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Impacts of Traditional, Digital, and AI-Integrated Home Literacy Environments on Children's Literacy Skills: A Cross-Sectional Study

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ABSTRACT

Research Fingdings: Building upon the foundational Home Literacy Environment (HLE) model, this study presents a contemporary framework that incorporates digital literacy practices and Artificial Intelligence (AI) technologies, such as ChatGPT, alongside traditional literacy activities. 74 U.S. families with children aged 5–7 participated in the study. Using hierarchical linear regressions, findings indicate a non-significant relationship between children's literacy skills and both digital literacy practices and the use of AI tools (e.g. ChatGPT) by parents and children. The study highlights children's active engagement in digital and AI-integrated literacy activities while reaffirming the essential role of parental involvement and print-based reading resources in fostering children's language development. *Practice or Policy:* The findings reveal the growing presence of digital and AI tools in early literacy practices, contributing to an evolving understanding of the HLE and emphasizing the effective and responsive integration of technology in early literacy environments. The study also advocates for equitable access to both digital and traditional literacy resources and calls for ongoing research into the long-term effects of digital and AI technologies on children's literacy development.

Introduction

Literacy refers to the ability to read, write, listen, and speak in a language (National Reading Panel, 2000). In early childhood, children begin developing early literacy skills, including decoding, phonological awareness, receptive vocabulary, and listening comprehension, which not only support language acquisition but also contribute to cognitive growth and social-emotional development (Levey, 2022; Roth & Clark, 1987; Scarborough & Dobrich, 1994). A key source of early literacy development is the Home Literacy Environment (HLE), which is the collection of resources, activities, and interactions within the home that promote children's literacy learning (Sénéchal & LeFevre, 2002; Sénéchal et al., 1998). The HLE includes factors such as access to books and reading materials, the frequency of shared reading between caregivers and children, parental attitudes toward literacy, and engagement in rich, meaningful conversations (Levey, 2022; Sénéchal & LeFevre, 2002). A strong HLE not only supports early language development and reading motivation but also lays the foundation for children's academic performance and long-term educational outcomes (De Jong & Leseman, 2001; Rodriguez et al., 2009; Serpell et al., 2005; Sonnenschein & Munsterman, 2002; Zimmerman et al., 2008). The HLE model, developed by Sénéchal and LeFevre (2002), offers a theoretical framework for understanding how literacy experiences within the HLE contribute to children's literacy development. According to the model, traditional HLE activities, such as shared reading, parental teaching in reading and writing, and exposure to storybooks, are significant predictors of early literacy skills

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and subsequent reading and writing performance. The HLE model provides critical insights into the mechanisms through which the HLE shapes children's literacy outcomes and has been widely adopted to assess home literacy practices across diverse linguistic, ethnic, and socioeconomic contexts (Araújo & Costa, 2015; Chen et al., 2010; Haney & Hill, 2004; Hood et al., 2008; Karpava, 2021; Zhang et al., 2020).

With the increasing integration of digital technology into the home environment, the HLE is undergoing significant transformation, introducing new forms of literacy experiences for children. Studies began to refer to the HLE that formed the basis of the HLE model and was primarily involved print media as the *Traditional HLE*, and to the HLE involving digital screens and media (e.g., ebook, literacy game) as the *Digital HLE* (Liu & Chung, 2025; Segers & Kleemans, 2020). Recent developments in Artificial Intelligence (AI) and Large Language Models (LLMs) have introduced entirely new literacy experiences for children at home. AI- and LLM-powered tools such as voice assistants (e.g., Alexa, Siri), conversational agents (e.g., ChatGPT, Gemini), and educational platforms built on AI technologies (e.g., Readability) are shaping an *AI-integrated HLE* (Druga et al., 2022; Xu et al., 2024). These emergent HLEs enrich children's exposure to conversational engagement, narrative exploration, vocabulary growth, and introduce adaptive and interactive features beyond traditional print that personalize learning experiences based on children's needs and interests (Sun et al., 2024; Xu et al., 2023, 2024; Zhang et al., 2022). However, despite the growing integration of digital technology into the HLE, research remains limited on how digital literacy activities, particularly those involving conversational AI, impact children's literacy development. While the HLE model provides a framework for understanding the roles of traditional literacy activities, there is a urgent need to explore how these roles evolve in the digital age.

Related work

Early literacy skills

Literacy refers to the ability to read, write, listen, and speak in a language (National Reading Panel, 2000), while early literacy skills encompass a set of foundational literacy abilities, such as phonological awareness, decoding, receptive vocabulary, and listening comprehension, that prepare children to read and write (Dickinson & Tabors, 2001; Scarborough & Dobrich, 1994; Sulzby & Teale, 1991). Phonological awareness refers to the ability to recognize and manipulate sound structures; it supports early reading by helping children understand letter-sound relationships (Gillon, 2005). Decoding skills, which involve applying letter-sound knowledge to pronounce words, are essential for reading fluency and comprehension (Ehri et al., 2001). Vocabulary refers to word knowledge, including both understanding word meanings and using words appropriately in context. Vocabulary development plays a crucial role in communication, with exposure to rich language environments significantly influencing children's vocabulary growth (Beck et al., 2002; Hart & Risley, 1995). Listening comprehension is the ability to understand spoken language. It lays the groundwork for social communication and reading comprehension, supporting later performance in reading, writing, and overall academic achievement (Scarborough & Dobrich, 1994). These literacy skills are shaped within the HLE and supported by activities such as shared reading, storytelling, and direct teaching from parents (Sénéchal & LeFevre, 2002).

Traditional home literacy environment

The traditional HLE encompasses the exposure to print materials and interactions with family members (De Jong & Leseman, 2001; Roskos & Neuman, 2001; Scarborough & Dobrich, 1994; Sonnenschein & Munsterman, 2002; M.; Zimmerman, 2018). Decades of research highlight the traditional HLE's essential role in fostering early literacy skills, with studies emphasizing the importance of shared reading, children's independent reading, oral and written communication, and access to books, newspapers, and other print materials (Burgess et al., 2002; Rodriguez et al., 2009). Sulzby and Teale (1987) identified three key traditional literacy experiences: parent-child literacy interactions (e.g., shared reading), children's independent literacy activities (e.g., self-directed book exploration), and parental literacy modeling (e.g., demonstrating reading and writing behaviors). These literacy experiences contribute to school readiness and long-term academic achievement by strengthening children's foundational literacy skills (Burgess et al., 2002; Scarborough & Dobrich, 1994; Sénéchal & LeFevre, 2002; Teale & Sulzby, 1987).

Sénéchal and LeFevre (2002) developed a traditional HLE Model through a five-year longitudinal study, categorizing home literacy activities into two forms: formal literacy activities and informal literacy activities. Formal literacy activities involve direct instruction from parents, such as teaching children to read and write. In contrast, informal literacy activities include shared reading, storybook exposure, and conversations about reading materials. The model suggests that both types of HLE activities contribute to early literacy development through direct and indirect pathways, with formal literacy experiences related to emergent literacy skills such as alphabet knowledge, print concepts, and decoding skills, and informal experiences associated with receptive language such as receptive vocabulary and listening comprehension (Sénéchal & LeFevre, 2002)

Digital home literacy environments

As technology becomes increasingly integrated into daily life, the HLE has expanded beyond traditional print-based interactions to include digital literacy experiences (Neumann, 2014; Turco et al., 2023). The digital HLE encompasses home literacy experiences that involve digital screens and media (Liu & Chung, 2025; Segers & Kleemans, 2020). Within a digital HLE, children engage in literacy through both exposure to digital devices and participation in literacy-related activities on digital media (Neumann, 2014; Turco et al., 2023). Digital device exposure refers to children's access to digital technologies such as tablets, computers, e-readers, which in turn provide access to digital resources like e-books, educational apps and games, and online reading platforms (Neumann & Neumann, 2014; Turco et al., 2023). Digital device exposure may positively contribute to HLE by expanding access to reading materials, supporting parent-child literacy interactions, and promoting engagement in literacy-related digital activities LRDA) (Neumann 2014; Neumann 2015; Neumann and Neumann 2014). LRDA encompasses digital interactions specifically designed to support literacy development, such as interactive storybooks, educational games that promote literacy skills, and AI-driven conversational tools that engage children in rich, language-focused interactions (Bus & Neuman, 2014; Reich et al., 2016, 2017; Xu et al., 2024). Compared to general digital activities, LRDA aligns closely with traditional literacy activities, showing the potential to foster language acquisition and literacy development (Neumann, 2018; Neuman & Wright, 2014). For example, tablets and e-readers provide access to digital libraries, allowing children to explore a broader range of books that may not be readily available at home (Korat & Shamir, 2008; Reich et al., 2016). Interactive features such as read-aloud functions, animated storytelling, and embedded vocabulary support can further enhance engagement, motivation, and comprehension, particularly for emergent readers and children with special needs (Aydemir et al., 2013; Bus & Neuman, 2014). Additionally, educational apps designed to reinforce phonemic awareness, letter recognition, and word decoding can complement traditional print materials by offering multimodal literacy support, helping to address the limitations of print books in delivering phonological instruction (Deault et al., 2009; Lonigan et al., 2003; Messer & Nash, 2018; Neumann, 2018). However, while research suggests that targeted digital tools can support early literacy development across diverse socioeconomic and linguistic contexts (Araújo & Costa, 2015; He et al., 2024; Neuman & Celano, 2001; Xu et al., 2023), studies have found no significant correlation between overall screen time and children's literacy outcomes (Turco et al., 2023). This contrast highlights the need to explore the impact of purposeful LRDA on children's literacy development in the context of digital HLE.

AI-Integrated home literacy environments

AI-integrated HLE refers to the incorporation of AI technologies such as conversational agents, intelligent tutoring systems, and AI-enhanced educational platforms into children's home literacy experiences. The AI-integrated HLE offers different experiences in comparison to the digital HLE, as it goes beyond the screens and enables adaptive, interactive, and personalized literacy experiences driven by real-time instant feedback and conversational engagement (Wang et al., 2024; Xu et al., 2024). As these tools become more embedded in home settings, it is crucial to understand how families interact with these tools to support children's literacy development. Research suggests that ChatGPT can act as an on-call facilitator for educators and caregivers (Ashraf, 2024; Entenberg et al., 2021, 2023), offering opportunities in AI-supported literacy learning (Maspul 2024; Sun et al. 2024; Xiao et al. 2023), and cognitive development (Kahn & Winters, 2017; Kasneci et al., 2023; Wang et al., 2024). Studies show that children using ChatGPT benefit from greater engagement, personalized learning experiences, and adaptive educational support (Lai et al., 2023; Liu et al., 2022; Yıldız, 2023; Zhou, 2023). For instance, Murgia et al. (2023) found that fourth graders using ChatGPT demonstrated improvements in language and cognitive skills, and Jauhiainen and Guerra (2023) reported that ChatGPT 3.5 personalized learning materials enhanced students' engagement in Social Science, Math, English, and Spanish. Despite these promising findings, most research has focused on classroom and controlled settings, with limited studies on AI's role in natural home learning environments, particularly among children under eight years old (Limna et al., 2023; Quan et al., 2024).

Gaps in prior research

Despite the current understanding of traditional, digital, and AI-integrated literacy experiences, there is still limited evidence on how these emergent environments shape the dynamics of the modern HLE and contribute to children's literacy development. The traditional HLE model has long emphasized the central role of parental involvement and print-based resources, yet it does not account for the complex, technology-rich home environments in which many children now grow up. Research on digital media use in the HLE has produced mixed and sometimes contradictory findings, highlighting the need for context-specific investigations that position digital literacy experiences within the broader framework of the HLE. At the same time, AI technologies are rapidly becoming part of children's everyday learning, but their role in shaping literacy development has yet to be examined within the HLE framework. Understanding how these traditional, digital, and AI-integrated elements integrate into the broader HLE framework and their impact on children's development is essential for capturing the realities of early literacy development in contemporary home settings.

The current study

To address these gaps, this study examines the relationships among traditional, digital, and AI-integrated HLE factors and their contributions to children's early literacy development within the HLE framework. Specifically, it examines whether parental involvement and print-based literacy resources continue to play a vital role in the evolving HLE, and how digital and AI-integrated literacy experiences contribute to key early literacy skills. The study is guided by the following research questions, inquiring that in the age of AI:

> RQ1: How do traditional HLE, such as parental involvement and print-based storybook exposure, predict children's literacy outcomes?

RQ2: How does digital HLE, such as digital device exposure and literacy-related digital activities (LRDA), associated with children's literacy skills?

RQ3: How does the AI-integrated HLE contribute to children's literacy development?

Methods

The study employed a quantitative cross-sectional research design, partially adapted from the original HLE model (Sénéchal & LeFevre, 2002). A cross-sectional study collects data from a population at a single point in time, allowing for the timely examination of relationships between variables and specific conditions or behaviors as they exist at that moment (Kesmodel, 2018; Setia, 2016). To explore the relationship between HLE experiences and children's literacy skills, data were collected through two main sources: a parent survey measuring traditional, digital, and AI-integrated literacy activities in the home, and a series of standardized literacy assessments administered to children to evaluate their early literacy skills.

Participants

This study recruited caregiver-child dyads, with caregivers fluent in English to complete the survey, and typically developing children aged 5–7, enrolled in U.S. schools, and fluent in English to accept the literacy assessment. There were no restrictions on gender, home language, or ethnicity. A power analysis was conducted using G*Power 3.1 to determine the minimum sample size required for the study. Assuming a medium effect size ($f^2 = 0.15$), a power level of 0.80, and a significance level of $\alpha = 0.05$, the results indicated that a minimum of 74 participants would be needed to ensure sufficient statistical power and reliability of the findings. Recruitment was conducted nationwide through professional and personal networks. Participation was voluntary. Parents first completed an HLE survey, followed by a set of literacy assessments administered to their children. A total of 87 parents participated in the initial survey; however, 13 responses were excluded from the final analysis due to incomplete data from either the parent survey or the child assessments, resulting in a final sample of 74 caregiver-child pairs.

Measures

Early literacy skills

Early literacy skills, including receptive vocabulary, listening comprehension, decoding skills, and phonological awareness, were assessed using standardized literacy assessments. Receptive vocabulary was measured with the Peabody Picture Vocabulary Test – Fifth Edition (PPVT-5) (Dunn, 2019; $\alpha \approx .97$), which requires children to select the picture that best represents a spoken word, providing an estimate of vocabulary knowledge. Listening comprehension was assessed using the Sentence Comprehension subtest of the Clinical Evaluation of Language Fundamentals – Fifth Edition (CELF-5) (Wiig et al., 2013; $\alpha \approx .90$), which measures the ability to interpret spoken sentences of increasing complexity. Phonological awareness was evaluated with the Elision subtest of the Comprehensive Test of Phonological Processing – Second Edition (CTOPP-2) (Wagner et al., 2013; $\alpha \approx .87$), where children are asked to repeat a word while omitting a designated sound, assessing their awareness of and ability to manipulate phonemes. Decoding skills were measured using the Word-Letter Identification subtest of the Woodcock-Johnson IV Tests of Achievement (WJ IV ACH) (Schrank et al., 2014; $\alpha \approx .94$), which examines children's ability to identify letters and accurately decode printed words (Table 1). These assessments were individually administered to each child in one-on-one sessions conducted by the investigator. In accordance with the HLE

Table 1. Literacy assessment.

Literacy Skill	Instrument
Receptive Vocabulary	Peabody Picture Vocabulary Test –5th Edition (PPVT-5)
Listening Comprehension	Sentence Comprehension Subtest of the Clinical Evaluation of Language Fundamentals, Fifth Edition (CELF-5)
Phonological Awareness	Elision Subtest of the Comprehensive Test of Phonological Processing, Second Edition (CTOPP-2)
Decoding Skills	Word-Letter Identification Subtest of the Woodcock-Johnson IV Standard Test of Achievement (WJ IV ACH)

Model (Sénéchal & LeFevre, 2002), receptive vocabulary and listening comprehension were combined into a single construct labeled "receptive language" through dimensional reduction for subsequent analyses.

Survey

The survey that gathers information about HLE was adapted from Sénéchal and LeFevre (2002) and expanded by the authors to include components related to digital and AI-integrated HLE experiences. Screening questions were used to identify primary caregivers and confirm eligibility based on the study's focus on typically developing children, without prior emotional, behavioral, or cognitive diagnoses. The demographic section collected data on parent and child gender, race, age, home language, and household income. The HLE section was structured into three subsections: the traditional HLE, the digital HLE, and the AI-integrated HLE.

Traditional HLE. The Traditional HLE section is fully adopted from Sénéchal and LeFevre's (2002) original HLE model, including various home literacy activities. Special focus was placed on how frequently parents teach their children to read and write (e.g., the names of alphabet letters, how to print alphabet letters, how to read and print words) and the number of printed storybook exposures at home ($\alpha = .946$). These two variables served as independent predictors in addressing whether parental teaching and storybook exposure serve as predictors of children's literacy skills.

Digital HLE. The Digital HLE section is developed by authors based onTurco et al.'s (2023) work and related studies (Bus & Neuman, 2014; Marsh et al., 2017; Sonnenschein et al., 2021). The survey construct measures both the number of digital devices to which children are exposed at home (e.g., laptops, tablets, TV, smartphones), and the types and frequency of their engagement in literacy-related digital activities (LRDA). These activities include taking online reading classes, playing literacy-focused digital games/ apps, reading e-books, listening to audiobooks, doing reading/writing homework using digital media, and chatting online ($\alpha = .637$). Digital device exposure was assessed by counting the number of devices accessible to children in the household. A composite LRDA variable was created by calculating the mean value of relevant survey items, which was then used as a predictor in subsequent analyses.

AI in HLE. The survey construct used for assessing AI-integrated HLE was adapted from (Quan et al.'s, 2024) work ($\alpha = .813$). ChatGPT was selected as the representative AI tool in HLE because it was one of the few widely accessible and commonly used AI tools among families at the time of the study. The survey grounded in the Technology Acceptance Model (TAM) (Davis, 1989; Sánchez-Prieto et al., 2020), included items measuring the frequency of ChatGPT usage by both parents and children, the purpose of use (general learning and language-specific learning), as well as parents' attitudes toward the tool. These attitudes encompassed perceptions of ChatGPT's educational value, concerns about children's use, and the degree of parental guidance provided. Responses were recorded on a Likert scale ranging from 1 (Never/Strongly Disagree) to 5 (Very Often/Strongly Agree). A composite variable was created by conducting factor analysis and calculating the mean value, and then used as a predictor in subsequent analyses.

Procedure

Institutional Review Board (IRB) approval was obtained prior to participant recruitment and data collection to ensure ethical compliance. Recruitment materials, including a flyer with a survey link and QR code, were distributed via social media and bulletin boards through both professional and personal networks. Interested participants accessed the online survey by scanning the QR code or visiting the link, which directed them to a parental consent form followed by the survey questions. Eligible participants then completed a 20–30-minute online survey. Upon completion, they were provided with a link to schedule a literacy assessment for their child. Before the assessment, oral assent was obtained from the child using age-appropriate, child-friendly language. Audio and video recordings were made during the assessments, and confidentiality procedures were clearly explained to both parents and children in advance to ensure transparency and protect privacy. All assessments followed standardized protocols and were conducted individually in one-on-one sessions by the investigator. Each assessment session lasted approximately 40–60 min.

Data analysis

Data were cleaned and analyzed using SPSS Version 29.0. Following the HLE framework (Sénéchal & LeFevre, 2002), Pearson correlation analyses and a series of hierarchical linear regression models were conducted to examine the relationships between HLE variables and children's early literacy skills. The dependent variables included three early literacy skills: (1) receptive language, measured by receptive vocabulary and listening comprehension scores; (2) decoding skills; and (3) phonological awareness. Five predictor variables representing three dimensions of the HLE were included in their corresponding models: parent teaching to read and write and storybook exposure (traditional HLE); LRDA and digital device exposure (digital HLE); and ChatGPT usage (AI-integrated HLE). Pearson correlation analyses were conducted prior to the regression analyses to identify potential covariates, following the analytic approach outlined by Sénéchal and LeFevre (2002). Outliers and missing data were assessed, and cases with incomplete responses were excluded from the final sample.

Results

Demographics

The sample included 74 caregiver-child dyads. The parent demographic was predominantly female (86.3%) and aged between 36–40 years (45.9%). A majority of parents identified as non-Hispanic (97.3%) and Asian (81.1%), with other ethnicities represented, including White (13.5%), Black or African American (2.7%), and Other (2.7%). Over half of parents reported a household income exceeding $200,000 (63.4%). The parent participants were mainly mothers (83.8%), with fathers (14.9%) and grandparents (1.4%) also participating. The 74 children had an average age of 78 months, with a gender distribution of 47.3% girls and 52.7% boys. The children's ethnic backgrounds included non-Hispanic (95.9%) and Asian (77.5%), with other ethnicities represented, including White (11.3%), Black or African American (1.4%), and other (9.9%). In terms of educational enrollment, 70.3% of children attended elementary school, 21.6% were in kindergarten, and 8.1% were in pre-K. Regarding language background, 18.9% of children were monolingual English speakers, while 81.1% were reported as bilingual and multilingual speakers who speak more than one language (Table 2).

Correlations

According to the HLE model (Sénéchal & LeFevre, 2002), the covariates included in the hierarchical linear regression were selected based on their significant correlations with children's literacy skills. Pearson correlation analyses revealed three demographic covariates: adult books at home and receptive language ($r = .261$, $p < .05$), children's age and decoding skills ($r = .681$, $p < .01$), and household

Table 2. Demographics and descriptive statistics of participants ($N = 74$).

Category	Variable	Descriptive Statistics (N, %, or M)
Caregivers	Age	36–40 years (45.9%), 31–35 years (20.3%), 41–45 years (20.3%)
	Gender	Female (86.3%), Male (13.7%)
	Role	Mother (83.8%), Father (14.9%), Grandparent (1.4%)
	Ethnicity	Non-Hispanic (97.3%)
	Race	Asian (81.1%), White (13.5%), Black or African American (2.7%), Other (2.7%)
	Household Income	> $200,000 (63.4%)
Children	Age	$M = 77.9$(Months, $SD = 9.18$)
	Gender	Girl (47.3%), Boy (52.7%)
	Ethnicity	Non-Hispanic (95.9%)
	Race	Asian (77.5%), White (11.3%), Black or African American (1.4%), Other (9.9%)
	School Level	Elementary (70.3%), Kindergarten (21.6%), Pre-K (8.1%)
	Language Background	Monolingual-English (18.9%), Bilingual/Multilingual (81.1%)

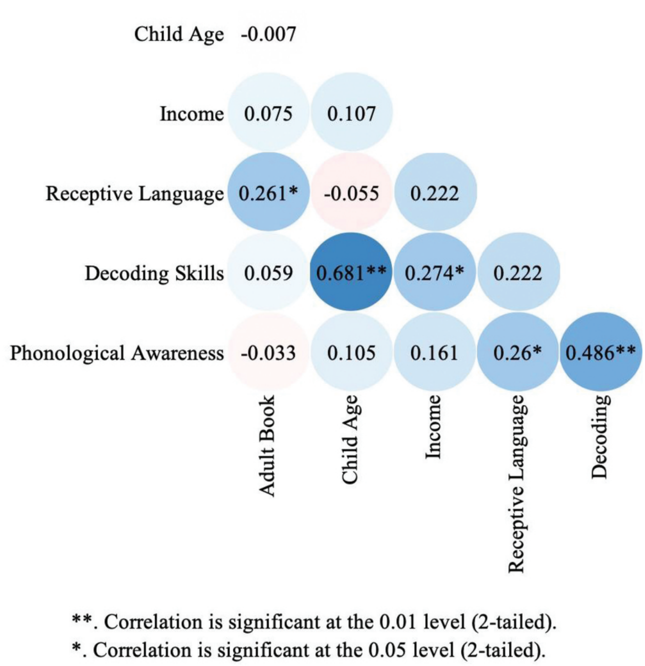

Figure 1. Correlation matrix.

income and decoding skills ($r = .274$, $p < .05$). Additionally, strong interrelationships were found among literacy skills, with receptive language correlating with phonological awareness ($r = .260$, $p < .05$), and decoding skills correlating with both receptive language ($r = .222$) and phonological awareness ($r = .486$, $p < .01$). Based on these findings, adult books, child age, household income, as well as receptive language, decoding, and phonological awareness were included as control variables in their respective hierarchical regression models (Figure 1).

Home literacy environments and children's literacy skills

Hierarchical linear regression analyses were conducted to examine the influence of traditional HLE, digital HLE, and AI in HLE activities on children's receptive language, decoding skills, and phonological awareness (PA). Covariates for each step were selected based on their correlations with literacy skills identified in the correlation analyses.

Traditional HLE and children's literacy skills

Three hierarchical linear regression models were conducted to examine the relationship between traditional HLE and children's literacy skills. For receptive language, adult books in the home (R^2 = .068, p = .025) and PA (ΔR^2 = .069, p = .02) were entered first as covariates, accounting for 13.8% of the variance. Parent teaching (ΔR^2 = .029, p = .126) and storybook exposure (ΔR^2 = .003, p = .608) were subsequently added to the model, together contributing an additional 3.2% of the variance. For decoding skills, child age (R^2 = .467, p < .001), household income (ΔR^2 = .041, p = .02), and PA (ΔR^2 = .161, p < .001) were entered into the model as covariates, accounting for 66.8% of the variance. Parent teaching (ΔR^2 = .017, p = .064) and storybook exposure (ΔR^2 = .007, p = .227) were then introduced, contributing an additional 2.4% of the variance. For PA, receptive language (R^2 = .067, p = .025) and decoding skills (ΔR^2 = .193, p < .001) were first included as covariates and explained 26% of the variance. Parent teaching (ΔR^2 = .001, p = .819) and storybook exposure (ΔR^2 = .011, p = .32) were then added to the model and explained an additional 1.2% of the variance. In summary, traditional HLE factors explained 3.2% of the variance in receptive language, 2.4% in decoding skills, and 1.2% in PA at a non-significant level (Table 3).

Digital HLE and children's literacy skills

Three hierarchical regression analyses were conducted to examine the relationship between digital HLE and children's literacy skills. For receptive language, adult books (R^2 = .068, p = .027) and PA (ΔR^2 = .069, p = .021) were included as covariates, collectively explaining 13.7% of the variance. LRDA (ΔR^2 = .012, p = .323) and digital device exposure (ΔR^2 = .001, p = .835) were subsequently added to the model and contributed 1.3% at a non-significant level. For decoding skills, child age (R^2 = .447, p < .001), household income (ΔR^2 = .046, p = .016), and PA (ΔR^2 = .169, p < .001) served as covariates, accounting for 66.2% of the variance. The addition of LRDA (ΔR^2 = .001, p = .636) and digital resources (ΔR^2 = .004, p = .367) had a minimal impact, explaining 0.5% of the variance. For PA, receptive language (R^2 = .068, p = .026) and decoding skills (ΔR^2 = .20, p < .001) together explained 26.8% of the variance. When digital resource exposure was added, it accounted for a significant additional 4.9% of the variance in PA (ΔR^2 = .049, p = .03), whereas LRDA had a negligible effect on children's PA (ΔR^2 = .000, p = .848). Overall, digital HLE factors accounted for 1.3% of the variance in receptive language and 0.5% in decoding skills, both at non-significant levels, but the digital device exposure explained a significant 4.9% of the variance in PA. (Table 4).

Table 3. Hierarchical regression analysis for traditional HLE and Receptive language, decoding skills, and PA.

				Change Statistics		
Model	R	R Square	Adjusted R Square	R Square Change	F Change	Sig. F Change
Receptive Language						
Adult Book	.261[a]	.068	.055	.068	5.210	.025
PA	.371[b]	.138	.113	.069	5.635	.020
Parent Teaching	.408[c]	.167	.130	.029	2.393	.126
Storybook Exposure	.412[d]	.170	.121	.003	.265	.608
Decoding Skills						
Child Age	.683[a]	.467	.459	.467	60.341	< .001
Household Income	.712[b]	.507	.493	.041	5.633	.020
PA	.817[c]	.668	.653	.161	32.498	< .001
Parent Teaching	.828[d]	.685	.666	.017	3.560	.064
Storybook Exposure	.832[e]	.692	.669	.007	1.485	.227
Phonological Awareness						
Receptive Language	.260[a]	.067	.055	.067	5.209	.025
Decoding Skills	.510[b]	.260	.239	.193	18.510	< .001
Parent Teaching	.511[c]	.261	.229	.001	.053	.819
Storybook Exposure	.521[d]	.271	.229	.011	1.003	.320

Note. PA = Phonological Awareness. Superscripts indicate stepwise regression entry order.

Table 4. Hierarchical regression analysis for digital HLE and Receptive language, decoding skills, and PA.

				Change Statistics		
Model	R	R Square	Adjusted R Square	R Square Change	F Change	Sig. F Change
Receptive Language						
Adult Book	.260[a]	.068	.054	.068	5.087	.027
PA	.37[b]	.137	.112	.069	5.555	.021
LRDA	.387[c]	.15	.112	.012	0.992	.323
Digital Resources	.388[d]	.150	.099	.001	.044	.835
Decoding Skills						
Child Age	.669[a]	.447	.439	.44	55.009	< .001
Household Income	.702[b]	.493	.478	.046	6.105	.016
PA	.814[c]	.662	.647	.169	32.945	< .001
LRDA	.814[d]	.663	.642	.001	0.227	.636
Digital Resources	.817[e]	.668	.642	.004	0.824	.367
Phonological Awareness						
Receptive Language	.260[a]	.068	.054	.068	5.148	.026
Decoding Skills	.517[b]	.268	.247	.200	19.137	< .001
LRDA	.518[c]	.268	.236	.000	.037	.848
Digital Resources	.564[d]	.318	.278	.049	4.930	.030

Note. PA = Phonological Awareness. Superscripts indicate stepwise regression entry order.

AI-Integrated HLE and children's literacy skills

A composite variable of ChatGPT usage was created by calculating the mean value of the construct. Factor analysis was conducted, and the item of parental concerns was excluded from the analysis due to low factor loading ($\lambda = .079$). The mean value of $M = 2.28$ (out of 5, $SD = 0.69$) indicated a moderate usage of ChatGPT among participants. Three hierarchical regression analyses were conducted to examine the relationship between ChatGPT usage and children's literacy skills. For receptive language, adult books ($R^2 = .047$, $p = .074$) and PA ($\Delta R^2 = .078$, $p = .018$) were entered first as covariates. ChatGPT usage was added later but contributed limited power to the model ($\Delta R^2 = .003$, $p = .655$). For decoding skills, child age ($R^2 = .460$, $p < .001$), household income ($\Delta R^2 = .043$, $p = .022$), and PA ($\Delta R^2 = .153$, $p < .001$) were included first as covariates. The addition of ChatGPT usage contributed 0.6% at a non-significant level ($\Delta R^2 = .006$, $p = .288$). For PA, receptive language ($R^2 = .079$, $p = .018$) and decoding skills ($\Delta R^2 = .18$, $p < .001$) were entered first as covariates, while the subsequent inclusion of ChatGPT usage added little explanatory power to the model ($\Delta R^2 = .004$, $p = .561$). Overall, the models indicated that ChatGPT usage had limited explanatory power across all three literacy outcomes, accounting for 0.3% of the variance in receptive language, 0.6% in decoding skills, and 0.4% in PA (Table 5).

Table 5. Hierarchical regression analysis for AI in HLE and Receptive language, decoding skills, and PA.

				Change Statistics		
Model	R	R Square	Adjusted R Square	R Square Change	F Change	Sig. F Change
Receptive Language						
Adult Book	.216[a]	.047	.033	.047	3.29	.074
PA	.353[b]	.125	.098	.078	5.888	.018
ChatGPT Usage	.357[c]	.128	.087	.003	0.201	.655
Decoding Skills						
Child Age	.679[a]	.460	.452	.460	55.474	< .001
Household Income	.710[b]	.504	.488	.043	5.553	.022
PA	.810[c]	.657	.640	.153	28.065	< .001
ChatGPT Usage	.814[d]	.663	.641	.006	1.149	.288
Phonological Awareness						
Receptive Language	.281[a]	.079	.066	.079	5.838	.018
Decoding Skills	.509[b]	.259	.237	.18	16.323	< .001
ChatGPT Usage	.513[c]	.263	.230	.004	.342	.561

Note. PA = Phonological Awareness. Superscripts indicate stepwise regression entry order.

Discussion

Drawing on data from 74 U.S. families with children aged five to seven, this study examined the effects of traditional, digital, and AI-integrated HLE factors on children's early literacy skills. The results indicated that traditional HLE factors remain the most influential in supporting children's literacy development, while the impact of digital and AI-integrated HLE components appears limited and needs further investigation.

Traditional HLE

Caregivers in the current study demonstrated active involvement in traditional home literacy activities. Specifically, parents reported teaching their children to read and write with an average frequency rating of 3.36 on a 5-point scale. Additionally, 67.6% of parents reported their children owning more than 80 storybooks at home, indicating that children in the current study continue to grow up in print-rich home environments.

Regression analyses indicated that traditional HLE, represented by parent teaching and storybook exposure, continues to play the most critical role in shaping children's language skills. The predictive powers of the traditional HLE are broadly aligned with the original HLE model, suggesting a continued importance of parental involvement in children's literacy development in the digital age. The unique benefit of social interaction and joint attention may explain the irreplaceable role of parental involvement. Vygotsky (1978) emphasized social interaction as a core mechanism in language development, while pragmatic theory (Bates, 1976) highlights the importance of communicative exchanges in fostering language acquisition. When parents teach their children to read and write, the interaction not only conveys instructional content but also facilitates language learning through responsive, meaningful communication. Joint attention further reinforces this process. During shared reading, children benefit from joint attention – focus on the same text or activity with their parents – through exposure to social cues such as eye contact, gestures, and facial expressions. These cues guide attention and support language processing. A large body of research has demonstrated that joint attention plays a foundational role in early language acquisition (Puckett et al., 2009). In contrast, digital media and AI conversational tools may lack or fail to reproduce these essential social features of human communication, potentially limiting their effectiveness in supporting language development. As such, even in digitally enriched home environments, parental engagement remains the most critical and consistent predictor of children's early literacy outcomes.

Digital HLE

Findings from the digital HLE suggest that children are actively interacting with digital devices and engaging in literacy-related digital activities (LRDA) within the home environment. Specifically, children in the current study have an average of $M = 1.74$ digital device access at home and participate in LRDA with an average frequency of 2.07 out of 5. These findings align with existing research that highlights the prevalence of digital activity exposure among young children (Chaudron et al., 2015; Holloway et al., 2013) and further support the idea that children in the digital age are increasingly immersed in digital-rich environments, which significantly reshape their literacy experiences at home (Marsh et al., 2017; Turco et al., 2023; Wartella et al., 2013).

Results from the regression models yielded a significant correlation between digital device exposure and children's phonological awareness. This finding supported by prior research that interactive digital tools can effectively promote phonological development, as such tools often incorporate multimedia elements including sound, animation, and interactivity, which reinforce learning in ways that extend beyond traditional print reading resources (Deault et al., 2009; Lonigan et al., 2003; Messer & Nash, 2018; Neumann, 2018). In the current study, parents most frequently reported that their children used tablets, laptops, smartphones, and televisions, all devices that provide both auditory and visual input. These multimodal features may support the development of phonological awareness by offering rich sensory cues that help children recognize and manipulate sounds.

However, the overall findings from the regression models revealed a minimal effect of digital HLE on children's literacy skills, indicating that while engagement with digital devices and participation in LRDA is prevalent and active, the direct impact of digital HLE on most literacy outcomes remains limited. Three potential explanations may account for this non-significant finding. First, the way of LRDA being engaged and how the digital devices are used are under covered. A concrete body of research on parental mediation and joint media engagement has shown that active involvement from caregivers when children engaging in digital media, such as discussing content or helping children make connections between digital content and real-world experiences, is essential for maximizing the educational potential of digital tools (Livingstone et al., 2018; Nikken & Haan, 2018; Strouse et al., 2013; Takeuchi & Stevens, 2011). It is possible that the absence of guidance or scaffolding diminishes the effectiveness of these activities in supporting literacy development. Second, although many digital tools and media are designed with educational intentions, some are found to be more entertaining than educational (Guernsey, 2012; Hirsh-Pasek et al., 2015; Plowman et al., 2010). The exposure to digital devices and LRDA may not consistently translate the educational purpose into measurable gains in literacy skills as a result. Third, children aged 5 to 7 are still developing self-regulation and sustained attention (Puckett et al., 2009), which means they may not be able to independently benefit from digital literacy activities without adult guidance. Structured learning environments with educator supervision are often more effective at promoting literacy growth than self-directed digital engagement (Neumann, 2015; Vandewater & Lee, 2009).

Overall, the non-significant findings may suggest that digital device exposure and LRDA are less effective than traditional parent teaching in supporting children's literacy skills, especially when they lack direct, targeted educational content and active adult involvement.

AI-integrated HLE

Results from the AI-integrated HLE revealed active ChatGPT usage among parents and children at home. 52.7% of parents reported that they have utilized ChatGPT in assisting their children in both general and language learning in a moderate frequency ($M = 2.23$, $SD = 0.85$). 8.1% of parents reported that their children had used ChatGPT in some way ($M = 1.28$, $SD = 0.69$), demonstrating an active, though limited, usage of ChatGPT among young children at home. These findings align with recent research highlighting the growing integration of AI-powered conversational tools in home learning environments (Lai et al., 2023; Yıldız, 2023; Zhou, 2023).

However, while findings indicate that AI tools are actively used by parents and, to a lesser extent, by children, their direct impact on literacy development remains limited at this stage. Subsequent regression analyses revealed minimal and non-significant correlations between AI tool (e.g., ChatGPT) usage and children's literacy skills. These findings suggest that while AI tools like ChatGPT are capable of generating rich communicative content and are increasingly integrated into the modern HLE, their direct contribution to children's literacy development, at least as measured by the metrics used in this study, has yet to be clearly demonstrated. Three possible explanations may account for this finding. First, the usage intensity was relatively low. Only 8.1% of children were reported to have used the platform, which likely limited the statistical power needed to detect meaningful effects. This finding aligns with previous research indicating that young children's engagement with generative AI tools like ChatGPT in home settings remains limited and exploratory (Quan et al., 2024). The small number of users and the lack of validated instruments to measure AI-specific literacy outcomes may both contribute to the absence of significant findings. Second, the usage context may also be a key factor. A recent study (Quan et al., 2025) found that while some parents reported using ChatGPT for literacy-related purposes such as storytelling and vocabulary support, most children engaged with the tool for information-seeking or play-driven activities. This suggests that the way in which AI tools are used at home may not effectively support literacy development, particularly when interactions are not guided by educational goals or focused on language learning. Third, the survey used ChatGPT as a representative example of AI tools; however, AI tools beyond conversational agents (e.g., ChatGPT) vary widely in design, functionality, and interactivity. Such variation can lead to different patterns of use and adoption (Quan et al, 2025), potentially limiting the generalizability of the survey to capture the broader impact of AI-integrated literacy experiences.

Nevertheless, the continued emergence of commercial AI applications that focus on language learning (e.g., Readability, Buddy.ai), which offer interactive learning experiences, individualized feedback, and multimodal content, reflects a growing trend in the integration of AI into literacy practices. Existing research has provided some validation for the positive effects of these practices in areas such as interactive storytelling (Xu et al., 2023), reading motivation (Liu et al., 2022), and culturally responsive parent – child co-reading (He et al., 2024). These findings point to the potential of AI in supporting language development when integrated with intentional design. As findings from traditional HLE reaffirm the irreplaceable role of social interaction in children's language development, an important design consideration is to leverage AI's social capabilities, particularly to consider incorporating human-like social cues during interactions with children, to effectively promote language learning.

In summary, while the current study did not detect significant effects of AI tool usage on children's literacy outcomes, the active engagement with ChatGPT reported by both parents and children reflects the increasing role of AI technologies within the HLE. As these technologies continue to evolve, their capacity to support literacy and language development will likely expand, making the monitoring and evaluation of AI integration in home literacy environments a valuable direction for future research.

Limitations and future work

This study examined the effects of traditional HLE, digital HLE, and AI tool usage (e.g., ChatGPT) on young children's early literacy development, reaffirming the critical role of parental involvement and print-based storybook exposure while highlighting the emerging, though still limited, influence of digital and AI-integrated literacy practices in the home. While these findings contribute to a growing body of research on the evolving landscape of the HLE in the age of AI, a few limitations and corresponding future directions are considered and detailed below.

Sample homogeneity

The use of snowball sampling and limited network outreach reduced sample diversity, raising concerns about sample homogeneity. 63.4% of participants in the current study were from high socioeconomic backgrounds (annual incomes exceeding $200,000), and 81.1% of them are Asian American. This homogeneity introduces limitations in the representativeness of the broader U.S. population, potentially constraining the significance and generalizability of the findings (Altman & Bland, 2014; Parker et al., 2019). The lack of diversity within the sample group likely limits the ability to detect significant relationships between variables and literacy outcomes, particularly given the strong cultural emphasis on education observed among Asian American families (Louie, 2001; Sun, 1998). The limitations stemming from sample homogeneity underscore the importance of recruiting a more diverse participant base in future research to enhance representativeness and improve the robustness of the findings. A more systematic and inclusive recruitment strategy could involve partnerships with educational institutions across various geographic and socioeconomic settings, thereby broadening the demographic scope of the sample.

Measurement reliability

In contrast to the well-established traditional HLE model, validated constructs for measuring digital HLE, especially those involving AI, are still in the early stages of development due to the novelty of these technologies. In particular, survey items related to AI-integrated HLE provided limited insight into how and to what extent the AI tools were used for home literacy practices. It restricts the ability to draw reliable conclusions about its educational impact and limits the generalizability of the findings to AI-enhanced learning tools other than ChatGPT. Future research should examine a broader range of AI tools and move beyond basic usage metrics to capture more nuanced insights into how and to what extent these tools are used, in order to better understand their potential for supporting early literacy development. Furthermore, because the HLE is a dynamic and interconnected system, future research should consider moving beyond examining its components separately and instead explore how print resources, digital media, AI tools, and parental involvement interact within the home environment to provide children with integrated literacy experiences, and how these multimodal practices shape children's language development. Particular attention should be given to AI, as parent-child interactions with AI technologies are likely to represent a new form of parental involvement in the AI era.

Methodological limitation

The study's cross-sectional design offers a timely evaluation of digital literacy practices at home but limits the ability to examine the long-term effects of digital and AI-integrated HLE on children's literacy development. Additionally, the reliance on quantitative data does not fully capture the nuanced ways in which families engage with those digital tools, which may further undermine the statistical findings. Incorporating qualitative data, such as follow-up interviews or open-ended survey responses, would provide richer insights into children's engagement with LRDA and AI technologies and provide a better explanation of the statistical findings. This limitation highlights the need for more rigorous, nuanced, and developmentally informed methods to evaluate the impact of digital and AI tools in early literacy development. Future research should consider adopting a mixed-methods approach to gain a deeper understanding of how children engage with these tools, how parents and children interact both with the technology and with one another, and under what conditions they are most effective in supporting literacy growth. Additionally, future research could include a longitudinal design to explore the long-term impact of AI-integrated home literacy practices on children's development.

Implications

The current study proposes an evolving HLE framework by extending the traditional HLE model to incorporate digital device exposure, literacy-related digital activities, and the use of AI tools such as ChatGPT, reflecting contemporary home learning practices. The findings have several implications for educators, caregivers, and stakeholders. First, the findings reinforce the importance of maintaining strong parental involvement and access to print-based materials, even as digital tools become more prevalent in children's lives. While these technologies show promise and are viewed positively by some parents, they are not yet capable of replacing the vital role that parents play in supporting children's language development. Instead, parents and educators should prioritize engaging children in meaningful, socially rich human interactions, alongside the use of print-based reading materials, to effectively foster language growth.

Second, the study highlights the need for intentional design of digital and AI tools to effectively support language acquisition and literacy development among young children. While AI technologies such as ChatGPT are increasingly used in home environments and hold potential for delivering personalized and interactive learning experiences, their educational effectiveness remains uncertain and should be carefully monitored. The findings suggest that tools aiming to support early literacy should prioritize the social-emotional dimension of interaction, simulating human-like conversations that foster meaningful language use. Effective design should also incorporate systematic, structured instruction and deliver developmentally appropriate content and pacing aligned with children's cognitive, linguistic, and social-emotional capacities to ensure these tools meaningfully support early literacy development.

Lastly, ensuring equitable access to both traditional and digital literacy resources is essential for addressing disparities in early literacy development. These findings point to the need for policymakers, educators, and technology developers to proactively address digital access gaps, particularly as AI-integrated tools become more embedded in early learning contexts. Without intentional efforts to ensure equitable distribution of high-quality digital resources, such technologies may unintentionally widen existing disparities in early literacy development. Practitioners and policymakers should remain mindful of these inequities when incorporating digital tools into instruction and seek to complement technology use with accessible, low-barrier literacy practices to ensure all children, regardless of socioeconomic or linguistic background, can benefit from enriched home learning environments.

Conclusion

Grounded in the Home Literacy Environment (HLE) model, this cross-sectional study explored how traditional, digital, and AI-integrated HLE factors relate to young children's early literacy development. Results from 74 U.S. families with children aged 5 to 7 reveal that traditional HLE activities, particularly parent teaching children to read and write and exposure to printed storybooks, remain the strongest predictors of children's early literacy outcomes. Although children today are growing up in technology-rich environments and increasingly interacting with digital devices and AI tools, the influence of digital and AI-integrated HLE factors on literacy development was statistically limited and needs further investigation. These findings reinforce the continued importance of parental involvement and access to print-based resources, underscore the evolving nature of the HLE. Future research should explore how digital and AI tools can be intentionally designed and effectively used, and how printed resources, digital media, AI tools, and parental involvement interact to create integrated literacy experiences that are most beneficial. Particular attention should be given to parent – child interactions with AI technologies as it may emerge as a new form of parental involvement in the AI era.

Disclosure statement

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