Tan, Y. V., Lee, J. A. C., Khan, R. U., Chen, C. J., Ghani, K. A., Juan, S. F. S., & Loh, C. S. B. (2025). Analyzing the effectiveness of the READi system in helping non-native English-speaking preschoolers in Sarawak learn the alphabet: A pilot study. *Journal of Educational Technology Development and Exchange*, *18*(2), 25-46. https://doi.org/10.18785/jetde.1802.02

Analyzing the Effectiveness of the READi System in Helping Non-Native English-Speaking Preschoolers in Sarawak Learn the Alphabet: A Pilot Study

Yen Vee Tan
University of Malaysia Sarawak, Malaysia
Email: jovietan2000@gmail.com
https://orcid.org/0009-0008-8726-8902

Julia Ai Cheng Lee
University of Malaysia Sarawak, Malaysia
Child and Adolescent Learning and Wellbeing Centre, UNIMAS, Malaysia
aclee@unimas.my
https://orcid.org/0000-0001-9149-3848

Rehman Ullah Khan
University of Malaysia Sarawak, Malaysia
krullah@unimas.my

Chwen Jen Chen
University of Malaysia Sarawak, Malaysia
cjchen@unimas.my

Kartini Abdul Ghani
University of Malaysia Sarawak, Malaysia
Child and Adolescent Learning and Wellbeing Centre, UNIMAS, Malaysia
gkartini@unimas.my

Sarah Flora Samson Juan
University of Malaysia Sarawak, Malaysia
sjsflora@unimas.my

Chung Shiong Brian Loh
Swinburne University of Technology Sarawak Campus, Malaysia
Email: bloh@swinburne.edu.my
https://orcid.org/0000-0002-4034-4233

Abstract: *In Sarawak, Malaysia, many children come from multicultural backgrounds and are predominantly non-native English speakers, making preschool education essential for developing early literacy skills in English. However, high teacher-child ratios can impede effective learning. The READi system, a module-based multisensory web-based early literacy intervention, was introduced as a supplementary classroom tool to address this challenge. This pilot study specifically evaluated the effectiveness of the "Alphabet Adventure" module within the READi system on enhancing alphabet knowledge, with a focus on letter recognition and letter name knowledge. The research design employed a pretest-posttest control group approach grounded in the positivist paradigm. Participants were selected through teacher referrals and paired based on their pretest performance to ensure comparable baselines before being randomly assigned to either the experimental or control group. Data analyses were conducted using the Wilcoxon Signed Rank and Mann-Whitney U tests. The results indicated that the READi system significantly improved uppercase letter recognition among children. These findings offer valuable insights into future adaptations of the READi system, aimed at better addressing children's educational challenges and improving teaching practices..*

Keywords: preschoolers, web-based reading instruction, preschool digitalization, non-native speakers, English, early literacy, alphabet knowledge, educational interventions

1. Introduction

Preschool education is crucial in helping children develop essential language and literacy skills, with the learning environment significantly influencing their growth (Buckingham et al., 2023). In Malaysian public preschools, the typical teacher-to-student ratio is 1:25, meaning each teacher is responsible for 25 children (Kong, 2023; Ministry of Education Malaysia [MOE], 2018). However, this ratio can increase to as high as 1:28 due to a shortage of teachers, which further challenges the learning experience (Rahmatullah et al., 2021).

The Malaysia Education Blueprint 2013-2025 outlines the Ministry of Education's expectation for children in Malaysia to achieve a certain level of proficiency in the English language (Ministry of Education Malaysia [MOE], 2013). However, in a multilingual environment like Malaysia, English is not the first language for most children. In Sarawak, home to more than 18 ethnic groups, children's primary languages include Sarawak Malay, Iban, Malay, Bidayuh, and Chinese (Lee et al., 2020). A previous study on preschoolers in Sarawak reported that while most preschoolers (78.3%) possess alphabetic knowledge, approximately 21.7% struggle to establish a strong foundation in this area (Wang & Lee, 2020). Consequently, these children often require additional support from teachers to effectively develop their language skills and keep pace with their peers (Magnuson et al., 2007).

While reducing class sizes is known to enhance educational outcomes, this is often a costly solution (Kedagni et al., 2021). An alternative approach is to use multisensory digital systems to enhance children's language learning experiences in the classroom (Fadeev & Milyakina, 2021; O'Brien et al., 2022). Despite their potential benefits, this area remains largely unexplored among preschoolers in Sarawak, Malaysia. This study aims to address this gap by conducting an experimental investigation that will provide valuable insights for teachers and policymakers

regarding the effectiveness of such digital interventions in preschool settings.

1.1. Significance of the Study

The significance of this study lies in its potential to evaluate the effectiveness of a multisensory web-based early literacy intervention aimed at improving early literacy instruction. Specifically, it focuses on enhancing letter name knowledge and letter recognition among preschool children. The study seeks to raise awareness among educators about innovative teaching methods by demonstrating the advantages of integrating digital technologies into preschool pedagogy. Furthermore, it provides valuable insights for policymakers and educators, advocating for the use of multisensory web-based interventions to enhance literacy-focused instruction in early childhood education.

1.2. Context of The Study

According to the Ministry of Education (2013), children in Malaysia are expected to achieve proficiency in both English and Malay. However, many children in Sarawak grow up in multilingual environments where English is not their first language (Lee et al., 2020). Given this context, preschools play a vital role in fostering early literacy skills in English. However, the teacher-child ratios often exceed 1:25, which limits individualized attention and interactive learning opportunities. This study sought to determine whether a multisensory web-based early literacy intervention could serve as a supplementary tool for teachers, potentially enhancing children's acquisition of alphabet knowledge in English. Specifically, this pilot study sought to determine the effectiveness of this intervention in developing letter recognition and letter naming skills among preschoolers who are non-native English speakers. The study addressed the following research questions:

1. How does the multisensory web-based early literacy intervention affect children's uppercase and lowercase letter recognition skills?

2. How does the multisensory web-based early literacy intervention affect children's uppercase and lowercase letter naming skills?

3. In what ways does the recognition of uppercase and lowercase letters differ between children who received the intervention and those who did not?

4. In what ways does the naming of uppercase and lowercase letters differ between children who received the intervention and those who did not?

1.3. Research Framework

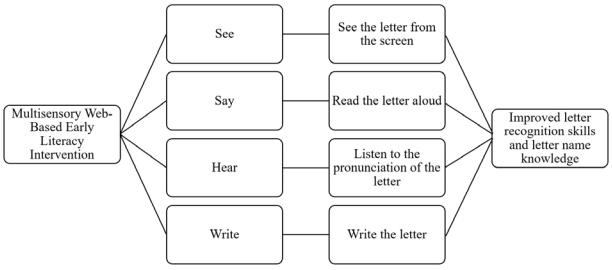
1.3.1. Conceptual framework

This study utilized a multisensory web-based early literacy intervention aimed at improving preschoolers' letter recognition skills and letter name knowledge. The multisensory framework for this study integrates four key sensory modalities: seeing, saying, hearing, and writing, as highlighted by previous research (Farrell & Sherman, 2011; Zanatta & Rosales-Ruiz, 2021). The "See" component enables children to visually identify letters displayed on a screen, while

the "Say" component encourages them to vocalize the letters, reinforcing verbal recognition. The "Hear" element fosters auditory engagement, allowing children to listen to the correct pronunciation of the letters. Lastly, the "Write" component promotes tactile and kinesthetic learning through the physical act of writing the letters. These interconnected sensory experiences create a robust learning environment that enhances information encoding, retrieval, and overall literacy outcomes (see Figure 1). By employing this multisensory approach, this intervention aims to address shortcomings in early traditional literacy instruction and provide children with an engaging and effective learning experience.

Figure 1

Conceptual Framework



2. Literature Review

2.1. Alphabet Knowledge

Developing early literacy skills is crucial for laying the groundwork for later reading proficiency and overall academic success. These foundational skills include alphabet knowledge, phonological awareness, rapid automatized naming of letters, digits, objects, or colors, name writing, letter writing, and phonological memory (National Early Literacy Panel [NELP], 2008). Among these skills, alphabet knowledge strongly predicts later literacy development, influencing reading and spelling abilities (Castles et al., 2018; NELP, 2008). Thus, fostering alphabet knowledge is essential to mitigate challenges related to emergent literacy and long-term academic achievement (Heilmann et al., 2018; Piasta et al., 2022).

Alphabet knowledge encompasses recognizing letter shapes, knowing their names, and understanding their corresponding sounds, all of which are crucial for children to grasp the alphabetic principle and learn to read (Allen et al., 2005; Drouin et al., 2012; Gehsmann & Mesmer, 2023). These components are interconnected; for instance, letter recognition skills predict letter name knowledge (Foulin, 2005), while letter name knowledge, in turn, predicts letter sound knowledge (Huang et al., 2014; Treiman et al., 2008). Given this progression, this study focuses on letter recognition and letter name knowledge as foundational skills that support the later development of letter sound knowledge and subsequent early literacy skills.

2.1.1. Letter recognition skills

Letter recognition can be explained using the template-matching model, which assumes that each letter is stored in memory as multiple shapes. Recognition occurs when the target item matches one of these stored shapes (Grainger et al., 2008; Larsen & Bundesen, 1996). When children encounter new letter forms that differ from those stored in their memory, a new template is learned and stored (Grainger et al., 2008). As children become more proficient at quickly recognizing letters, they start to group them together rather than identifying each letter individually (Carreker, 2011).

Distinguishing between letters during letter recognition can be challenging for children because many letters look similar at first glance (Mayarita et al., 2024). In alphabetic orthographies, uppercase and lowercase letters form a single dimension (Bowles et al., 2014). It is typically easier for children to learn uppercase letters compared to lowercase ones, as many lowercase letters share similar forms, such as b, p, d, and q (Adhe et al., 2024; Anthony et al., 2021; Bowles et al., 2014).

Young children's understanding of lowercase letters is largely based on their resemblance to uppercase versions (Piasta, 2023; Treiman & Kessler, 2004). Consequently, children are more likely to recognize lowercase letters that closely resemble their uppercase counterparts (Piasta, 2023; Treiman & Kessler, 2004; Vinter et al., 2023). Thus, Piasta (2023) recommended teaching uppercase letters first or simultaneously alongside lowercase letters to improve letter recognition in young learners.

2.1.2. Letter name knowledge

Letter name knowledge is considered vital for reading development (De Abreu & Cardoso-Martins, 1998; Evans et al., 2006; Foulin, 2005; Paige et al., 2018). Understanding the name of each letter enables children to uniquely label different letter shapes, leading to easier and more accurate recall of information (Allen et al., 2005). When children can name letters, they can more readily learn letter sounds and spellings without difficulties (Adams, 1994; Paige et al., 2018). Otaiba et al. (2010) demonstrated a moderate correlation (r = .54) between letter naming and preschool children's spelling ability.

Research indicates that having the knowledge of letter names can help children predict letter sounds, as a phonetic link often exists between the two. This connection offers clues to early readers, as certain letter sounds correspond to letter names (Huang et al., 2014; Piasta, 2023; Treiman et al., 2008). For instance, children may quickly associate the sound /vi/ with the letter name /v/ (Treiman et al., 2008). Nevertheless, Adams (1994) cautioned that without a solid grasp of letter names, children might be confused between letter names and their sounds.

2.2. Digital Learning System for Letter Learning

Digital learning systems foster interactive, self-paced, and personalized learning environments, which significantly improve reading outcomes (Blikstad & Davies, 2017; Liang et al., 2005), particularly for children with weaker reading skills (Elbaum et al., 2000). Research shows that integrating speech technologies in one-on-one digital English classrooms provides more opportunities for children to practice speaking than traditional group settings (Yang et

al., 2005). Furthermore, a survey conducted by Chang (2016) revealed that 70.7% of teachers believed that one-on-one digital learning enhances communication skills, including reading and writing abilities.

Several studies highlight the effectiveness of digital learning systems in enhancing early literacy skills. Van Daal and Reitsma (2000) found that preschoolers who engaged in up to sixteen hours of computer-based practice demonstrated comparable proficiency in letter knowledge and word reading to peers who received three months of traditional instruction. Similarly, Samur (2019) found that kindergarteners participating in a six-week digital game intervention outperformed those receiving standard classroom instruction. Notably, Chen et al. (2023) reported significant improvements in uppercase letter recognition among preschoolers using a letter-learning application on iPad. Cornito (2023) also concluded that digital learning positively impacted children's alphabet knowledge. Building on these findings, both Elimelech and Aram (2019) and Metsala and Kalindi (2022) emphasized that web-based digital systems could effectively enhance preschoolers' alphabet learning, further supporting the potential of technology-driven interventions in early literacy development.

Despite the supporting evidence, Patel et al. (2022) noted that the effectiveness of digital systems was more pronounced in children who already possessed some English literacy skills before the intervention. Liu et al. (2024) and Bautista et al. (2023) emphasized the need for future research to explore the impact of digital systems on teaching alphabet knowledge, as the existing literature on this topic was still limited.

2.3. Multisensory Learning

Children entering preschool possess a diverse range of skills. For instance, some of the students may already be able to decode words or know some letter-sound correspondences, while others have little or no knowledge of the alphabet (National Reading Panel [NRP], 2000). Incorporating multisensory instruction into lesson delivery can enhance students' reading readiness (Amico, 2022; Joshi et al., 2002).

According to Farrell and Sherman (2011), multisensory instructional strategies engage four key senses: seeing, saying, hearing, and writing. Murray et al. (2016) further supported this approach, suggesting that environmental stimuli interact to facilitate information encoding in a multisensory context, aiding both information processing and retrieval. Additionally, Zanatta and Rosales-Ruiz (2021) emphasized that training children to hear, see, say, and write could significantly enhance their learning.

Presently, preschool teachers commonly employ multisensory learning approaches in physical activities, such as singing alphabet songs, reading nursery rhymes, and displaying pictures of letters (Amico, 2022).

2.3.1. Multisensory learning system

Recently, digital systems designed for children have increasingly incorporated multisensory learning. Notable examples of such systems include the *STTory* system (Ponticorvo et al., 2019),

the *Interactive Multi-Sensory Environments* (iMSEs, Garzotto et al., 2020), and the *See Word Reading* program (O'Brien et al., 2022).

The STTory system is a storytelling tool that engages children by allowing them to experience stories through multiple senses, including taste, smell, and touch (Ponticorvo et al., 2019). Additionally, it provides physical and digital materials for children to manipulate (Ponticorvo et al., 2019).

An example of the *Interactive Multi-Sensory Environments* (iMSEs) is the *Magic Room,* where children can interact with various materials while their movements and gestures are detected by the Kinect device (Garzotto et al., 2020). Research involving primary school children has shown that these systems enhanced engagement in the learning process (Garzotto et al., 2020) and improve learning outcomes (Ponticorvo et al., 2019).

Previous studies have explored the potential of multisensory digital technology to improve learning outcomes for students with disabilities (Garzotto et al., 2020) and primary school students (Garzotto et al., 2020; Ponticorvo et al., 2019). However, there is limited knowledge regarding the effectiveness of these digital systems in enhancing early literacy learning among preschoolers. Nonetheless, recent research by O'Brien et al. (2022) highlighted that incorporating multisensory learning within a digital system can significantly improve the early literacy skills of preschool children, as demonstrated by the success of the *See Word Reading* program. This finding suggests that multisensory digital technology can be a valuable tool for supporting early literacy development in preschool-aged children.

3. Method

3.1. Research Design

The study used a pretest-posttest control group design within a positivist paradigm. The pretest-posttest design was used to determine how a change in the environment (such as an intervention) impact performance over time (Bordens & Abbott, 2014). However, relying solely on a pretest-posttest approach could potentially compromised the internal validity (Bordens & Abbott, 2014). To enhance the internal validity of the study, a control group was included (Bordens & Abbott, 2014).

3.2. Participants

The participants in this pilot study comprised 18 children from a government preschool in Kuching, Sarawak. Initially, 20 children were recruited for this study. Two children dropped out for different reasons: one due to personal health issues and the other for withdrawal from the intervention. The mean age of the remaining participants at the pre-test was 5.37 years (*SD* = .55), with 50% being male. The preschoolers attended half-day classes, participating in daily 30-minute sessions of the Smarter Phonics Program and 60-minute weekly sessions of the Common European Framework of References (CEFR) lessons focused on learning English. The Smarter Phonics Program emphasizes letter recognition through phonics by encoding, decoding,

and blending individual sounds to form words (Liu et al., 2021). In contrast, the CEFR lessons focus on listening, reading, speech interaction, speech production, and writing skills (Ishak & Mohamad, 2018).

The inclusion criteria for this study required that parents provide informed consent for their children, and that teachers refer to children identified as at risk for early literacy challenges. The exclusion criteria included children with severe developmental disabilities such as classic autism and Down syndrome, as well as those with visual or hearing impairments and non-verbal children. Using a pretest-posttest control group design, the study employed a matched sampling method (Creswell & Creswell, 2018), with participants selected based on teacher referrals to ensure that each pair had similar baseline characteristics.

3.3. Research Instrument

READi is a multisensory web-based early literacy intervention system developed by Lee et al. (2023) that engages multiple senses to deliver instructional materials. It is accessible through standard web browsers and consists of three modules: Module 1 focuses on alphabet knowledge, Module 2 emphasizes on word adventure, and Module 3 centers on stories. In the present study, Module 1 was delivered to provide interventions to enhance children's alphabet knowledge. The intervention was implemented up to letter H due to time constraints. Important to note is that this pilot study used READi version 1.0, which has since undergone numerous improvements based on the findings of this study, as well as system and user testing, and ongoing feedback from school staff.

3.4. Measures

3.4.1. Letter name knowledge

The ability of children to name letters of the alphabet was assessed using the Letter Name Knowledge test from the Early Literacy Test Administrator Kit developed by Lee et al. (2020). The test came in the uppercase and lowercase format, with each format comprising 26 letters that were presented randomly. Each child was instructed to name the letters presented to them, with each correct response counted as one point. The same tests were administered for the pretest and the posttest. Scores ranged between 0 and 26.

3.4.2. Letter recognition

The ability of children to recognize uppercase and lowercase letters of the alphabet was also assessed using the Letter Name Knowledge assessment (Lee et al., 2020). Children had to identify and point out the correct letters from a verbally presented list of random alphabet letters. The number of letters correctly recognized was recorded, with each correct identification earning one point. Scores ranged from 0 to 26.

3.5. Procedures of Data Collection

During the screening process, preschool teachers were asked to identify children from their

classes who could participate in this study. The children were screened, and those who met the inclusion criteria were selected to participate (see 3.1 participants). All assessments and the intervention were conducted in the school's computer lab.

A pretest was administered to evaluate the participants' letter recognition skills and letter name knowledge. The results indicated that the children demonstrated lower proficiency in identifying and naming lowercase letters than uppercase letters. Participants with similar baseline performance based on the average pre-test scores comprising lowercase letter recognition and letter name knowledge were paired and randomly assigned to either the experimental or control groups.

The control group received a traditional business-as-usual learning approach, which included the school's Smarter Phonics Program and CEFR lessons. In contrast, the experimental group engaged in daily interventions using the READi program and the traditional business-as-usual learning approach. The intervention lasted two weeks, with sessions being held from Monday to Friday, each lasting approximately 60 minutes.

After the intervention, a posttest was administered to all participants. Figures 2 and 3 illustrate the data collection procedures, while Figure 4 features a child participating in the intervention in the school's computer lab.

Figure 2

Data Collection Procedures for the Control Group

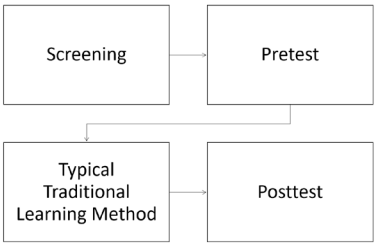


Figure 3

Data Collection Procedures for the Experimental Group

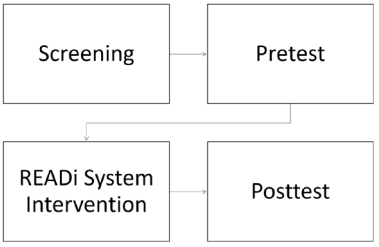


Figure 4

A Child Using the READi Version 1 Web-Based Reading Intervention System

3.6. Data Analysis

Data analysis was conducted using SPSS version 21, which enabled the calculation of descriptive, correlational, and inferential statistics. Descriptive statistics and correlational analysis were employed to provide an overview and to examine the relationships between the identified variables. Non-parametric tests were used to address research questions due to the small sample size of the present study (n = 18) (Pallant, 2020). Specifically, the Wilcoxon Signed Rank test was utilized to compare the pretest and posttest results of the experimental group. In contrast, the Mann-Whitney U test was used to compare the mean scores between the experimental and control groups.

4. Results

4.1. Descriptive Statistics and Correlation Analysis

Descriptive statistics for experimental and control groups are presented in Table 1. During the pretest phase, the experimental group exhibited lower average scores in uppercase letter name knowledge and uppercase letter recognition than the control group. Conversely, the experimental group outperformed the control group in lowercase letter name knowledge and lowercase letter recognition. Notably, the standard deviations of the experimental group were generally larger than those of the control group during the pretest, except for uppercase letter recognition. After the intervention, the experimental group exhibited higher average scores than the control group across all measures in the posttest phase. The standard deviations for the experimental group remained larger than those of the control group during the posttest.

Table 1

Means, Standard Deviations (SD), and Ranges

	Pretest				**Posttest**			
	EG (n = 8)		CG (n = 10)		EG (n = 8)		CG (n = 10)	
Test	*M (SD)*	Range	*M (SD)*	Range	*M (SD)*	Range	*M (SD)*	Range
Uppercase LNK	4.00 (3.207)	0 - 8	4.70 (2.751)	0 - 8	5.63 (3.114)	0 - 8	4.60 (2.875)	0 - 8

Lowercase LNK	4.00 (2.928)	0 - 8	2.90 (2.514)	0 - 7	3.88 (3.044)	0 - 8	3.50 (2.877)	0 - 7
Uppercase LR	3.63 (2.560)	0 - 7	3.80 (2.616)	0 - 8	4.38 (3.335)	0 - 8	4.20 (2.573)	0 - 8
Lowercase LR	3.125 (2.588)	1 - 8	2.90 (2.234)	0 - 6	3.25 (2.816)	0 - 8	2.90 (2.331)	0 - 6

Note. EG = Experimental Group; CG = Control Group, LNK = Letter Name Knowledge, LR = Letter Recognition

Tables 2 and 3 present the Pearson correlations for pretest and posttest measures of uppercase letter name knowledge, lowercase letter name knowledge, uppercase letter recognition, and lowercase letter recognition for children in experimental and control groups. Although the primary focus of the research is on comparing the experimental and control groups, as well as pretest and posttest outcomes, these correlation tables are included to provide valuable insights into the relationships between key variables, offering a more in-depth and comprehensive understanding of the dataset.

Table 2

Correlation of the Measures of the Experimental Group

		Pretest				Posttest			
		Uppercase-LNK	Lowercase-LNK	Uppercase-LR	Lowercase-LR	Uppercase-LNK	Lowercase-LNK	Uppercase-LR	Lowercase-LR
Pretest-Uppercase-LNK	*r*	1.000							
	p	-							
Pretest-Lowercase-LNK	*r*	.879**	1.000						
	p	.001	-						
Pretest-Uppercase-LR	*r*	.937**	.736*	1.000					
	p	.000	.015	-					
Pretest-Lowercase-LR	*r*	.838**	.878**	.737*	1.000				
	p	.002	.001	.015	-				
Posttest-Uppercase-LNK	*r*	.849**	.901**	.775**	.742*	1.000			
	p	.002	.000	.008	.014	-			
Posttest-Lowercase-LNK	*r*	.765**	.924**	.607	.732*	.908**	1.000		
	p	.010	.000	.063	.016	.000	-		
Posttest-Uppercase-LR	*r*	.837**	.906**	.767**	.746*	.997**	.911**	1.000	
	p	.003	.000	.010	.013	.000	.000	-	
Posttest-Lowercase-LR	*r*	.652*	.849**	.545	.554	.864**	.944**	.879**	1.000
	p	.041	.002	.103	.096	.001	.000	.001	-

Note. LNK = Letter Name Knowledge, LR = Letter Recognition

Table 3

Correlation of the Measures of the Control Group

		Pretest				Posttest			
		Uppercase-LNK	Lowercase-LNK	Uppercase-LR	Lowercase-LR	Uppercase-LNK	Lowercase-LNK	Uppercase-LR	Lowercase-LR
Pretest-Uppercase-LNK	*r*	1.000							
	p	-							
Pretest-Lowercase-LNK	*r*	.944**	1.000						
	p	.000	-						
Pretest-Uppercase-LR	*r*	.722*	.634	1.000					
	p	.043	.091	-					
Pretest-Lowercase-LR	*r*	.758*	.886**	.647	1.000				
	p	.029	.003	.083	-				
Posttest-Uppercase-LNK	*r*	.821*	.817*	.872**	.715*	1.000			
	p	.013	.013	.005	.046	-			
Posttest-Lowercase-LNK	*r*	.879**	.943**	.685	.889**	.790*	1.000		
	p	.004	.000	.061	.003	.020	-		
Posttest-Uppercase-LR	*r*	.913**	.916**	.652	.764*	.867**	.793*	1.000	
	p	.002	.001	.080	.027	.005	.019	-	
Posttest-Lowercase-LR	*r*	.819*	.878**	.509	.851**	.639	.829*	.836**	1.000
	p	.013	.004	.198	.007	.088	.011	.010	-

Note. LNK = Letter Name Knowledge, LR = Letter Recognition

The pretest correlations represent baseline relationships among variables, such as the association between uppercase letter name knowledge and recognition. In contrast, the posttest correlations highlight how these relationships shifted after the intervention. The experimental group showed consistent growth in correlations from the pretest to the posttest. For example, the correlation between uppercase and lowercase letter name knowledge increased from $r = 0.879$ to $r = 0.908$, and the correlation between uppercase letter name knowledge and lowercase letter recognition rose from $r = 0.838$ to $r = 0.864$.

In contrast, the control group showed inconsistent patterns, with some measures regressing. The correlation between uppercase and lowercase letter name knowledge dropped from r = 0.944 to $r = 0.790$ and between lowercase letter name knowledge and recognition from $r = 0.886$ to $r = 0.829$.

4.2. How Does the Web-Based Early Literacy Intervention Affect Children's Uppercase and Lowercase Letter Recognition and Naming Skills?

The results of the Wilcoxon Signed-Rank test for children in the experimental group are presented in Table 4. After the intervention, a significant improvement was observed in uppercase

letter name knowledge (p = .026) among the children in the experimental group. However, there were no significant differences found in lowercase letter name knowledge (p = .655), uppercase letter recognition (p = .194), and lowercase letter recognition (p = .748) for the same group.

Table 4

Wilcoxon Signed-Rank Results

	Pretest/ Posttest	
Test	*Z*	*p*
Uppercase LNK	-2.226	.026
Lowercase LNK	-.447	.655
Uppercase LR	-1.300	.194
Lowercase LR	-.322	.748

Note. LNK = Letter Name Knowledge, LR = Letter Recognition

4.3. In What Ways Does the Recognition and Naming of Uppercase and Lowercase Letters Differ Between Children Who Received the Intervention and Those Who Did Not?

The results of the Mann-Whitney U test for the pretest and posttest scores of children in the experimental ($n1$ = 8) and control groups ($n2$ = 10) are presented in Table 5. The pretest findings indicated no significant difference ($p > .05$) in letter name knowledge and letter recognition skills between the two groups, demonstrating that both groups started at similar baseline levels. In the posttest, there were no significant differences between the experimental and control groups in uppercase letter name knowledge (p = .313), lowercase letter name knowledge (p = .787), uppercase letter recognition skills (p = .720), and lowercase letter recognition skills (p = .964).

Table 5

Mann-Whitney U Results of Experimental and Control Groups

	Pretest			Posttest		
Test	*U*	*z*	*p*	*U*	*z*	*p*
Uppercase LNK	34.500	-.493	.622	29.000	-1.009	.313
Lowercase LNK	31.000	-.806	.420	37.000	-.270	.787
Uppercase LR	38.500	-.135	.892	36.000	-.358	.720
Lowercase LR	38.000	-.182	.856	39.500	-.045	.964

Note. LNK = Letter Name Knowledge, LR = Letter Recognition

5. Discussion

The primary goal of this study was to assess the effectiveness of a multisensory web-based early literacy intervention designed to teach alphabet knowledge. The intervention focused on letter recognition and letter name knowledge among preschoolers who are non-native English speakers. The study analyzed children's performance in these areas before and after they receive either the intervention or traditional classroom instruction.

5.1. Key Findings

This study underscores the potential of the READi system to enhance children's ability to recognize uppercase letters more effectively than lowercase letters within just two weeks of intervention.

Although the pretest and posttest results for the experimental group did not demonstrate statistically significant differences in either uppercase or lowercase letter recognition, a closer analysis of the mean values revealed modest improvements in both outcome measures for the experimental group. Specifically, uppercase letter recognition increased from 3.63 to 4.38 and lowercase letter recognition improved slightly from 3.13 to 3.25. Significant improvement was observed only in the experimental group's ability to name uppercase letters. However, no notable differences were found in the letter naming and recognition abilities of children who received the intervention and those who did not. These results suggest that after using the READi system, children's ability to recognize uppercase letters improved more than their recognition of lowercase letters. This aligns with the findings of Chen et al. (2023), which suggested that digital systems may support more effective learning of uppercase letter recognition in children. One possible explanation, supported by previous research, is that uppercase letters are generally easier for children to identify due to their more straightforward and distinct shapes (Adhe et al., 2024; Bowles et al., 2014).

In addition to letter recognition, this study identified a significant improvement in children's ability to name uppercase letters following a two-week intervention. The uppercase letter name knowledge increased from 4 to 5.63. In contrast, no comparable improvement was evident in naming lowercase letters. This observation was consistent with findings from Drouin et al. (2012), which suggested that children generally found uppercase letters easier to learn than lowercase letters. The weaker recognition skills associated with lowercase letters may hinder children's letter naming ability, as letter recognition usually precedes letter naming (Foulin, 2005). Consequently, preschool children often master uppercase letters before becoming proficient in lowercase letters, a trend supported by previous research (Adhe et al., 2024; Anthony et al., 2021; Bowles et al., 2014).

Furthermore, the findings indicated a general improvement in letter recognition skills and letter name knowledge in both the experimental and control groups. While the experimental group outperformed the control group in the mean scores for all tested constructs at posttest, these differences did not reach statistical significance. Nevertheless, these improved outcomes are consistent with previous research suggesting that web-based digital systems can support preschool children enhance their alphabet learning (Elimelech & Aram, 2019; Metsala & Kalindi, 2022).

Additionally, engaging multiple senses using the READi system may have contributed to more effective learning. This is consistent with findings from Elimelech and Aram (2019), who reported that auditory and visual support significantly enhanced children's acquisition of alphabetic knowledge compared to learning without such support. Similarly, the results of the current study align with those of O'Brien et al. (2022), who found that digital systems that incorporate a multisensory framework could improve children's learning outcomes.

However, this study's lack of statistical significance in lowercase letters may be attributed to limited exposure and repetition in learning the alphabet. As children were introduced to each letter only once, they may not have had sufficient opportunities to reinforce their understanding. Vinter et al. (2023) emphasized that mastering letter names, shapes, and sound associations required repeated practice. This suggests that increasing the frequency of practice could lead to better learning outcomes.

5.2. Limitations and Future Research

This pilot study has several limitations. Firstly, the small sample size of preschool children presents challenges for conducting an experimental study with adequate experimental and control group participants. Specifically, the number of participants falls short of the optimal requirement for a larger sample size (e.g., 30 participants per group). Non-parametric tests tend to be more reliable with larger sample sizes, as they better represent the population and increase the power to detect significant differences. Therefore, future research should aim to include a larger sample size to effectively evaluate the impact of the READi system on early literacy skills among preschoolers.

Another limitation is the restricted number of exposures provided to participants. Each participant was only introduced to each letter of alphabet once, and the intervention lasted only 10 days, consisting of 10 sessions, each 60 minutes long. Due to time constraints, providing multiple exposures was not feasible. Future studies should investigate the effects of varying intervention intensity and the number of exposures per letter.

Rrecognizing the specific limitations of the web-based system used in this study is important. Some preschoolers reported experiencing discomfort due to heavy headphones, which may have impacted their engagement. The researchers also observed that the computer lab setup at the school, including the chair and table, was not ergonomic for preschoolers, which could affect their concentration. Future research must actively partner with funders and schools to ensure preschoolers' accessibility to comfortable seating arrangements, optimized desktops, and specialized equipment designed to meet their needs. Given preschoolers' familiarity with touchscreen devices, future studies could collaborate with schools to equip computer labs with tablets and explore using tablets as an alternative to enhance user experience and engagement.

Another limitation of this pilot study is the restricted number of letters tested, primarily due to time constraints. This narrow scope may impact the generalizability of the findings. To address this limitation, future research should include all 26 letters of the alphabet in the intervention. Doing so will provide a more comprehensive understanding of the READi system's effectiveness and its impact on early literacy skills among preschoolers.

Moreover, the assessment format for letter recognition utilized in this pilot study also has limitations. Future research should consider conducting experimental studies on children's recognition proficiency with different numbers of letters presented simultaneously, such as comparing recognition with a set of letters versus all 26 letters. This would provide a more accurate measurement and contribute to the extant literature.

Finally, the duration of the pretest and posttest sessions in the pilot study may have surpassed

the preschoolers' optimal attention span. To enhance reliability, future studies should extend the duration of these test administration sessions or split the pretests into multiple shorter sessions. This approach would better accommodate the limited attention spans of young children, allowing for enhanced focus and more valid results.

5.3. Implications for practice

Despite the limitations, this pilot study underscores the importance of integrating digital technologies, such as the READi system, to improve preschool children's understanding of the alphabet. Educators can leverage these tools as practical supplementary resources to enhance children's mastery of alphabet knowledge. The findings highlight the need for careful selection of assessment tools and consideration of children's comfort, as these factors are critical for accurately measuring the system's effectiveness.

In the context of Malaysian preschool education, where a single teacher often supervises up to twenty-five children (MOE, 2018), this study has policy implications for digitalizing early literacy education. Additionally, this pilot study emphasizes the necessity of preparing preschoolers for school readiness by incorporating digital technologies and providing teachers with the resources to foster early literacy skills. By establishing a strong foundation in early literacy, policymakers can help ensure that school readiness becomes a practical reality for children.

5.4. Conclusion

This study suggests that the READi system effectively facilitates uppercase letter naming among children in the experimental group. While some progress in recognizing both uppercase and lowercase letters was observed, these improvements did not reach statistical significance. Nonetheless, the experimental group generally outperformed the control group, highlighting the potential benefits of digital interventions in early literacy development.

This study contributes valuable insights to the existing literature on integrating technology into preschool education, demonstrating its potential to enhance instructional efficiency and support individualized learning. Furthermore, the findings emphasize the importance of collaboration between educational interventionists (represented by the second author) and system developers. Such partnerships are crucial for designing digital learning tools that address the needs of young learners, allowing them to progress at their own pace and achieve mastery in early literacy skills.

Several areas for future research should be explored to strengthen the effectiveness of digital learning interventions. First, expanding the sample size and extending the intervention duration would provide a more comprehensive evaluation of the impact of the READi system. Additionally, increasing the frequency of letter exposure and adjusting the intensity of the intervention could further enhance letter recognition and memory retention. Future studies should also address participant-related factors, such as the usability and accessibility of digital tools. This includes considering ergonomic setups and exploring touchscreen devices to enhance preschooler engagement.

One recommendation regarding the study's context for future consideration is that schools and policymakers prioritize technology readiness by ensuring preschoolers have access to developmentally appropriate digital tools, such as tablets and child-friendly keyboards. Inappropriate or inadequate technology setups may inhibit learning effectiveness, underscoring the importance of thoughtful integration of digital systems into early education environments. By addressing these aspects, future research and policy initiatives can contribute to the continued refinement of digital learning tools, maximizing their positive impact on early childhood education. Additionally, all preschool participants are recommended to be given introductory lessons on digital literacy to ensure appropriate digital engagement, safe usage, and balanced screen time. Highly recommended is to offer parents and caregivers with guidelines and skills in providing active guidance and mediation should READi be used in the home in the future.

Credit Authorship Contribution Statement

Yen Vee Tan: Conceptualization, Methodology, Review, Editing, Drafting, Investigation.

Julia Ai Cheng Lee: Supervision, Conceptualization, Review, Proofreading, Editing, Funding Acquisition.

Rehman Ullah Khan, Sarah Flora Samson Juan, Chen Chwen Jen, Kartini Abdul Ghani, and **Brian Loh Chung Shiong:** Conceptualization (supporting)

Declaration of Generative AI and AI-Assisted Technologies in The Writing Process

While preparing this work, ChatGPT and Grammarly was employed solely to enhance the manuscript's clarity and linguistic quality. Following the utilization of this tool, the authors meticulously reviewed and edited the content as required, assuming full responsibility for the content of the publication.

Acknowledgments

This research was funded by Universiti Malaysia Sarawak under the Smart Partnership grant (F04/Partners/2123/2021) and the Ministry of Higher Education of Malaysia under the Fundamental Research Grant Scheme (FRGS/1/2022/SSI07/UNIMAS/02/4). We thank the principal, assistant principal, preschool teachers, and preschoolers for making this study possible. We also thank Professor Dr. Wang Yin Chai and his graduate students, Peter Wong Pa Lin and Tay Chee Tat, for their assistance as programmers for the pilot system.

Ethics Approval Statement

Ethical approval (HREC (NM)/FSKPM/2023(12) was granted by the Human Research Ethics Committee of the Faculty of Cognitive Science and Human Development, Universiti Malaysia Sarawak. The approval to conduct research at the school was granted by the Ministry of Education Malaysia.

References

Adams, M. J. (1994). *Beginning to read: Thinking and learning about print*. MIT Press. https://mitpressbookstore.mit.edu/book/9780262510769

Adhe, K. R., Mustaji, M., Suprapto, N., Suryanti, S., & Ling, L. Y. (2024). Difficulty of visual recognition: Identifying the direction confusion of reading letters in young children. *International Journal of Education in Mathematics Science and Technology, 12*(2), 334–344. https://doi.org/10.46328/ijemst.3888

Allen, K., Neuhaus, G. F., & Beckwith, M. (2005). Alphabet knowledge: Letter recognition, naming, and sequencing. In Judith R. Birsh (Ed.) *Multisensory teaching of basic language skills* (2nd ed.), pp 113-150. Paul Brookes.

Amico, A. (2022). *The effects of multisensory learning in the reading readiness process of preschool children* (Publication No. 29163255) [Doctoral dissertation, Caldwell University]. ProQuest Dissertations and Theses Global. https://www.proquest.com/dissertations-theses/effects-multisensory-learning-reading-readiness/docview/2652848589/se-2

Anthony, J. L., Chen, Y. I., Williams, J. M., Cen, W., & Erazo, N. A. (2021). U.S. children's understanding of the English alphabet: Its acquisition, conceptualization, and measurement. *Journal of Educational Psychology, 113*(6), 1073–1087. https://doi.org/10.1037/edu0000534

Bautista, G. F., Ghesquière, P., & Torbeyns, J. (2023). Stimulating preschoolers' early literacy development using educational technology: A systematic literature review. *International Journal of Child-Computer Interaction, 39*, 100620. https://doi.org/10.1016/j.ijcci.2023.100620

Blikstad-Balas, M., & Davies, C. (2017). Assessing the educational value of one-to-one devices: have we been asking the right questions? *Oxford Review of Education, 43*(3), 311–331. https://doi.org/10.1080/03054985.2017.1305045

Bordens, K. S., & Abbott, B. B. (2014). *Research design and methods: A process approach.* McGraw-Hill.

Bowles, R. P., Pentimonti, J. M., Gerde, H. K., & Montroy, J. J. (2014). Item response analysis of uppercase and lowercase letter name knowledge. *Journal of Psychoeducational Assessment, 32*(2), 146–156. https://doi.org/10.1177/0734282913490266

Buckingham, J., Beaman, R., & Wheldall, K. (2023). Why poor children are more likely to become poor readers: The early years. *Educational Review, 66*(4), 428–446. https://doi.org/10.1080/00131911.2013.795129

Carreker, S. (2011). Teaching reading: Accurate decoding. In J. R. Birsh (Ed.), *Multisensory teaching of basic language skills* (3rd ed., pp. 207-250). Paul Brookes.

Castles, A., Rastle, K., & Nation, K. (2018). Ending the reading wars: Reading acquisition from novice to expert. *Psychological Science in the Public Interest, 19*(1), 5–51. https://doi.org/10.1177/1529100618772271

Chang, C. (2016). The efficacy of a one-to-one technology initiative in improving the four Cs. *Journal of Educational Technology Development and Exchange, 9*(2). https://doi.org/10.18785/jetde.0902.02

Chen, J. J., Kacerek, C. R., & Ruiz, M. (2023). The Letter-Naming benchmarks, growth profiles, and the efficacy of an interactive learning app on Uppercase Letter-Name Learning for preschool children. *International Journal of Technology in Education, 6*(1), 113–135. https://doi.org/10.46328/ijte.360

Cornito, C. M. (2023). The effectiveness of contextualized digital game-based learning resource in improving kindergarten pupil's alphabet knowledge level. *International Journal on Studies*

in Education, 5(2), 130–140. https://doi.org/10.46328/ijonse.103

Creswell, J. W., & Creswell, J. D. (2018). *Research design: Qualitative, quantitative, and mixed methods approaches* (5th ed.). SAGE.

De Abreu, M. D., & Cardoso-Martins, C. (1998). Alphabetic access route in beginning reading acquisition in Portuguese: The role of letter-name knowledge. *Reading and Writing, 10*(2), 85–104. https://doi.org/10.1023/a:1007939610145

Drouin, M., Horner, S. L., & Sondergeld, T. A. (2012). Alphabet knowledge in preschool: A Rasch model analysis. *Early Childhood Research Quarterly, 27*(3), 543–554. https://doi.org/10.1016/j.ecresq.2011.12.008

Elbaum, B., Vaughn, S., Hughes, M. T., & Moody, S. W. (2000). How effective are one-to-one tutoring programs in reading for elementary students at risk for reading failure? A meta-analysis of the intervention research. *Journal of Educational Psychology, 92*(4), 605–619. https://doi.org/10.1037/0022-0663.92.4.605

Elimelech, A., & Aram, D. (2019). Using a digital spelling game for promoting alphabetic knowledge of preschoolers: The contribution of auditory and visual supports. *Reading Research Quarterly*. https://doi.org/10.1002/rrq.264

Evans, M. A., Bell, M., Shaw, D., Moretti, S., & Page, J. (2006). Letter names, letter sounds and phonological awareness: An examination of kindergarten children across letters and of letters across children. *Reading and Writing, 19*(9), 959–989. https://doi.org/10.1007/s11145-006-9026-x

Fadeev, A., & Milyakina, A. (2021). Multisensory learning environments. Research project education on Screen. *SHS Web of Conferences, 130*, 02003. https://doi.org/10.1051/shsconf/202113002003

Farrell, M. L., & Sherman, G. F. (Ed.). (2011). Multisensory structured language education. In J. R. Birsh (Ed.), *Multisensory teaching of basic language skills* (3rd ed., pp. 25-47). Paul Brookes.

Foulin, J. N. (2005). Why is letter-name knowledge such a good predictor of learning to read? *Reading and Writing, 18*(2), 129–155. https://doi.org/10.1007/s11145-004-5892-2

Garzotto, F., Beccaluva, E., Gianotti, M., & Riccardi, F. (2020). Interactive multisensory environments for primary school children. *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems,* 1–12. https://doi.org/10.1145/3313831.3376343

Gehsmann, K. M., & Mesmer, H. A. (2023). The alphabetic principle and concept of word in text: Two priorities for learners in the emergent stage of literacy development. *The Reading Teacher, 77*(2), 156–166. https://doi.org/10.1002/trtr.2225

Grainger, J., Rey, A., & Dufau, S. (2008). Letter perception: from pixels to pandemonium. *Trends in Cognitive Sciences, 12*(10), 381–387. https://doi.org/10.1016/j.tics.2008.06.006

Heilmann, J. J., Moyle, M. J., & Rueden, A. M. (2018). Using alphabet knowledge to track the emergent literacy skills of children in head start. *Topics in Early Childhood Special Education, 38*(2), 118–128. https://doi.org/10.1177/0271121418766636

Huang, F. L., Tortorelli, L. S., & Invernizzi, M. A. (2014). An investigation of factors associated with letter-sound knowledge at kindergarten entry. *Early Childhood Research Quarterly, 29*(2), 182–192. https://doi.org/10.1016/j.ecresq.2014.02.001

Ishak, W. I. W., & Mohamad, M. (2018). The implementation of Common European Framework of References (CEFR): What are the effects towards LINUS students' achievements? *Creative Education, 09*(16), 2714–2731. https://doi.org/10.4236/ce.2018.916205

Joshi, R. M., Dahlgren, M., & Boulware-Gooden, R. (2002). Teaching reading in an inner city school through a multisensory teaching approach. *Annals of Dyslexia, 52*(1), 229–242. https://doi.org/10.1007/s11881-002-0014-9

Kedagni, D., Krishna, K., Megalokonomou, R., & Zhao, Y. (2021). Does class size matter? How, and at what cost? *European Economic Review, 133*, 103664. https://doi.org/10.1016/j.euroecorev.2021.103664

Kong, K. (2023). Early childhood education in Malaysia. In L.P. Symaco & M. Hayden (Eds.), *International handbook on education in Southeast Asia* (559-590). https://doi.org/10.1007/978-981-16-8136-3_13-2

Larsen, A., & Bundesen, C. (1996). A template-matching pandemonium recognizes unconstrained handwritten characters with high accuracy. *Memory & Cognition, 24*(2), 136–143. https://doi.org/10.3758/bf03200876

Lee, J. A. C., Chen, C. J., Ghani, K. A., Khan, R. U., Samson Juan S. F., & Loh, B. C. S. (2023). *Inclusive pedagogical model for multisensory early reading intervention for young children with dyslexia* [Unpublished manuscript, Universiti Malaysia Sarawak].

Lee, J. A. C., Lee, S., Yusoff, N. F. M., Ong, P. H., Nordin, Z. S., & Winskel, H. (2020). An early reading assessment battery for multilingual learners in Malaysia. *Frontiers in Psychology, 11*. https://doi.org/10.3389/fpsyg.2020.01700

Liang, J., Liu, T., Wang, H., Chang, B., Deng, Y., Yang, J., Chou, C., Ko, H., Yang, S., & Chan, T. (2005). A few design perspectives on one-on-one digital classroom environment. *Journal of Computer Assisted Learning, 21*(3), 181–189. https://doi.org/10.1111/j.1365-2729.2005.00126.x

Liu, O., Tee, O., Loy, N., & Hoon, O. (2021). 'i want to go to school but ...' The case of the Penan and Orang Asli children of Malaysia. *Proceedings of the 1st International Conference on Science and Technology in Administration and Management Information, ICSTIAMI 2019*. https://doi.org/10.4108/eai.17-7-2019.2303383

Liu, S., Reynolds, B. L., Thomas, N., & Soyoof, A. (2024). The use of digital technologies to develop young children's language and literacy skills: A systematic review. *SAGE Open, 14*(1). https://doi.org/10.1177/21582440241230850

Magnuson, K. A., Ruhm, C., & Waldfogel, J. (2007). The persistence of preschool effects: Do subsequent classroom experiences matter? *Early Childhood Research Quarterly, 22*(1), 18–38. https://doi.org/10.1016/j.ecresq.2006.10.002

Mayarita, Y., Amelasasih, P., & Yulyanto, Y. (2024). The effectiveness of the Jolly Phonics method on letter recognition ability in 5-year-old children through letter card media. *Jurnal Impresi Indonesia, 3*(2), 176–183. https://doi.org/10.58344/jii.v3i2.4640

Metsala, J. L., & Kalindi, S. C. (2022). The effects of a computer-based early reading program on the literacy skills of kindergarten students. *Computers in the Schools,* 1–21. https://doi.org/10.1080/07380569.2022.2127344

Ministry of Education Malaysia (2013). *Malaysian Education Blueprint 2013-2025 (Preschool to Post-Secondary Education.* Kementerian Pendidikan Malaysia. https://www.pmo.gov.my/wp-content/uploads/2019/07/Malaysia-Education-Blueprint-2013-2025.pdf

Ministry of Education Malaysia. (2018, February). *KPM preschool management guidelines*. https://www.moe.gov.my/index.php/surat-siaran-kpm-bil-3-tahun-2019

Murray, M. M., Lewkowicz, D. J., Amedi, A., & Wallace, M. T. (2016). Multisensory processes: A balancing act across the lifespan. *Trends in Neurosciences, 39*(8), 567–579. https://doi.

org/10.1016/j.tins.2016.05.003

National Early Literacy Panel. (2008). *Developing early literacy: Report of the National Early Literacy Panel.* National Institute for Literacy. https://lincs.ed.gov/publications/pdf/NELPReport09.pdf

National Reading Panel. (2000). *Report of the National Reading Panel: Teaching children to read: An evidence-based assessment of the scientific research literature on reading and its implications for reading instruction.* National Institute of Child Health and Human Development, National Institutes of Health. https://www.nichd.nih.gov/sites/default/files/publications/pubs/nrp/Documents/report.pdf

O'Brien, B. A., Seward, R., & Zhang, D. (2022). Multisensory interactive digital text for English phonics instruction with bilingual beginning readers. *Education Sciences, 12*(11), 750. https://doi.org/10.3390/educsci12110750

Otaiba, S. A., Puranik, C. S., Rouby, D. A., Greulich, L., Sidler, J. F., & Lee, J. (2010). Predicting kindergarteners' End-Of-Year spelling ability based on their reading, alphabetic, vocabulary, and phonological awareness skills, as well as prior literacy experiences. *Learning Disability Quarterly, 33*(3), 171–183. https://doi.org/10.1177/073194871003300306

Paige, D. D., Rupley, W. H., Smith, G. S., Olinger, C., & Leslie, M. (2018). Acquisition of letter naming knowledge, phonological awareness, and spelling knowledge of kindergarten children at risk for learning to read. *Child Development Research, 2018*, 2142894, 1–10. https://doi.org/10.1155/2018/2142894

Pallant, J. (2020). *SPSS survival manual: A step by step guide to data analysis using IBM SPSS*. McGraw-Hill Education (UK).

Patel, P., Torppa, M., Aro, M., Richardson, U., & Lyytinen, H. (2022). Assessing the effectiveness of a game-based phonics intervention for first and second grade English language learners in India: A randomized controlled trial. *Journal of Computer Assisted Learning, 38*(1), 76–89. https://doi.org/10.1111/jcal.12592

Piasta, S. B. (2023). The science of early alphabet instruction: What we do and do not know. In S. Q. Cabell, S. B. Neuman, & N. P. Terry (Eds.), *Handbook on the science of early literacy* (pp. 83-94). Guilford Publications. https://www.guilford.com/books/Handbook-on-the-Science-of-Early-Literacy/Cabell-Neuman-Terry/9781462555024?srsltid=AfmBOorm0Am3hrL1YOZaCoq2vK_4r3IWDt7AjD6kxWH08-I8QUaVyg3e

Piasta, S. B., Logan, J. A. R., Farley, K. S., Strang, T. M., & Justice, L. M. (2022). Profiles and predictors of children's growth in alphabet knowledge. *Journal of Education for Students Placed at Risk, 27*(1), 1–26. https://doi.org/10.1080/10824669.2021.1871617

Ponticorvo, M., Di Fuccio, R., Ferrara, F., Rega, A., & Miglino, O. (2019). Multisensory educational materials: Five senses to learn. In *Advances in intelligent systems and computing* (pp. 45–52). https://doi.org/10.1007/978-3-319-98872-6_6

Rahmatullah, B., Rawai, N. M., Samuri, S. M., & Yassin, S. M. (2021). Overview of early childhood care and education in Malaysia. *The Hungarian Educational Research Journal, 11*(4), 396–412. https://doi.org/10.1556/063.2021.00074

Samur, Y. (2019). Kes Sesi: A mobile game designed to improve kindergarteners' recognition of letter sounds. *Journal of Computer Assisted Learning, 35*(2), 294–304. https://doi.org/10.1111/jcal.12331

Treiman, R., & Kessler, B. (2004). The case of case: Children's knowledge and use of upper- and lowercase letters. *Applied Psycholinguistics, 25*(3), 413–428. https://doi.org/10.1017/

s0142716404001195

Treiman, R., Pennington, B. F., Shriberg, L. D., & Boada, R. (2008). Which children benefit from letter names in learning letter sounds? *Cognition, 106*(3), 1322–1338. https://doi.org/10.1016/j.cognition.2007.06.006

Van Daal, V., & Reitsma, P. (2000). Computer-assisted learning to read and spell: results from two pilot studies. *Journal of Research in Reading, 23*(2), 181–193. https://doi.org/10.1111/1467-9817.00113

Vinter, A., Bard, P., Lukowski-Duplessy, H., & Poulin-Charronnat, B. (2023). Learning to name uppercase and lowercase letters in preschoolers and kindergarteners: An investigation of the effects of child- and letter-related factors. *Early Education and Development, 35*(7), 1570–1590. https://doi.org/10.1080/10409289.2023.2252706

Wang, J. J. Y. & Lee, J. A. C. (2020). Alphabetic knowledge and phonological awareness: A comparison between Malaysian preschool children from public and private kindergartens. *Journal of Cognitive Sciences and Human Development, 6*(2), 1-15. https://doi.org/10.33736/jcshd.2200.2020

Yang, N. J. C., Lai, N. C. H., & Chu, N. Y. M. (2005). Integrating speech technologies into a one-on-one digital English classroom. *IEEE International Workshop on Wireless and Mobile Technologies in Education (WMTE'05)*, 159–163. https://doi.org/10.1109/wmte.2005.39

Zanatta, L., & Rosales-Ruiz, J. (2021). The effects of hearsee/say and hearsee/write on acquisition, generalization, and retention. *Behavior Analysis in Practice, 14*(3), 631–643. https://doi.org/10.1007/s40617-020-00427-w