests from TPRI)	Individual	1 school year of daily sessions (15 mins)
53	Tracey and Young (2007)	English (US, North America)	Quasi-experimental	*N* = 265 5-7 y From low SES; At-risk for early literacy delays	Media comparison (I-BAU)	PA (LAC Test)	Individual	32 weeks of daily sessions (15 mins)
54	van de Sande et al. (2016)	Dutch (Netherlands, Europe)	True experimental	*N* = 101 4-7 y No other specifications	1: Value-added 2: Media comparison (A-ET/EL)	LSK; PA (tasks from existing tests)	Individual	10 sessions in 5 weeks (20 mins)
55	Van der Kooy-Hofland et al. (2012)	Dutch (Netherlands, Europe)	True experimental	*N* = 110 5-6 y At-risk for or with early literacy delays	Media comparison (A-ET/EL)	LSK; PA (measures created for the study)	Individual	15 sessions in 15 weeks (10-15 mins)

No.	Author (Year)	Language (Country, Continent)	Study design	Study participants	Study approach (Subcategory[a])	Early literacy component (Measure)	Grouping structure of intervention	Duration of intervention (Session length)
56	Vanbecelaere et al. (2020)	Dutch (Belgium, Europe)	Quasi-experimental	*N* = 191 5-6 y No other specifications	1: Value-added 2: Media comparison (A-NET/EL)	LSK (Letterkennistoets 1 and 2 by Aarnoutse et al., 2010); PA (standardized test by Aarnoutse et al., 2010)	Individual	5 sessions in 5 weeks (30 mins)
57	Willoughby et al. (2015)	English (Canada, North America)	Quasi-experimental	*N* = 94 3-4 y No other specifications	1-2: Media comparison (A-NET/EL)	LSK (task created for the study); PA (initial sound-same subtest from TOPA-K)	Varied (individual and small-group)	16 sessions in 8 weeks (20 mins)
58	Wood et al. (2013)	English (US, North America)	Single-subject (Multiple-probe)	*N* = 4 5-7 y At-risk for reading failure	Media comparison (I-BAU)	PA (PSF subtest from DIBELS)	Pair: Tutor/tutee	Varied (7 mins)

Note. CAP = Concepts about Print; CMF = Valutazione delle Competenze Metafonologiche; CTOPP = Comprehensive Test of Phonological Processing; DIBELS = Dynamic Indicators of Basic Early Literacy Skills; GMRT = Gates-MacGinitie Reading Test; GRADE = Group Reading Assessment and Diagnostic Evaluation; ISF = Initial Sound Fluency; LAC = Lindamood Auditory Conceptualization; LSK = letter-sound knowledge; OSELA = Observation Survey of Early Literacy Achievement; PA = phonological awareness; PALS-PreK = Phonological Awareness Literacy Screening for pre-Kindergarten; PASS-T = Phonological Awareness Skills Screening Test for Turkish; PAT = Phonological Awareness Test; PAT-OP = Phonological Awareness Test by Oral Production; PhAB = Phonological Awareness Battery 2nd Edition; PRAW = print awareness; RAN = rapid automatized naming; STAR = Standardized Test for the Assessment of Reading; TOPA-K = Test of Phonological Awareness – kindergarten version; TPI = Test of Phoneme Identities; TPRI = Texas Primary Reading Inventory; WJ III = Woodcock-Johnson Tests of Achievement III.

[a] A-ET/EL = active control group with educational technology/early literacy treatment; A-ET/NEL = active control group with educational technology/non-early literacy treatment; A-NET/EL = active control group with non-technology/early literacy treatment; A-NET/NEL = active control group with non-technology/non-early literacy treatment; I-BAU = inactive control group with unclear description or business as usual.

Appendix B

Table 3

Overview of Primary Studies (Findings)

No.	Author (Year)	Study approach (Subcategory[a])	Educational technology and early literacy condition/s	Activities in the control condition/s	Main findings			
					Significant difference between conditions[b]	Effect size[c]	Investigated features of educational technology and its implementation[d]	Investigated learner characteristics[d]
1	Amorim et al. (2020)	Media comparison (I-BAU)	Game-enhanced instructional program using "Escribo Play" tablet application	No intervention	No (0)	NA	NA	NA
2	Anthony (2016)	Media comparison (A-ET/NEL)	Computer games for PA from "Earobics Step 1" software	“Building Blocks” math software	No (0)	NA	NA	Pretest scores (-with rhyme skills)
3	Bauserman et al. (2005)	Media comparison (A-ET/NEL)	PLATO ILS "Beginning Reading for the Real World, Level A" as part of computer center time	Varied literacy and math programs as part of computer center time	Yes (+)	Medium	NA	NA
4	Brabham et al. (2006)	1: Value-added 2-3: Media comparison (A-NET/EL)	Independent practice center using computer e-book focusing on phonemes 1: Independent practice center using computer e-book focusing on vocabulary	2: Independent practice center using printed books and audiotape read-aloud focusing on phonemes 3: Independent practice center using printed books and audiotape read-aloud focusing on vocabulary	2-3: Yes (-)	Small	1: Instructional focus [Vocabulary vs. Phoneme (+ for phoneme-focus)]	NA
5	Campbell and Mechling (2009)	Media comparison (I-BAU)	Small-group CAI using SMART Board technology (large interactive touch screen)	No intervention	Yes (+)	NA		
6	Carson (2020)	Media comparison (I-BAU)	Reading Doctor iPad applications instead of usual small group instruction	No intervention	Yes (+)	Large	NA	NA
7	Cassady and Smith (2003)	Media comparison (A-NET/EL)	ILS Waterford "Early Reading Program"	Professional development on reading promotion for teachers	Yes (+)	Medium for PRAW Large for PA	NA	NA

No.	Author (Year)	Study approach (Subcategory[a])	Educational technology and early literacy condition/s	Activities in the control condition/s	Main findings			
					Significant difference between conditions[b]	Effect size[c]	Investigated features of educational technology and its implementation[d]	Investigated learner characteristics[d]
8	Chai et al. (2015)	Media comparison (I-BAU)	Researcher-developed iPad application "Touch Sound"	No intervention	Yes (+)	NA		
9	Chera and Wood (2003)	Media comparison (I-BAU)	Computer e-books with activity pages	No intervention	Yes (+)	NA	NA	NA
10	Comaskey et al. (2009)	Media comparison (A-ET/EL)	Synthetic phonics activities from web-based computer program "ABRACADABRA" as part of reading center Analytic phonics activities from web-based computer program "ABRACADABRA" as part of reading center	NA	Mixed: in favor of synthetic group for PA blending, and common-coda; analytic group for PA common-rime	NA	NA	NA
11	Davidson et al. (2009)	Media comparison (A-NET/EL)	"Ready, Set, Learn" technology-enhanced literacy program with paper-based technology	Non-technology literacy program	No (0)	Small	NA	NA
12	de Graaff et al. (2007)	1-2: Value-added	Computer training program using integrated-picture mnemonics with fading procedure 1: Embedded without fading condition 2: Without picture condition	NA	NA	NA	1: Fading condition [Embedded vs. Fading (+ in favor of fading)] 2: Pictorial cue [Without vs. With (0)]	Age (0) Segmentation ability (0 with fading condition)

No.	Author (Year)	Study approach (Subcategory[a])	Educational technology and early literacy condition/s	Activities in the control condition/s	Main findings			
					Significant difference between conditions[b]	Effect size[c]	Investigated features of educational technology and its implementation[d]	Investigated learner characteristics[d]
13	Elimelech and Aram (2020)	1-2: Value-added 3: Media comparison (A-ET/EL)	Researcher-designed digital spelling game on laptop with auditory support 1: Digital spelling game with auditory and visual support 2: Digital spelling game without support 3: Narrative e-book watching	NA	3: Yes (in favor of digital spelling game)	Med to large	1-2: Modality [No Support vs. Auditory Support vs. Auditory+Visual Support (0 for LSK; + in favor of groups with support for PA, no difference between groups with support)]	NA
14	Gilliver et al. (2016)	Media comparison (A-ET/EL)	Researcher-developed tablet teaching activities with explicit PA instruction Researcher-developed tablet teaching activities with vocabulary-focused instruction	NA	Yes (in favor of explicit-PA group)	NA	NA	Pretest scores (+ with phoneme-level skills)
15	Goffredo et al. (2016)	Media comparison (I-BAU)	Researcher-developed computer platform "En Plein" with interactive motion-based activities	No intervention	Yes (+)	NA	NA	NA
16	Gong and Levy (2009)	1-3: Value-added	Computer e-book story sessions - Story Control condition 1: Bouncing ball condition 2: Violation condition 3: Action condition	NA	NA	NA	1-3: Attention and Readability [Story Control (0), Bouncing Ball (0), Violation (+), Action (+)] Interactivity [Violation vs. Action (+ in favor of Action)]	NA

No.	Author (Year)	Study approach (Subcategory[a])	Educational technology and early literacy condition/s	Activities in the control condition/s	Main findings			
					Significant difference between conditions[b]	Effect size[c]	Investigated features of educational technology and its implementation[d]	Investigated learner characteristics[d]
17	Helland et al. (2011)	Media comparison (A-ET/EL)	Computer-based training program "Fast ForWord" with BU approach Computer-based training program "Omega-Is" with TD approach	NA	Yes (in favor of BU condition)	Large	NA	At-risk status for dyslexia (0 with BU condition)
18	Hooshyar et al. (2018)	Value-added	Language learning tablet game - adaptive condition Language learning tablet game - non-adaptive condition	NA	NA	NA	Adaptivity (+)	NA
19	Ihmeideh (2014)	Media comparison (A-NET/EL)	E-book reading with book-related activities	Printed book reading with book-related activities	Yes (+)	NA	NA	Gender (0)
20	Kartal et al. (2016)	1-2: Media comparison (A-NET/EL; I-BAU)	Researcher-developed computer software with 14 modules of exercises embedded in story	1: Non-technology game-like in-class training 2: No intervention	1-2: Yes (+), but none in follow-up	Medium	NA	NA
21	Kartal and Terziyan (2016)	Media comparison (A-ET/NEL)	Computer software "JerenAli" with exercises embedded in stories	Math software	Mixed (+ for LSK and PA phoneme segmentation; 0 for other PA subtests)	NA	NA	NA
22	Korat and Blau (2010)	1: Value-added 2: Media comparison (I-BAU)	Researcher-developed "considerate" e-book with different modes - Three-session condition 1: Five-session condition	2: No intervention	2: No (0)	NA	1: Number of sessions [3 vs. 5 sessions (0 for PA, but + for word reading)]	NA
23a	Korat and Segal-Drori (2016) (Study 1)	1: Value-added 2: Media comparison (I-BAU)	Researcher-developed "considerate" e-book with different modes - Three-session condition 1: Five-session condition	2: No intervention	2: Yes (+)	Medium	1: Number of sessions [3 vs. 5 sessions (+ in favor of 5 sessions)]	Age (0)
23b	Korat and Segal-Drori (2016) (Study 3)	1: Value-added 2-3: Media comparison (A-NET/EL; I-BAU)	Researcher-developed "considerate" e-book reading with adult support 1: Without adult support condition	2: Printed book reading with adult support 3: No intervention	2-3: Mixed (+ for PA, but 0 for PrAw and LSK)	Medium	1: Scaffolding [Mixed (+ for PA, but 0 for PrAw and LSK)]	NA

No.	Author (Year)	Study approach (Subcategory[a])	Educational technology and early literacy condition/s	Activities in the control condition/s	Main findings			
					Significant difference between conditions[b]	Effect size[c]	Investigated features of educational technology and its implementation[d]	Investigated learner characteristics[d]
24	Korat and Shamir (2007)	1-2: Media comparison (A-NET/EL; I-BAU)	Researcher-developed "considerate" e-book reading with different modes	1: Printed book reading with limited adult support 2: No intervention	1-2: No (0)	NA	NA	SES (0)
25	Korat and Shamir (2008)	1-2: Value-added 3: Media comparison (I-BAU)	Researcher-developed "considerate" e-book reading - Story only condition 1: Dictionary mode condition 2: Play mode condition	3: No intervention	3: No (0 for PA, but + for word meaning and word recognition)	NA	1: Dictionary (0 for PA, + for word meaning and recognition) 2: Hotspot [PA vs. Story Comprehension (0)]	SES (-)
26	Korat et al. (2011)	1: Value-added 2: Media comparison (I-BAU)	Researcher-developed "considerate" e-book reading with adult support 1: Without adult support condition	2: No intervention	2: Mixed (+ for PA opening and closing phoneme, 0 for PA sub-syllabic segmentation)	Medium to large	1: Scaffolding (+)	NA
27	Kozminsky and Asher-Sadon (2013)	Media comparison (A-NET/EL)	Researcher-developed e-book reading with two story sessions and three sessions for digital literacy activities	Printed book reading session with two story sessions and three sessions for literacy activities with experimenter	Mixed (0 for PA, - for PRA)	Medium	NA	NA
28	Lonigan et al. (2003).	Media comparison (A-NET/EL)	CAI programs "Daisy's Quest" and "Daisy's Castle"	Non-technology Head Start program	Mixed (+ for Rhyme Matching, Word Elision, Syllable and Phoneme Elision; 0 for other PA subtests)	Large	NA	Pretest scores [Vocabulary (+); Letter knowledge (0)] Amount of time spent on the intervention (+) Non-verbal cognitive abilities (0) Rating of CAI program (0)

No.	Author (Year)	Study approach (Subcategory[a])	Educational technology and early literacy condition/s	Activities in the control condition/s	Main findings			
					Significant difference between conditions[b]	Effect size[c]	Investigated features of educational technology and its implementation[d]	Investigated learner characteristics[d]
29	Macaruso and Rodman (2011a)	Media comparison (A-ET/NEL)	CAI programs "Lexia Early Reading" and "Primary Reading"	Unstructured computer use with varied literacy and math activities	Mixed (+ for PA; 0 for PRA)	Med	NA	Pretest scores (-)
30a	Macaruso and Rodman (2011b)	Media comparison (I-BAU)	CAI program "Lexia Early Reading"	No intervention	Yes (+)	Large	NA	NA
30b	Macaruso and Rodman (2011b) (Study 2)	Media comparison (I-BAU)	CAI programs "Lexia Early Reading" and "Lexia Primary Reading"	No intervention	No (0)	NA	NA	NA
31	Macaruso and Walker (2008)	Media comparison (A-NET/EL)	CAI program "Lexia Early Reading"	Non-technology language arts activities	Yes (+)	NA	NA	Pretest scores (-)
32	Maureen et al. (2018)	1-2: Media comparison (A-NET/EL; I-BAU)	Digital storytelling activities using projection device	1: Oral storytelling 2: No intervention	1-2: Yes (+)	Large	NA	NA
33	Mioduser et al. (2000)	1-2: Media comparison (A-NET/EL; I-BAU)	Reading program "I have a secret - I can read" using touchscreen software	1: Same reading program with printed materials only 2: No intervention	Yes (+)	NA	NA	NA
34	Neumann (2018)	Media comparison (I-BAU)	iPad literacy program with selected apps "Endless Alphabet", "Letter School", and "Draw Buddy"	No intervention	Mixed (+ for LSK, 0 for PRAW)	Medium	NA	NA
35	Nicholas et al. (2016)	1: Value-added 2: Media comparison (A-NET/EL)	Researcher-developed tablet application "A to Z Safari" with guided reading sessions - Integrated picture cues condition 1: Form-taking picture cues condition	2: Non-technology teacher-led activities in guided reading session	2: Yes (-)	NA	1: Pictorial cues [Form-taking vs. Integrated (0)]	NA

No.	Author (Year)	Study approach (Subcategory[a])	Educational technology and early literacy condition/s	Activities in the control condition/s	Main findings			
					Significant difference between conditions[b]	Effect size[c]	Investigated features of educational technology and its implementation[d]	Investigated learner characteristics[d]
36	O'Callaghan et al. (2016)	Media comparison (I-BAU)	Online CAI program Lexia Reading Core5 without adult-mediated support	No intervention	Mixed (+ for PA blending; 0 for PA phoneme segmentation)	Small to medium	NA	Gender (0) Phonological working memory (+) English language learner status (0) Amount of time spent on the intervention (0)
37	Pan et al. (2021)	Value-added	Researcher-developed book set as part of learning center - AR condition 2D condition		NA	NA	Realism [2D vs. AR (+ in favor of AR)]	NA
38	Penuel et al. (2012)	Media comparison (A-ET/NEL)	Media-rich curriculum supplement "PBS Kids Raising Readers Curriculum Supplement"	Science media supplement	Mixed (+ for LSK; 0 for PA)	Medium	NA	SES (0)
39	Putman (2017)	Media comparison (I-BAU)	ILS Istation "Early Reading"	No intervention	Mixed: (+ for PA and LSK; 0 for PRAW)	NA	NA	NA
40	Reitsma and Wesseling (1998)	Media comparison (A-ET/EL)	CAI training program with exercises focusing on blending Same computer program with exercises for vocabulary	NA	Yes (in favor of blending exercises)	Large	NA	NA
41	Ross and Joseph (2021)	Media comparison (I-BAU)	iPad application "Build a Word - Easy Spelling with Phonics"	No intervention	Yes (+)	Medium	NA	NA
42	Samur (2019)	1: Value-added 2: Media comparison (I-BAU)	Researcher-developed mobile game "Kes Sesi" - without categorization condition 1: With predefined sound categorization condition	2: No intervention	2: Yes (+)	Medium	1: Sound categorization (0)	NA

No.	Author (Year)	Study approach (Subcategory[a])	Educational technology and early literacy condition/s	Activities in the control condition/s	Main findings			
					Significant difference between conditions[b]	Effect size[c]	Investigated features of educational technology and its implementation[d]	Investigated learner characteristics[d]
43	Segers and Verhoeven (2004)	1: Value-added 2: Media comparison (A-ET/EL)	Researcher-developed computer program with rhyming and synthesis games - Normal speech condition 1: Slowed down speech condition 2: Computer vocabulary games condition	NA	2: Yes (in favor of rhyming and synthesis games)	Large	1: Speech manipulation [Slowed vs. Normal (+ in favor of normal)]	NA
44	Shamir (2009)	Media comparison (I-BAU)	Researcher-developed e-book with different modes and pair activity	No intervention	No (0 for PA, but + for total early literacy score with PA and word meaning)	NA	NA	Collaborative talk (+)
45	Shamir (2017)	1: Value-added 2: Media comparison (I-BAU)	Researcher-developed e-book with different modes - Metacognitive guidance condition 1: Without metacognitive guidance condition	2: No intervention	2: Yes (+)	Medium	1: Metacognitive guidance (+)	NA
46	Shamir and Korat (2007)	Value-added	Researcher-developed e-book with different modes and activity - Pair condition Value-added (Individual condition)	NA	NA	NA	Grouping structure [Individual vs. Pair (0)]	Gender (0)
47	Shamir et al. (2008).	1: Value-added 2: Media comparison (I-BAU)	Commercially available e-book with different modes and activity sessions - Pair condition 1: Individual condition	2: No intervention	Mixed (+ for PA sub-syllabic, 0 for other PA subtests)	Partial Eta^2 = 0.15	1: Grouping structure [Individual vs. Pair (+, even greater for tutor)]	NA
48	Shamir et al. (2012)	1-2: Media comparison (A-NET/EL; I-BAU)	Researcher-developed e-book with different modes and structured activities	1: Small-group adult-led reading of printed book) 2: No intervention	1: Mixed (+ for PA; 0 for PRAW) 2: Yes (+)	Large	NA	NA

No.	Author (Year)	Study approach (Subcategory[a])	Educational technology and early literacy condition/s	Activities in the control condition/s	Main findings			
					Significant difference between conditions[b]	Effect size[c]	Investigated features of educational technology and its implementation[d]	Investigated learner characteristics[d]
49	Shamir and Lifshitz (2013)	1: Value-added 2: Media comparison (I-BAU)	E-book with different modes - Metacognitive guidance condition 1: Without metacognitive guidance condition	2: No intervention	2: Yes (+)	Medium	1: Metacognitive guidance (+)	NA
50	Shamir and Shlafer (2011)	Media comparison (I-BAU)	Researcher-developed e-book with different modes	No intervention	Yes (+)	Small to medium	NA	At-risk status for learning disabilities (+ with PRAW, 0 with PA)
51	Shamir et al. (2017)	Media comparison (I-BAU)	ILS Waterford "Early Reading Program"	No intervention	Mixed (+ for PA STAR; 0 for PRAW, PA DIBELS)	NA	NA	NA
52	Shamir et al. (2018)	Media comparison (I-BAU)	ILS Waterford "Early Reading Program"	No intervention	Mixed (+ for LSK; 0 for PA)	Medium	NA	Special education status (0) English language learner status (0) Ethnicity (0)
53	Tracey and Young (2007)	Media comparison (I-BAU)	ILS Waterford "Early Reading Program" Level 1	No intervention	No (0 for PA-Lindawood, but + on other PA tests)	NA	NA	NA
54	van de Sande et al. (2016)	1: Value-added 2: Media comparison (A-ET/EL)	Computer (laptop) software "Schatkist met de Muis" with PA and letter knowledge learning games - Embedded EF support condition 1: Without EF support condition 2: Computer language discovery games from the same program	NA	2: No (0 for immediate post-test, but + for follow-up)	Small	1: EF Support (0 for immediate post-test, but + for follow-up)	NA
55	Van der Kooy-Hofland et al. (2012)	Media comparison (A-ET/EL)	Web-based computer program "Living Letters" with adaptive games E-books "Living Books" with oral narration and no printed text	NA	Mixed (in favor of games for PA; 0 for LSK)	Medium	NA	Error rate (- with PA)

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					Significant difference between conditions[b]	Effect size[c]	Investigated features of educational technology and its implementation[d]	Investigated learner characteristics[d]
56	Vanbecelaere et al. (2020)	1: Value-added 2: Media comparison (A-NET/EL)	Researcher-developed tablet reading game - Adaptive condition Non-adaptive condition	2: Pen-and-paper exercises	2: No (0)	Small to medium	1: Adaptivity (0)	Pretest score (0) Home language (0) SES (0)
57	Willoughby et al. (2015)	1-2: Media comparison (A-NET/EL)	Alphabet e-book for iPad	1: Printed alphabet book 2: Storybook	1-2: No (0)	Small	NA	Time spent oriented to book (0)
58	Wood et al. (2013)	Media comparison (I-BAU)	Supplemental computer-assisted (laptop with mouse) reciprocal peer tutoring using tutorials made with Microsoft PowerPoint	Media comparison	Yes (+)	NA		

Note. AR = augmented reality; BU = bottom-up; CAI = computer-assisted instruction; EF = executive functioning; ILS = integrated learning system; PA = phonological awareness; TD = top-down.

[a] A-ET/EL = active control group with educational technology/early literacy treatment; A-ET/NEL = active control group with educational technology/non-early literacy treatment; A-NET/EL = active control group with non-technology/early literacy treatment; A-NET/NEL = active control group with non-technology/non-early literacy treatment; I-BAU = inactive control group with unclear description or business as usual.

[b] 0 denotes no significant difference between conditions; + denotes a significant difference between conditions in favor of the intervention condition; - denotes a significant difference between conditions, in favor of the control condition.

[c] NA means not applicable, not reported, or unclear; for interpreting effect sizes, the basic rules of thumb are: Cohen's d = 0.20 (~small), 0.50 (~medium), 0.80 (~large); partial Eta squared = 0.01 (~small), 0.06 (~medium), 0.14 (~large).

[d] NA means not applicable or not investigated; 0 denotes no significant association between the feature/characteristic and the effectiveness of educational technology; + denotes a significant positive association between the feature/characteristic and the effectiveness of educational technology; - denotes a significant negative association between the feature/characteristic and the effectiveness of educational technology.