



Evaluating Touchscreen Applications for Emergent Reading Skills Development: Evidence from a Systematic Review and Meta-Analysis

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Article Info	ABSTRACT
Article type: Research Article	Touchscreen-based applications are increasingly used in early childhood classrooms to support early literacy development; however, empirical findings regarding their effectiveness remain mixed. This study presents a systematic review and meta-analysis examining the impact of touchscreen applications on emergent literacy outcomes among young children. Following PRISMA guidelines, a comprehensive search of Scopus, Web of Science, and ProQuest identified 24 independent studies published between 2009 and 2024, from which 41 effect sizes were extracted. Included studies involved children aged 2 to 5 years and compared touchscreen-based literacy interventions with traditional or non-digital instructional approaches. A random-effects meta-analysis revealed a moderate positive effect of touchscreen applications on emergent reading outcomes Hedges' $g = 0.505$, 95% CI [0.363, 0.647] Moderator analyses indicated that intervention effectiveness varied by type of application, child age, and instructional setting, with stronger effects observed when touchscreen activities were accompanied by adult guidance. Assessment of publication bias suggested that the overall findings were robust. These results suggest that touchscreen applications can meaningfully support emergent reading development when thoughtfully integrated into early childhood educational contexts. Implications for classroom practice, app design, and teacher scaffolding are discussed.
Article history: Received: 13 April 2026 Accepted: 27 May 2026 Published online: 29 June 2026	
Keywords: Instructional Leadership, Academic Motivation, School Principals, School Climate, Self- Determination Theory.	

Cite this article: Ghodsi, A., Taheri, M., & Foroughi, Y. (2026). Evaluating Touchscreen Applications for Emergent Reading Skills Development: Evidence from a Systematic Review and Meta-Analysis. *Iranian Journal of Applied Educational Research*, 2(2), 9-25. DOI: <https://doi.org/10.22111/ijaer.2026.55553.1044>
Publisher: University of Sistan and Baluchestan



Introduction

Touchscreen technology, mainly through devices like iPads, is increasingly recognized for advancing early literacy among young children. Studies show these technologies can support reading, writing, and communication skills while fostering engagement and learning in early education settings. Research highlights several key points regarding the benefits and challenges of integrating touchscreen technology into early literacy education. Enhanced literacy development is closely linked to teachers' positive attitudes toward iPad use. When teachers embrace these tools, they can significantly improve preschool children's literacy skills by promoting active engagement in reading and writing ([Oladunjoye, 2013](#)). Additionally, touchscreen technology provides essential support for diverse learners. Open-ended tablet applications empower English Language Learners and students with special needs by offering multi-modal communication tools. These tools enable students to express their ideas and collaborate effectively with their peers ([McGlynn-Stewart et al., 2017](#)). Despite these benefits, there remains a significant gap in teacher training for technology integration in early literacy education. Many preservice educators feel unprepared to effectively incorporate digital tools into their teaching practices ([Voogt & McKenney, 2017](#)). Addressing this issue through targeted teacher education programs is crucial for maximizing the potential of touchscreen technology in classrooms. Furthermore, the evolving communication technology landscape has broadened the definition of literacy. As digital tools become more prevalent, literacy encompasses more diverse skills, making it essential to conduct focused classroom research on digital literacy practices in education ([Neumann & Merchant, 2022](#)). Research on the effects of touchscreen devices on emergent reading development suggests that these technologies can provide significant benefits for young learners, particularly in fostering essential literacy skills. However, their impact depends on several factors, including the application quality and interactions between children, caregivers, and educators. Studies indicate that touchscreen device use is linked to improvements in phonological awareness, letter naming, and rapid automatized naming skills. However, the extent of these benefits can vary depending on caregiver influence and the specific context in which the devices are used ([Chowsomchat et al., 2023](#)). In Australia, research has shown that greater access to touchscreen tablets is associated with improved letter-sound recognition and name-writing skills. This finding underscores the importance of quality interactions with the technology rather than merely focusing on the time spent using these devices ([Neumann & Neumann, 2014](#)). The potential of tablets to enhance emergent writing and letter knowledge is widely acknowledged. However, to maximize their literacy benefits, it is essential to provide adequate scaffolding and ensure the availability of high-quality app content ([Ehri & Roberts, 2006](#)). Additionally, a focused study on tablet use as a mobile learning tool suggests that it may support foundational literacy skills. However, the relationship between tablet use and literacy development is complex, highlighting the need for further research to determine best practices for technology integration in early education ([Grigorakis, 2020](#)); Digital technologies have become widespread and popular among the public. This is partly a consequence of significant technological developments and their integration into everyday life. Digital technologies can be defined as the intersection of various technological tools. Touchscreen tablets, like the Apple iPad and Samsung Galaxy Tab, have gained widespread popularity in technology-driven societies. In the initial weeks, over 3 million iPads were sold, and this trend has persisted with the introduction of newer generations of iPads and the iPad mini ([Murray & Olcese, 2011](#)). Touchscreen devices are transforming education, especially for children with special educational needs and disabilities (SEND). Their interactive and multimedia capabilities enhance engagement, making lessons more enjoyable and stimulating than traditional materials. These devices allow students to learn independently while leveraging features like visual aids, touch-based interactions, and customizable settings. Research highlights that touchscreen technology can improve attention spans, interaction levels, and academic performance. However, challenges remain, such as designing applications that are simple, accessible, and tailored to individual needs. When properly implemented, touchscreen devices hold the potential to become indispensable tools in inclusive education ([Durgungoz & Durgungoz, 2021](#)). Early literacy skills, such as recognizing letter names and sounds, early writing, understanding print concepts, and phonological awareness ([Byrne & Fielding-Barnsley, 1989](#); [Levin et al., 2006](#); [Lomax & McGee, 1987](#); [Mann & Foy, 2003](#)), are crucial precursors for fostering future reading and writing abilities ([Bowman & Treiman, 2004](#); [Whitehurst & Lonigan, 1998](#)). With their print-based interfaces, tablets possess distinctive features that can enhance the development of emergent reading skills. Unlike conventional computers, touchscreen tablets offer children an easier-to-use and more intuitive interface ([McManis &](#)

[Gunnewig, 2012](#)). Unlike traditional desktop computers, tablets are portable, handheld devices that rely on touch screens. This allows children to use them in various settings, such as on their laps or lying down, fostering collaboration during playtime. The interactive touch-based interface of tablet computers, like iPads, allows young children to engage with the digital realm from an early age. According to [Marsh et al. \(2012\)](#), as suggested by Vygotsky (1978), this sociocultural aspect enables tablets to transmit knowledge through various digital media experiences. This can help children use meaning-making systems ([Kucirkova et al., 2015](#); [McManis & Gunnewig, 2012](#)). Learning through tablet interactions can be facilitated by an adult or the app's built-in features ([Neumann, 2016](#)). As a result, tablets offer young children learning opportunities that can foster the development of literacy and understanding. As children play with apps, their emergent reading skills may be nurtured by exploring print elements, such as icons, symbols, letters, and words, displayed on tablet screens. These skills develop from infancy when babies explore surrounding print visually ([Bowman & Treiman, 2004](#); [Neumann, 2016](#)). Developing emergent reading skills is crucial in preschool as these skills significantly impact future reading and writing abilities ([Puranik et al., 2011](#); [Saada-Robert, 2004](#)). Alphabet knowledge, phonological awareness, and emergent writing are essential as strong predictors of future reading success ([Ehri et al., 2006](#); [Noel Foulin, 2005](#); [Storch & Whitehurst, 2002](#)). Research has emphasized that non-digital early literacy activities, such as reading alphabet books and environmental print recognition, support emergent reading skills before formal schooling ([Ehri & Roberts, 2006](#)). Furthermore, digital tools like tablets and apps also have the potential to support the skills, although research in this area is limited ([Aram & Chorowicz Bar-Am, 2016](#)). A 2014 study by the National Literacy Foundation found that 70% of children now read on tablets and smartphones more often than traditional paper books, marking a significant shift toward screen reading among youth. This trend suggests that studying this phenomenon from 2013 to 2022 is crucial ([Picton, 2014](#)). Experimental studies on interactive reading apps indicate that they impact children's emergent reading, including story comprehension, vocabulary, engagement, and motivation ([Korat & Falk, 2019](#)). These findings underscore the importance of continued research to understand how digital tools shape literacy development in young children. The present meta-analysis will attempt to check whether these characteristics moderate the effect of touchscreen on young children's emergent reading skills.

Method

This review aimed to assess the effectiveness of touchscreen apps for flourishing emergent reading. The growing popularity of touchscreen devices with internet connectivity, like smartphones and tablets, is evident. ([Brito & Ramos, 2017](#)); In keeping with this definition, we include There are several types of touch screens, including resistive, capacitive, infrared, and multi-touch screens a study to be included as experimental, no matter if it was a between- or within-subjects experiment, there had to be a comparison condition between children's interactive reading apps and paper books or essential e-books (no dynamic effects). The children were narrated by their parents when reading the paper books, whereas, during the experiment, the adults acted as guides when using an interactive reading app, minimizing the interaction with the children ([Korat & Falk, 2019](#)). And imitating a natural reading session. We focus on the app's effects on children's emergent literacy (learning outcomes and behaviors), such as story comprehension, recall and retention, vocabulary, motivation, attention, engagement, and so forth—all skills directly related to later learning outcomes in school ([Whitehurst & Lonigan, 1998](#)). We also consider the effectiveness of the app's multimedia features and interactive functions.

Search Method

The review examined the literature published between January 2010 (inventing touch screen) to 2024 in the following databases: Scopus, Web of Science, and ProQuest. A manual search was also conducted using Google Scholar and the reference section of the publication. The search terms were a combination of Emergent reading AND Touch Screen AND Tablet AND Interactive apps (inventing touch screen) to 2023 in the following databases: Scopus, PubMed, and Web of Science; see Table S1 for the database-specific search strategies.

Overview of the Present Study

Based on the detailed exposition of the pedagogic effect of touchscreens mentioned above, a prominent and crucial issue concerns the generality of the touchscreen effect on young children's learning, which is an open question. These inconsistencies were the impetus for our meta-analytic investigation. This meta-analysis was conducted to address the following three.

Questions

RQ1: Can learning Emergent reading through traditional methods be replaced with a touch screen?

RQ2: Are there any potential moderators of the effect of touchscreens on young children's emergent reading skills?

RQ3: Which emergent reading skills will be developed through touchscreen apps?

Coding of Studies

Tree types of information were collected from each study (see Table 1): basic information (authors, year of publication, sample size), quantitative information for the calculation of effect sizes, and characteristics related to the potential moderators (age, learning material domain, comparison group, test media, and experimental environment). 1) Age. Participants' mean age was coded. The unit was converted to monthly. Data were extracted and coded for the studies investigating age differences in touchscreen learning according to different age groups. This was done to guarantee age-related analysis. 2) Comparison group. Comparison group. Among the included studies, the touchscreen group was usually compared with various groups, such as baseline and traditional classrooms. 3) Test various media, such as touchscreen devices, paper, physical objects, or oral tests, and usually test participants in different studies. Coding studies into these categories was based on the test medium. 4) Experimental environment. The experiments were generally conducted in different environments, such as classrooms and laboratories. Coding studies into these categories were based on the exact environment. For example, data from Russo-Johnson et al. (2017) were collected in a lab room and coded as a laboratory.

Table1. Description of subjects

Study	Sample size	Mean ages (months)	Comparison group	Test media	Experimental environment	Types of emergent reading	Country	Duration	Outcome
(Almansoori et al., 2024)	.19 17	60	Jolly Phonics Traditional condition	Touchscreen Devices	Classroom Setting Integration of Technology	Letter knowledge	(UAE)	8 weeks	effectiveness of the Jolly Phonics Lessons application in improving students' literacy skills, specifically in letter blending and letter
(Amorim et al., 2022)	331 418	56	Escribo Play mobile game	Escribo Play	center-based child care setting	Comprehension Phonological awareness	Brazil	10 weeks	improving both reading and writing skills

			The regular instructional strategies		Writing					
(Baltzaki & Chlapan, 2023)	32 16	49.36	Digital tablet	game Blended learning group	ICT-Exclusive Approach tablets and appropriate educational software	center-based child care setting	Vocabulary	Greece	8weeks	participated in the animated book reading intervention, demonstrated significant gains in several emergent reading skills
(Chen et al., 2023)	8 8	40.25	Interactive Traditional instruction	apps	digital application	preschool setting	Letter	United States	5 weeks	The interactive learning app significantly improved uppercase letter-name recognition among preschool children.
(Jariya Porn Chowso mchat et al., 2023) Boonru smee, and Therdp ong Thongs eiratch(2023)	252 65	66	Touch screen None touchscreen	Rama Pre-Read (RPR) software program	primary schools with kindergartens		Phonological Awareness	Thailand	Daily 2 hours	While initial analyses suggested that touchscreen device use was associated with better emergent reading skills, these associations were not maintained after controlling for other factors.
(Mauren et al., 2018)	12 13	64.68	Digital storytelling Traditional	Tablet			Alphabet knowledge	Indonesia	Touchscreen Condition Face-to-Face Condition Video Condition	Touch screen
(Beurden, 2021)	19 21	64.7	Tablet Non-tablet group	Tablet	Classroom		Phonological awareness	Netherlands	Collaborative Words" app focused on rhyming and word-onset skills against a different type of activity that did not directly target these	Digital apps

								phonologica l awareness skills	
(Piotro wski & Krcmar , 2017)	40 38	58.8	Hotspot Condition Nonhotspot	Interacti ve stories presente d on a tablet	One acted as the researcher interacting with the child, while the other operated the video recording equipment.	Comprehensi on Narrative skills	Netherlands	Single session of 10 mins for every child	Hotspots may increase the number of comments children make, but they do not necessarily enhance attention or comprehens ion of the story.
(Tang et al., 2024)	12 12	66	Digital game Traditional instruction	digital game	Digital game	Writing Letter knowledge Recognition words	Taiwan	35 minutes for each session	Digital game-based learning can significantly improve preschooler s' English writing skills.
(Zipke, 2017)	25 25	54.12	Computer Condition (E- Book Condition) Print Condition	Print Books E-books	Participants were read to in pairs from a recorded voice on a tablet and allowed to explore the e-book app independently.	Letter knowledge	United States	30 minutes for each session	E-books facilitated better word recognition, and participants enjoyed the interactive nature of e- books.
(Maure en et al., 2018)	24 13	64.68	Digital story Traditional	Oral Storytell ing Digital Storytell ing	Classroom Setup	Print awareness	Indonesia	three weeks	Integrating storytelling approaches with instructional design principles can be a promising strategy for enhancing literacy and digital literacy developmen t in early childhood education settings.
McKen ney, S., & Voogt, J. (2009)	87 65	48	PictoPal intervention	consiste d of a structur ed Early Literacy Skills Test	A technology- supported learning setting designed to enhance children's understanding of the nature and function of written language.	Letter knowledge	Netherlands	8 weeks	PictoPal intervention showed promise in enhancing emergent reading skills.
(Neuma nn, 2018)	24 24	45.19	iPad Groups Non-iPad Groups	an iPad applicati on called	Classroom setting.	Print awareness Letter knowledge.	Australia	9 weeks	The iPad group demonstrate d

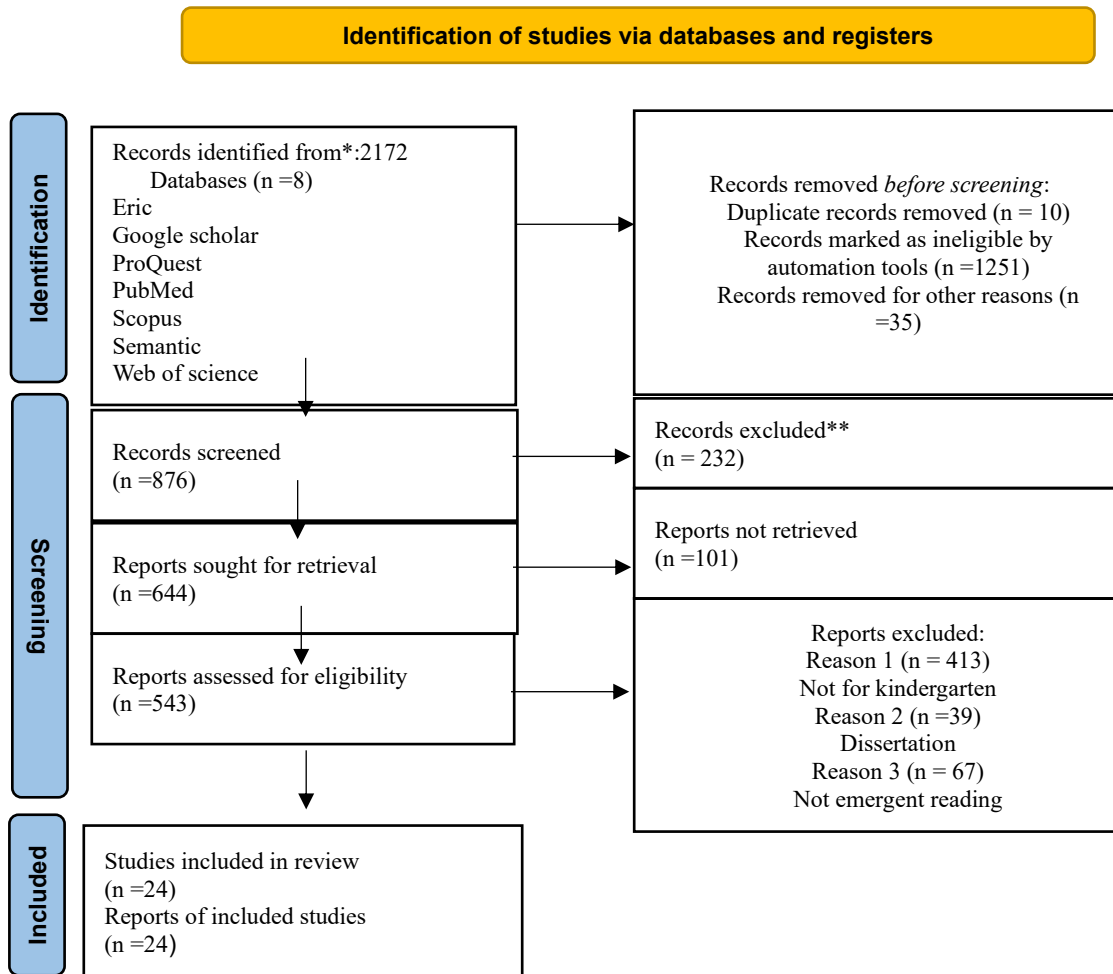
				Draw Buddy					significantly more gains across all emergent reading measures.
(Teepe et al., 2017)	44 27	40.26	(TES) activity Traditional instruction	technology-enhanced storytelling (TES) activity	preschool settings	Expressive vocabulary	Netherlands	10 minutes per child.	TES had a significant positive effect on productive vocabulary knowledge
(Schryer et al., 2015)	28 22	74 months	e.book Traditional instruction	e-book	Child care center	Vocabulary Alphabet knowledge Print awareness Phonological Awareness	Canada	three sessions, with each session lasting approximately 35 minutes	-book intervention positively influenced children's emergent literacy skills
(Shami r, 2009)	48 48	49.34	Animated Books	Baseline	Kindergarten	Phonological awareness Vocabulary	Israel	5 weeks,	significant gains in several emergent reading skills
(Smeets & Bus, 2012)	20 27	54.50 months.	Electronic storybooks Paper books	Touchscreen devices	classroom setting	Vocabulary	Netherlands	Not mentioned	Interactive electronic storybooks can significantly enhance vocabulary acquisition among kindergartners.
(Tadiboyina et al., 2024)	45 41	72	the Control Group (CG) and the Intervention Group (IG)	Digital Catcher Game Traditional Instruction	classrooms	Alphabet knowledge	India	8 weeks	Ame-based learning (GBL) intervention was significantly more effective than traditional methods for alphabet training
(Vanbecelaere et al., 2020)	45 41	70.5	Adaptive Game Condition: Non-Adaptive Game Condition: pen-and-paper exercises	Adaptive and non-adaptive reading game (RG) versions are played on tablets.	Tablets are used for the game conditions, and paper-and-pen tasks are used for the control condition.	Letter knowledge	Belgium	5 weeks	The adaptive system did not demonstrate a clear advantage over traditional methods
(Tadiboyina et al.)	45 41	60		digital game,	Classroom	Letter knowledge	India	8 weeks	Game-based learning

al., 2024)			The IG participated in alphabet training through the digital Catcher Game.	the Catcher Game					(GBL) intervention was significantly more effective than traditional methods for alphabet training.
(Walter-Laager et al., 2017)	27.3	Tablet Baseline	Word-Learning App	Word-Learning App Picture Cards	The experimental environment was structured to facilitate interaction with the learning materials while allowing for the observation of the children's engagement and vocabulary development.	Vocabulary	Germany	2 Months	Integrating technology, such as word-learning apps, into early childhood education can enhance vocabulary development, especially when combined with adult interaction.

Result

The PRISMA flowchart provides a structured approach to selecting studies for a systematic review, ensuring transparency and rigor in research selection. The process begins with the identification phase, where relevant studies are gathered from various sources, such as databases and registers. In this case, a total of 2,172 records were initially identified. However, before screening, 1,251 records were removed as they were deemed irrelevant, and 10 duplicate records were eliminated, leaving 876 records for further assessment. This step helps refine the dataset by removing redundancies and non-relevant studies at an early stage. The remaining 876 records were examined based on predetermined inclusion and exclusion criteria in the screening phase. Of these, 232 studies were excluded, leaving a smaller pool for further evaluation. The next step, the eligibility phase, involved retrieving 101 full-text reports for deeper analysis. Some reports were inaccessible, and further assessment led to additional exclusions: 413 studies were not focused on kindergarten education, 67 did not address emergent reading, and 39 were dissertations that did not meet the review criteria. This phase ensures that only studies directly related to the research question proceed to the final stage. Finally, in the inclusion phase, 24 studies were deemed eligible and included in the systematic review. These studies form the foundation for analysis, providing reliable and relevant data to support research conclusions. By following the PRISMA framework, researchers ensure a systematic, unbiased selection of studies, reducing the risk of including low-quality or irrelevant research. This structured approach enhances the credibility of systematic reviews and meta-analyses, making them valuable tools for evidence-based decision-making in various fields.

Figure 1. PRISMA flow diagram



The results table presents a comprehensive overview of various studies investigating touchscreen applications' effectiveness in enhancing children's emergent reading skills. Each entry includes essential details such as sample size, mean age, experimental conditions, types of emergent skills targeted, duration of the interventions, and outcomes. This structured approach allows for a thorough comparison across different studies, shedding light on the overall efficacy of touchscreen technology in early education. The sample size and age group diversity are notable aspects of the findings. The studies included a wide range of participants, from as few as 8 to over 400, reflecting variability in research scope and applicability. Mean ages ranged from approximately 12 to 74 months, emphasizing the focus on early childhood. This diversity enhances the generalizability of the results, suggesting that touchscreen applications can cater to various developmental stages in young learners. The effectiveness of touchscreen interventions is evident, with many studies reporting significant improvements in emergent reading skills, particularly in areas like letter knowledge and phonological awareness. For instance, interventions utilizing Jolly Phonics and Escribo Play enhanced literacy skills in the UAE and Brazil, respectively. However, the degree of effectiveness varied based on instructional strategies employed alongside the technology, indicating that integrating traditional methods could lead to even better outcomes. Most interventions lasted 5 to 10 weeks, suggesting that relatively short-term exposure to touchscreen apps can yield observable gains in literacy skills. This finding is particularly relevant for educators and policymakers implementing technology in early education. Furthermore, comparative outcomes highlighted that touchscreen apps often provided a comparable or superior learning experience to traditional instructional methods, underlining their potential in contexts where access to conventional educational resources may be limited.

Calculation of Effect Sizes

Data were analyzed using the Comprehensive Meta-Analysis (CMA) 2.0 software (<https://www.meta-analysis.com/>). Effect sizes were weighted using the reciprocal of their variances so that effect sizes based on studies with larger sample sizes were more heavily weighted in the analysis. The random-effects model was used for analyses because studies included in the meta-analysis differed on several variables (e.g., characteristics of participants, research design, and procedures), conforming to the assumption of the random-effects model that the actual effect sizes are not the same in all studies ([Amorim et al., 2022](#)). Effect sizes were calculated using standardized mean differences, expressed as Hedges' g , to quantify the magnitude of the effects of touchscreen-based interventions on emergent reading outcomes in young children. Hedges' g was selected as the primary effect size metric because it provides a bias-corrected estimate that adjusts for small sample sizes, which are common in early childhood educational research. This correction increases the accuracy and comparability of effect size estimates across studies. For each included study, effect sizes were calculated using post-intervention mean scores and standard deviations for the experimental and comparison groups. When studies did not report means and standard deviations, effect sizes were derived from alternative statistical information (e.g., t values, F values, or other inferential statistics) using standard meta-analytic conversion procedures. All effect sizes were coded so that positive values indicated superior emergent reading performance for children who participated in touchscreen-based interventions relative to those in comparison conditions. Several studies reported outcomes across multiple emergent reading domains (e.g., letter knowledge, phonological awareness, vocabulary, and print awareness). In these cases, multiple effect sizes were extracted from a single study when each outcome represented a distinct literacy construct. This approach allowed for a more comprehensive synthesis of the effects of touchscreen-based instruction across different aspects of emergent literacy development. Heterogeneity among effect sizes was examined to determine whether observed variations in study outcomes could be attributed solely to sampling error or whether meaningful differences existed across studies. Statistical heterogeneity was assessed using the Q statistic and the I^2 index. A statistically significant Q value indicates that variability among effect sizes exceeds what would be expected by chance alone. The I^2 index was used to estimate the proportion of total variance attributable to true between-study heterogeneity rather than random error. Consistent with conventional guidelines, I^2 values of approximately 25%, 50%, and 75% were interpreted as indicating low, moderate, and high heterogeneity, respectively. Evidence of substantial heterogeneity supported the use of a random-effects model and justified further exploration of potential moderators influencing intervention effectiveness.

Random Effects of Touchscreen-Based Interventions on Emergent Reading

The final meta-analysis included 24 independent studies examining the impact of touchscreen-based interventions on emergent reading outcomes among young children, encompassing a total of 2,709 participants. Given the diversity of study designs, participant characteristics, instructional settings, and outcome measures, a random-effects meta-analytic model was employed and interpreted as the primary analysis. Results from the random-effects model indicated a moderate and statistically significant positive effect of touchscreen-based interventions on emergent reading development (Hedges' $g = 0.505$, $SE = 0.073$, 95% CI [0.363, 0.647], $p < .001$). This finding suggests that, on average, children who engaged with touchscreen-based literacy applications demonstrated higher emergent reading performance than peers who received traditional or non-digital instruction. For comparison purposes, a fixed-effect model was also estimated and yielded a smaller random effect model Hedges' $g = 0.505$, 95% CI [0.363, 0.647]. However, because this model assumes a single true effect size across all studies and does not account for between-study variability, it was not considered the primary estimate. Individual study effects varied considerably, ranging from large positive effects to nonsignificant and, in some cases, negative effects. Several studies reported strong positive outcomes associated with touchscreen-based instruction ([Schryer et al., 2015](#); [Tadiboyina et al., 2024](#)) whereas others showed limited or adverse effects ([Homer et al., 2014](#)). This variability highlights the importance of examining contextual and instructional factors, including intervention design, implementation quality, instructional setting, and the presence of adult guidance, which may influence the effectiveness of touchscreen-based literacy interventions. The present meta-analysis was conducted using Comprehensive Meta-Analysis (CMA) software and was based on 41 independent studies.

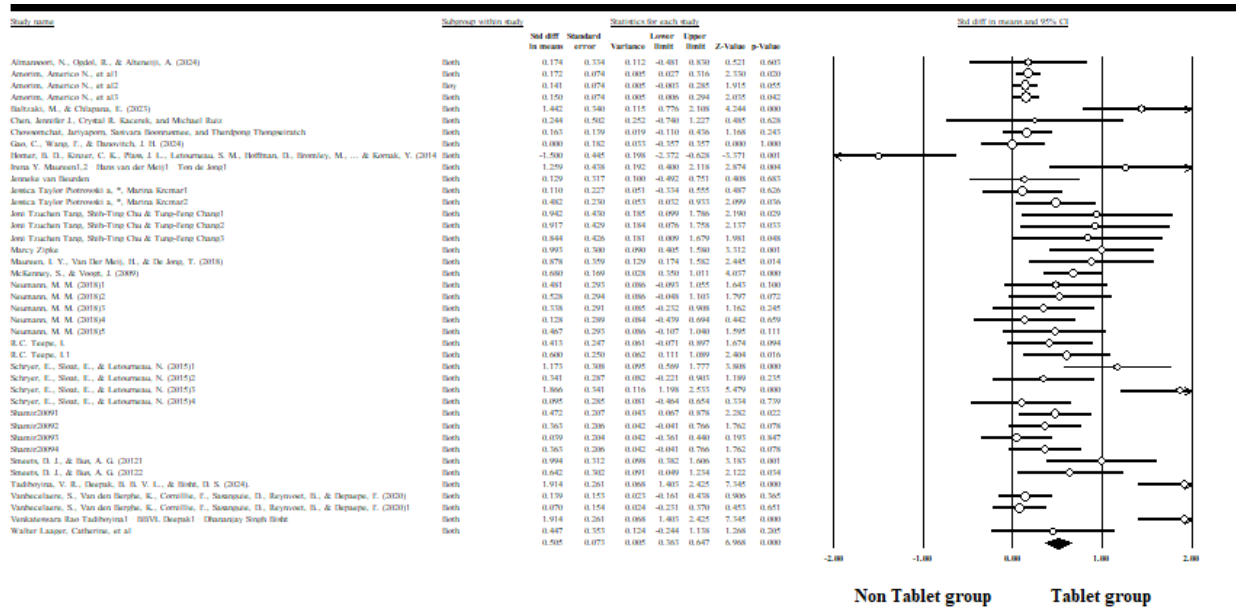
The standardized difference in means (Cohen's d) was selected as the effect size index. A random-effects model was employed, reflecting the assumption that the included studies represent a random sample drawn from a larger universe of potential studies. Accordingly, the results are intended to support inferences about this broader population of studies rather than being limited to the sampled studies alone (Borenstein, 2019); (Borenstein et al., 2010) (Borenstein et al., 2021) (Chandler et al., 2019; Hedges & Vevea, 1998).

The overall mean effect size was estimated at $d = 0.505$, with a 95% confidence interval ranging from 0.363 to 0.647. This indicates a moderate and statistically meaningful effect, suggesting that the true mean effect size across comparable studies in the population is likely to fall within this interval. A Z -test was conducted to evaluate whether the mean effect size differed significantly from zero. The resulting Z -value of 6.968 ($p < .001$) led to rejection of the null hypothesis at the $\alpha = .05$ level, confirming that the average effect in the population of interest is significantly different from zero. Heterogeneity among studies was assessed using the Q -statistic. The obtained Q -value was 190.481 with 40 degrees of freedom, which was statistically significant ($p < .001$). Using an alpha level of 0.10, this result indicates that the assumption of a common true effect size across all studies can be rejected, providing evidence of substantial variability in effect sizes beyond what would be expected by sampling error alone. Consistent with this finding, the I^2 statistic was 79%, indicating that approximately 79% of the observed variance in effect sizes reflects true differences across studies rather than random sampling variation. Further quantifying this heterogeneity, the estimated between-study variance (τ^2) was 0.142 in d units, and the corresponding standard deviation of true effect sizes (τ) was 0.377. Finally, a 95% prediction interval was calculated to estimate the range in which true effect sizes are expected to fall for comparable populations. Assuming a normal distribution of true effects, the prediction interval ranged from -0.272 to 1.282. This wide interval suggests that while the average effect is positive and moderate, the true effect size in individual populations may vary considerably, ranging from slightly negative to strongly positive.

Table 2. The effect size of using touchscreen devices on young children's emergent reading skills

Model	Effect size and 95% confidence interval						Test of null (2-Tail)		Heterogeneity		
	Number Studies	Point estimate	Standard error	Variance	Lower limit	Upper limit	Z-value	P-value	Q-value	df (Q)	P-value
Fixed	41	0.315	0.029	0.001	0.257	0.373	10.718	0.000	190.481	40	0.000
Random effects	41	0.505	0.073	0.005	0.363	0.647	6.968	0.000			

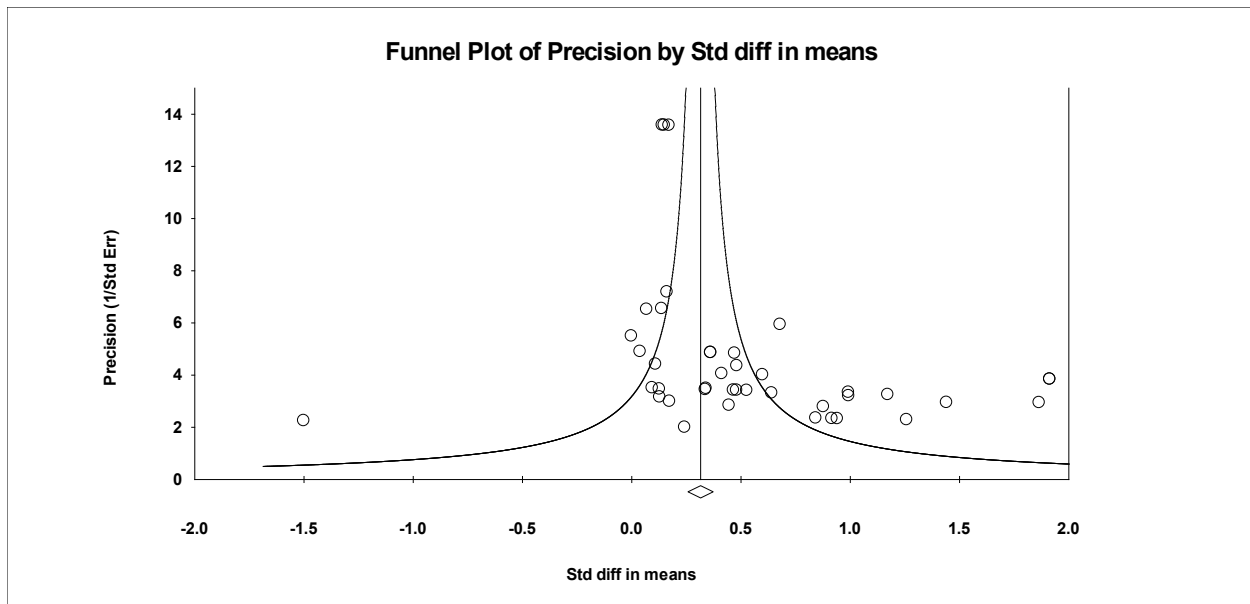
Figure 2. Random effects forest plot



Evaluation of Publication Bias

Publication bias was evaluated using multiple complementary methods to assess the robustness of the meta-analytic findings. First, visual inspection of the funnel plot was conducted to examine the symmetry of effect size distributions around the pooled estimate. The funnel plot did not display marked asymmetry, suggesting that the distribution of studies was relatively balanced and that smaller studies with negative or null findings were not systematically underrepresented. To further assess potential small-study effects, Egger's regression test was performed. The results of this analysis did not indicate statistically significant funnel plot asymmetry ($p > .05$), suggesting a low likelihood that the magnitude of the observed effects was influenced by selective publication or small-study bias (Egger et al., 1997). This finding provides additional support for the stability of the overall effect size estimate derived from the random-effects model. In addition, Orwin's fail-safe N analysis was used as a supplementary indicator to evaluate the sensitivity of the meta-analytic results to the presence of unpublished or missing studies. The analysis indicated that a substantial number of additional studies with trivial or null effects would be required to reduce the observed overall effect to a practically negligible level (Orwin, 1983). While this result suggests a degree of robustness in the pooled effect, fail-safe N is considered a conservative and indirect measure of publication bias and should therefore be interpreted with caution. Taken together, the convergence of evidence from funnel plot inspection, Egger's regression test, and fail-safe N analysis suggests that publication bias is unlikely to have substantially distorted the findings of this meta-analysis. Although the possibility of unpublished studies cannot be entirely ruled out, the available evidence indicates that the overall conclusions regarding the effectiveness of touchscreen-based interventions on emergent literacy outcomes are reasonably stable and not driven primarily by selective reporting, consistent with recommended practices for systematic reviews and meta-analyses (Page et al., 2021)

Figure 3. Funnel plot



Moderator Analysis

Moderator analyses were conducted within a random-effects framework to examine potential sources of variability in effect sizes across studies. The table analyzing touchscreen applications as moderators in enhancing emergent reading skills provides a comprehensive overview of various studies, each contributing valuable statistical insights. Each study is identified by its authors and year, making it easy to reference specific research. For example, Schryer et al. (2015) reported an SMD of 0.341 for alphabet knowledge, while Tadiboyina et al. (2024) showed an impressive SMD of 1.914 for the same skill. This variance highlights the effectiveness of touchscreen apps, particularly in facilitating foundational literacy skills. Such notable differences emphasize the potential of interactive features in touchscreen applications to engage young learners effectively. The confidence intervals further contextualize the effectiveness of these interventions. Schryer et al. reported an SMD of 0.341 with a confidence interval of (0.287, 0.903), indicating strong reliability of their findings. This means that the actual effect is likely to fall within this range, reinforcing confidence in the positive impact of touchscreen applications. In contrast, studies showing wider confidence intervals may suggest less certainty in their findings, underlining the need for careful interpretation. Statistical significance is also a key factor in understanding the results. Many studies report p-values below 0.05, with some, like Schryer et al., achieving a p-value of 0.000, indicating strong evidence against the null hypothesis. This suggests that touchscreen applications significantly enhance literacy skills. Conversely, studies with higher p-values imply a lack of significant effects, indicating the variability in effectiveness based on the type of literacy skill being assessed. Finally, the weight assigned to each study reflects its contribution to the meta-analysis. For instance, a study with a weight of 54.80% indicates a substantial influence on the overall findings. The table categorizes studies by specific literacy skills, revealing that while alphabet knowledge consistently shows positive effects (like an SMD of 1.914 for Tadiboyina et al.), other skills, such as writing, exhibit more mixed results, as seen with Neumann's SMD of 0.467. These statistical insights underscore the potential of touchscreen applications as effective moderators in promoting emergent reading skills while highlighting the importance of targeted content and instructional strategies.

Discussion & Conclusion

Although many empirical research studies the effect of touchscreen apps on children's learning process, the results of those effects on emergent reading are unclear. The current study is a sample of a successful effort to provide empirical investigation of the overall impact of touchscreen emergent reading skills on young children and potential moderators. The main question in the present study addressed whether touchscreens could improve emergent reading skills. The overall analysis provides a positive answer. Young children learning to use touch screen devices performed better than those who did not (0.51), which is in line with our hypothesis and numerous studies, and the role of children's phonological awareness during learning processes was somewhat emphasized. For young children like preschoolers, their ability of imagination develops with age. It proved that touchscreen apps are beneficial media for more than 2 years (53). The findings of this meta-analysis suggest that touchscreen technology holds potential for enhancing emergent reading, particularly in fostering letter recognition. However, its effectiveness is highly dependent on various factors, including the quality of digital interventions, the structure of the learning environment, and the specific literacy skills targeted. Thus, presumably, practicing emergent reading skills might be improved for older children (rather than younger children). This means interactive activities are better than technology because they help with physical manipulation on a touchscreen and their relatively good imagination capability ([Lorio et al., 2022](#); [Xie et al., 2018](#)). As letter knowledge plays a vital role in improving literacy instruction, touchscreen apps can be beneficial in improving it ([Tadiboyina et al., 2024](#)). Print awareness is a fundamental early literacy skill that involves understanding how print works and recognizing its role in everyday life. It helps children develop the foundation needed for reading and writing. Next to letter knowledge, print awareness can be taught through computer models ([Coşkun, 2024](#)). The positive impact on letter knowledge aligns with previous research, indicating that interactive and engaging digital experiences can reinforce alphabet recognition ([Neumann, 2018](#)). Digital games and interactive applications encourage repeated exposure to letters, enhancing children's ability to identify and differentiate them. However, the lack of significant benefits for comprehension and expressive vocabulary raises concerns about the limitations of digital interventions in supporting more profound literacy skills. These findings echo previous studies that emphasize the importance of social interaction in language development, suggesting that traditional storytelling and human interaction remain crucial components of early literacy education ([Bus et al., 2019](#)). The analysis highlights that touchscreen learning's effectiveness depends on the learning environment. Classroom-based interventions, where digital tools are integrated within structured learning activities, yield better results than touchscreen devices' unstructured, passive use. This supports the argument that digital tools should complement rather than replace traditional literacy practices. Furthermore, the adverse effects observed in phonological awareness and writing suggest that digital interventions may not adequately support these skills without proper scaffolding. Phonological awareness, which involves auditory discrimination and verbal interaction, may require more interactive and communicative teaching approaches beyond what current digital applications offer. Touch screen apps, e-books, and gamification apps dramatically affect the teaching and learning of emergent reading skills. Our results shed light on the role of touchscreen-related physical experience in early childhood education and hold promise for using touchscreens with physical interactivity functions to scaffold young children's learning in formal or informal educational settings. With the help of touchscreens, the physical experience can be either a long-term accumulation of experience or a salient short-term experience. Either way, parents, teachers, or educational practitioners should, at least partly, provide instructional support for touchscreen learning. However, it should be acknowledged that touchscreens are not suggested as educational intervention techniques in any condition or at any age point because the current study cannot respond to the question of whether using touchscreen devices has an underlying negative influence on other aspects (e.g., sleep quality, the ability of deferred gratification)

The findings of this systematic review and meta-analysis highlight the significant role that touchscreen applications can play in supporting emergent reading skills among young children. The overall positive random effect model ($d = 0.505$)(Table 2) suggests that touchscreen-based learning interventions offer notable benefits, particularly in letter recognition and phonological awareness. However, the effectiveness of these digital tools is influenced by several moderating factors, including age, the type of learning material, comparison groups, and the instructional environment. These insights emphasize the importance of designing and implementing high-quality digital literacy programs tailored to the developmental needs

of young learners. Despite the observed advantages, this study also underscores the limitations of touchscreen interventions in fostering more complex literacy skills, such as comprehension and expressive vocabulary. The results indicate that while digital applications can provide engaging and interactive learning experiences, they should complement traditional literacy practices rather than complement them. The findings also raise concerns regarding the role of social interaction in literacy development, highlighting the need for balanced learning approaches that integrate technology with teacher or caregiver support. Furthermore, the variability in effect sizes across studies suggests that not all touchscreen applications are equally practical. The quality of app design, the extent of adult guidance, and the structured use of digital tools within classroom settings are critical factors in determining their success. Future research should explore best practices for integrating touchscreen learning, ensuring that these technologies enhance rather than hinder early literacy development. Further investigation is needed to assess potential long-term effects on children's cognitive and social development

Acknowledgments

The authors sincerely acknowledge all researchers whose valuable published work formed the basis of this systematic review and meta-analysis. Their contributions have made this study possible.

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