education sciences

Article

Multisensory Interactive Digital Text for English Phonics Instruction with Bilingual Beginning Readers

Beth A. O'Brien [1,*], Reneé Seward [2] and Dongbo Zhang [3]

[1] National Institute of Education, Nanyang Technological University, Singapore 637616, Singapore
[2] College of Design Architecture Art and Planning, University of Cincinnati, Cincinnati, OH 45221, USA
[3] Graduate School of Education, University of Exeter, St Luke's Campus, Exeter EX1 2LU, UK
* Correspondence: beth.obrien@nie.edu.sg

Abstract: We investigated a technology-based tool for teaching English letter-sound correspondences with bilingual children learning phonologically and typologically distant languages: English and Chinese. We expect that learning about print at the phoneme level may be particularly challenging, given children's experience with the morphosyllabic language of Chinese. This randomized-controlled study with 90 kindergarteners examined the effects of an iPad-based supplementary reading program compared with a control condition. The *See Word Reading*® program utilized picture-embedded cues for teaching phonics within lessons directed at the letter, word, and text levels. Measures of decoding, word reading, and spelling were taken at the pretest, posttest, and follow-up for both groups. Results showed better gains in word reading for the reading group, indicating the positive impact of this supplementary reading tool. Further, data collected online from the app showed that different types of letter-sound pairings were more challenging to learn, including pairings that are inconsistent and with phonemes that are specific to English.

Keywords: phonics; digital text; picture cue mnemonics; early childhood; Chinese English bilingual

check for updates

Citation: O'Brien, B.A.; Seward, R.; Zhang, D. Multisensory Interactive Digital Text for English Phonics Instruction with Bilingual Beginning Readers. *Educ. Sci.* **2022**, *12*, 750. https://doi.org/10.3390/educsci12110750

Academic Editor: George Manolitsis

Received: 21 September 2022
Accepted: 20 October 2022
Published: 26 October 2022

1. Introduction

Language and literacy skills are essential to learning in school and for communication in general. Written language exposes children to a wider and deeper vocabulary than speech alone [1], so preparing children to become independent readers should further hone their language skills. The strongest early predictors of literacy attainment for English include alphabetic knowledge (names and sounds of printed letters) along with phonological awareness [2], and the most effective educational approaches include a phonics component [3–5]. Phonics, or teaching early literacy skills using letterforms paired with sounds, is more effective than purely auditory-based phonological training without letterforms [6–9]. This may be particularly true in the case where English is not the only or first language for the child. As August and Shanahan [10] concluded in their US national review, "young Spanish-speaking students learning to read in English might make the best progress when given more work with particular phonemes and combinations of phonemes in English that do not exist in their home language" (p. 3). The principle of instruction underscored in this review conclusion, however, has been rarely tested on young bilingual learners of English. The current paper aims to address this gap, focusing on early English reading acquisition for young bilingual children from Chinese language backgrounds, a language typologically and phonemically distant from English.

To give "more work" or practice with phonemes, we employ technology-based applications for teaching letter-sound correspondence (phonics) to beginning readers in kindergarten called *See Word Reading*® [11,12]. Increasingly, digital technologies are used in classrooms [13], and this is encouraged when based on established learning principles that support specific learning goals [14,15], including literacy goals [16]. Technology-based applications offer novel affordances to traditional print methods, such as embedded scaffolding, extended practice, and response-contingent feedback, in addition to increased student engagement. An embedded scaffolding approach was found effective for teaching emergent reading skills within e-books for preschoolers [17,18] and L2 learners in kindergarten [19]. The use of touchscreen devices such as iPads has been applied successfully to kindergarten literacy practice [20,21]. The current study utilizes a touchscreen app with digital text and embedded cues for training letter-sound correspondences referred to as embedded picture mnemonics in earlier studies [22].

1.1. Letter-Embedded Picture Mnemonics

Even though the importance of learning letter sounds is confirmed with research [23], the way in which the relations between the visual and phonological representations should be learned is less clear. Techniques where picture cues are integrated with letter forms are effective for teaching letter sounds. The use of picture cues follows from the general finding that memory for images is better than for language [24]. An earlier study by Ehri, Deffner, and Wilce [25] showed that constructing letters with embedded pictures of an object whose name begins with the letter's sound and whose shape resembles the letter yielded an effective mnemonic technique for linking the letter's shape and phoneme in memory. For example, 's' was embedded with a drawing of a snake, where the pictured object shared the initial sound with the letter's sound (/s/). The technique was more successful for children's learning of grapheme-phoneme correspondences than practice without pictures. In a short-term training program (6 days teaching 5 letter-sound pairs), the authors showed that integration of the picture cue with the letter form was key: children taught with integrated picture cues learned more than children taught with un-integrated pictures of the same objects or with no pictures, obtaining higher post-test scores on letter-sound identification and letter writing. This approach was also found effective with typically developing, at-risk, and special education students [26–29].

De Graaff et al. [30] utilized the picture-embedded cue technique for teaching kindergarteners' letter-sound correspondences by implementing mnemonic training sessions on a computer display. In their study, they demonstrated the importance of removing the cue and making the isolated letter shape salient by using a procedure where the integrated pictures gradually faded out over trials. Kindergarten children trained in their short-term training (12 letters over a 2-week period) with the fading procedure had better letter-to-sound recall (at immediate and 4-week follow-up points) compared to those in integrated-picture and no-picture conditions.

Shmidman and Ehri [31] extended this work using picture-embedded mnemonics to teach Hebrew grapheme-phoneme correspondence to English monolinguals (5-year-olds). A group trained with integrated-picture cues was compared to a group trained with un-integrated picture cues. Mastery of trained letter sounds was more efficient (took fewer trials) in their integrated-picture cue condition, and better accuracy was maintained after a week follow-up. Better performance by the integrated-picture cue group was also extended to word reading and spelling of simple English words spelled phonetically with Hebrew letters. Sener and Belfiore [32] found positive effects of embedded picture mnemonics for Turkish students who were struggling English learners. Manalo, Uesaka, and Sekiani [33] also found that Japanese-speaking children benefitted from integrated mnemonic images for learning English letter sounds. In their study, they utilized pictures of Japanese words to cue the children to the letter sounds and suggested this method could be applied in other contexts with similar challenges to developing second-language alphabetic knowledge.

The findings reviewed above have confirmed that picture-embedded methods can be particularly effective for teaching early English literacy. As Ehri [22] summarizes,

"Embedded picture mnemonics offer an effective way to teach grapheme-phoneme relations to beginners, especially children having letter learning difficulties. Embedded mnemonics can be used to teach harder-to-learn correspondences such as the short vowels sounds of A, E, I, O, and U; the consonants W, Y, and H; and the hard sounds for C /k/, and G /g/, all letters whose names do not contain their sounds. Also embedded mnemonics can be devised to teach letter-sound correspondences to students learning a foreign language . . . " (pp. 13–14).

Despite these potential instructional benefits, studies that utilized this type of method for teaching bilingual children, as opposed to monolingual English-speaking children, are very limited. To this end, the present study aimed to test the effectiveness of a platform we developed based on picture-embedded methods, esp. the earlier work by Ehri et al. [25], for promoting early literacy skills. We focused on Chinese-speaking bilingual learners of English, because the cross-language differences between Chinese and English, as described in the section below, made this group of children a particularly interesting case for testing how picture embedding methods may be effective for bilingual children.

1.2. Cross-Language Differences Related to Learning to Read

A significant proportion of children worldwide learn to read for the first time in an additional or non-dominant language [34]. This situation may present unique challenges, which technological tools can help to mitigate, among other pedagogical strategies, and address learning gaps among these children [35–37]. Two key challenges that we highlight in this study include, (1) the regularity or depth with which print precisely specifies the oral language, and (2) differences across languages in terms of the speech sounds that print represents. Chinese, the home language of children in the current study, is (1) typologically and (2) phonemically distant from English and therefore encompasses these two key challenges, as explained next.

First, with regard to the typological challenge, languages differ with regard to the regularity and consistency with which print codes the oral language. Languages that have consistent letter-to-sound mapping are referred to as transparent or shallow orthographies, whereas those with inconsistent mappings are referred to as more opaque or deep orthographies. Across alphabetic languages this orthographic depth has proven to be an important variable in the learning rate for beginning readers, with opaque languages taking longer to learn as they are more challenging [38]. English is considered a deep, opaque orthography because it contains inconsistencies in letter-sound mappings, otherwise known as grapheme-to-phoneme correspondence (GPC). This means that printed graphemes can be pronounced in multiple ways ('a' as in CAT or ANGEL), and also that phonemes may be spelled in multiple ways (/ā/ can be spelled as 'a', 'a-e', 'ai' or 'ay'); these inconsistencies are a challenge in learning to read, and they are found to affect naming and lexical decision times in both beginning and skilled readers [39–42].

Acquiring reading in English for bilingual learners may be difficult because of differences in the way that writing systems represent oral language. Writing systems differ in the "grain size" at which oral language is encoded: at the phoneme, syllable, or word levels [43], as well as the level of suprasegmental features such as stress or tone. Learning to read amplifies awareness at the level optimized by the writing system. While alphabetic languages code at the phoneme level and follow rules of GPC, Chinese script is morphosyllabic, in that character units code for syllables and are linked with meaning more so than sound representations. Following the larger grain size of Chinese, studies found that it is at the syllabic level and the level of larger sub-syllabic units of onset and rime that phonological awareness contributes to learning to read in Chinese [44–47], as well as for Chinese-English bilinguals learning to read in English [48]. This marks a clear contrast to English reading acquisition, where phonemic awareness has been found to play an essential role. Learning English as a second language (ESL) showed a positive effect of rime- and onset-rime awareness on English word reading by Chinese-speaking children (e.g., [49]). This suggests ESL children's approach to reading English differs in the relevant grain size, as shown in earlier studies where ESL learners from Chinese-speaking backgrounds were less skillful in using phonological strategies to read English words than proficiency-matched English L1 counterparts (e.g., [50,51]).

Second, with regard to the phonemic challenge, oral language can shape children's developing level of phonological awareness, a key contributor to reading acquisition across languages. For example, exposure to the Czech language, with its complex word onsets with many consonant clusters and blends, was related to a superior ability in segmenting sounds (phonemes) within consonant clusters by Czech-speaking children compared with English-speaking children [52]. On the other hand, exposure to the Chinese language was related to Chinese-speaking children's poorer subsyllable awareness at the onset, rime, and coda level as compared to English-speaking children [53]. Chinese has a simpler syllable structure than English, because consonant-vowel-consonant (e.g., /man/慢 *slow*) and open consonant-vowel (e.g., /wu/五 *five*) syllables predominate, and there are no consonant clusters [54], making syllable boundaries more salient in Chinese. A number of studies report that monolingual Chinese speakers have stronger syllable awareness compared with phoneme awareness [55,56], and protracted development of subsyllable awareness [44,53]. The same holds true for bilinguals whose first language (L1) is Chinese [57].

In addition to difficulty acquiring phonemic sensitivity, another challenge lies in phonemic differences across languages. Certain English phonemes are not expressed in Chinese, including /v/ (as in van), /z/ (zoo), /*S*/ (shoe), /ʒ/ (vision), /t*S*/ (chain), /d*Z*/ (jam), /θ/ (thin), // (this) for Mandarin. Thus, whereas Cantonese-speaking [58] and Mandarin-speaking [59] kindergarten children were found to be as good as English-speaking children in their performance with phonemes common to both Chinese and English (/p/ and /f/), they had more difficulty with spelling phonemes unique to English (/*S*/ and /θ/, and /v/ and /b/, respectively).

Based on the aforementioned cross-linguistic variations between English and Chinese, we expect that learning to read in English would be challenging for Chinese-English bilingual children because of the general difficulty in acquiring awareness at the level of the phoneme; and the challenge could be particularly salient for phonemes unique to English. While it is important that explicit instructional attention is given to the phonemic system of English and how phonemes are encoded in print for English-speaking children [5,36], it may be more so for bilingual learners with a Chinese language background.

1.3. The Current Study

Technology-based approaches to teaching letter-sound correspondence can offer additional features to traditional teaching methods. However, there is not much research using experimental designs to examine the effectiveness of such programs, and little research has been conducted on children from bilingual backgrounds, although a handful of studies examined second language learning [19,31–33]. The focus of the current paper is on increasing early English literacy skills with the support of modern technology for young bilingual children from predominantly Chinese language backgrounds.

We utilize a picture-embedded "mnemonic" technique to teach English letter-sound correspondences (phonics) to beginning readers in kindergarten and extend previous research in several ways. First, the presentation of the mnemonic cues was dynamic, and children could interact with the digital text. For example, as shown in Figure 1, when a child sees the letter "p" on the device screen, they can touch it and then view a series of photographic images that begin with the /p/ sound, such as peach, peapod, and penguin, superimposed on the letter, while hearing the name of each picture to emphasize the similar first sound. Each superimposed image follows the graphic and interactive communication design principles of distinctiveness, visibility, usability, memorability, universality, durability, and timelessness [60]. At the end of the sequence, the final bare form of the grapheme is similar to the fading out procedure of de Graaff et al. [30]. The premise is that after training, the letter then works as a visual trigger for recalling the images associated with it—images that cue the learner to its letter sound.

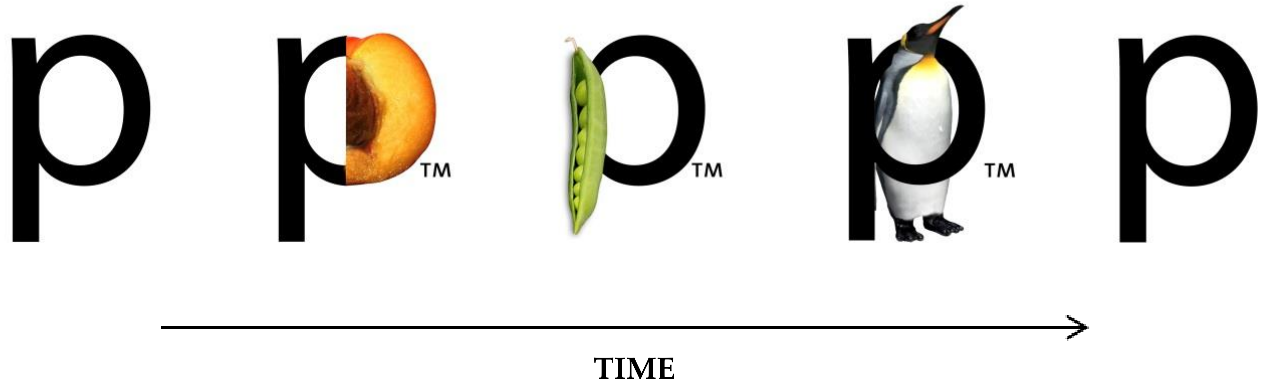

Figure 1. Example of digital text in *See Word Reading*® tool. Embedded picture cues are shown superimposed on the letter form in sequence after the letter is touched. The cues are used as a mnemonic device to help children remember the sound represented by the letter.

The second way we extend the previous research is that we include the letter fonts in activities that contextualize the letters into printed words and connected story texts within the same lesson. This was to draw children's attention to how letter sounds correspond to words and text in order to facilitate the transition from phonics learning to decoding words.

Third, we use more extensive training than the earlier studies, with a longer training period (14 weeks) covering a larger set of items trained (45 grapheme-phoneme pairings). We also examine outcomes over a longer time period.

Finally, we examine the use of this method for teaching English phonics to bilingual children coming from primarily Chinese-speaking families. For the reasons noted above, it was expected that children whose primary experience is with a morphosyllabic language would have particular challenges acquiring the phoneme-level grain size necessary for phonics learning and decoding. Therefore, we predicted that the current iPad app would be particularly beneficial for these children by helping to make the grapheme-phoneme pairings more explicit with the use of picture-embedded memory cues.

The current study addressed the following research questions:

1. Does a technology-based phonics teaching tool used as a supplement to classroom instruction impact the progress of bilingual kindergarteners' English decoding, word reading and encoding?
2. Are certain grapheme-phoneme pairs more difficult to learn for children due to the influence of their native language background?

2. Method

2.1. Design

We chose to use a randomized controlled design, in which small groups of children within the same classrooms or kindergarten centers with the same classroom teacher were assigned to conditions of either a reading intervention in addition to their classroom literacy instruction or a business-as-usual control condition with classroom instruction alone. To control for the novelty of using iPads in small group instruction, the business-as-usual group engaged with the teacher in small group instruction using apps on the iPads focused on a *Big Math for Little Kids* curriculum (see below), similar to the types of control groups used in previously published literacy intervention studies [61,62]. Thus, we investigated the effects of the iPad-based reading program (*See Word Reading*®) using a methodological design controlling for novelty effects of using iPads and spending class time in small groups, because both the reading intervention and control groups spent the same amount of time meeting in small groups to use iPad-based applications, with equal amounts of time with direct instruction/modeling from the small-group teacher and equal duration of the activities.

All children in the study participated in their regular kindergarten-2 classroom instruction on English language and literacy, which was administered during their classroom scheduled learning centers' time. Thus, all children participated in classroom instruction in English literacy that included daily 35-min lessons with whole-class story reading and commercial phonics programs, such as *Jolly Phonics*. The lessons did not utilize technology, as reported by principals and observed in the classroom during assessment phases. All children also participated in their classrooms' daily 40-min lessons in Chinese, which included both oracy instruction and the introduction of printed characters. Therefore, the intervention program is supplementary to regular classroom instruction, and the contrast between the experimental and control conditions (see Section 2.4) is thus a contrast between the supplementary app-based phonics program, and classroom instruction alone with a control for the novelty effects of working in small groups with tablets.

Prior to the intervention phase, baseline measures were taken during the final term of the school year when children were in first-year kindergarten (refer to Table 1); these measures included a parent-report language background questionnaire, and child measures of non-verbal reasoning, receptive vocabulary, and word reading (see Section 2.3). When children entered their second-year kindergarten (at 5 years old), they were formed into small groups (4–5), and the groups within schools were randomly assigned to experimental conditions. Children then completed the pretest measures, the small group intervention, the post-test measures, and the follow-up measures (see Section 2.3).

Table 1. Phases of the intervention study.

Baseline (K1) →	**Pre-test (K2)** →	**Intervention** →	**Post test** →	**Follow-up** ◆
ǀ Parent-report	ǀ Random assignment to experimental groups (48 experimental, 42 control)	ǀ14 weeks of 2–3 sessions, 90 minutes per week	ǀ Immediately after Intervention	ǀ 5 months after Intervention
ǀ Child baseline measures: nonverbal reasoning, vocabulary, word reading	ǀ Pre-test measures: phonological awareness, rapid naming ǀ Literacy measures: word reading, decoding, spelling	ǀ3–4 graphemes per session	ǀ Literacy measures: word reading, decoding, spelling	ǀ Literacy measures: word reading, decoding, spelling

2.2. Participants

Ninety children from 5 kindergarten centers in Singapore participated in the intervention study. Forty-eight were girls, and the overall mean age was 5.53 years (SD = 0.3). Of the sample, 48 were in the experimental group and 42 in the control group, and the groups were similar in terms of the percentage of males and females (46 and 54% for the experimental group and 48 and 52% for the control group).

The context for this study, Singapore, is a multilingual country in Southeast Asia with four official languages, including English and the three ethnic languages of the three major ethnic groups (i.e., Malay, and Indian in addition to Chinese). Singapore adopts a bilingual education system in which English is the medium of school instruction, and all children are required to learn English and their respective ethnic language concurrently. While a significant shift in home language use from ethnic language to English has been observed, many Chinese families still use Chinese as their dominant home language or use both Chinese and English at home [63], and children are exposed to early language and literacy in Chinese within the kindergarten classroom.

The kindergarten centers for this study were selected from primarily ethnic Chinese neighborhoods with similar socio-economic levels, and with a sufficient number of children meeting the selection criterion based on parent reports. The initial selection criterion included those children whose family spoke mostly Mandarin with them, or spoke Mandarin and English equally, based on the person they spent the most time with (reported as mother, father, or grandparent, etc.). Almost half of the children (46%) spent the most time with their mothers, while about a quarter of them (24%) spent the most time with their grandparents.

Of the final group of participants, 68% heard and spoke mostly Chinese to the person with whom they spent the most time, while an additional 20% used both Chinese and English equally. This pattern was consistent across the experimental and control groups (with 65% vs. 64% mostly Chinese use, and 19% vs. 14% mixed Chinese and English, respectively).

2.3. Measures

A parent-report survey was given at baseline (when children were finishing their first year of kindergarten). At this same time, a set of Baseline tests were administered to all children to assess their initial oral language and cognitive ability. Upon entry into kindergarten 2, when children were between 5 and 6 years of age, another set of literacy measures was administered along with measures of phonological awareness (Pretest). The literacy measures were re-administered after the reading intervention (Posttest) and at 5 months Follow-up (see Table 1). Cognitive and phonological awareness scores were used as covariates in the analyses, while the other measures were used descriptively.

2.3.1. Baseline Measures

General Cognitive Ability was assessed with the Raven's Colored Progressive Matrices test of non-verbal intelligence ([64], split-half reliability = 0.97). Standardized scores were calculated, because it was expected that differences from the normative sample would be minimal, given the non-verbal nature of the task.

Receptive Vocabulary was assessed in both English and Mandarin. The Peabody Picture Vocabulary Test (PPVT-IV [65], internal consistency = 0.97) was administered for English, and the Bilingual Language Assessment Battery (BLAB [66], reliability = 0.81) was administered for Mandarin. The BLAB is a locally developed measure that has been used in multiple published studies of kindergarteners in Singapore. Both vocabulary tests follow the same format, where children point to one of four pictures that correspond to a spoken word. All items from 1 to 72 were administered, and the number correct was scored for each language.

Word Reading was assessed with the sight word subtest of the Test of Word Reading Efficiency (TOWRE-2 [67], test-retest reliability = 0.97). The task is to read aloud as many words from a list as possible during a 45 s period. Two trials were given, and the average of correctly read words was taken across the trials.

2.3.2. Pretest Measures

The following measures of English literacy were given prior to the interventions.

Phonological awareness was assessed in English using the Comprehensive Test of Phonological Processing elision and sound matching (CTOPP-2 [68], internal consistencies = 0.91 and 0.93, respectively). Scores were tallied per subtest, and an overall total correct score was used as an indicator of phonological awareness and a covariate.

Rapid symbol naming was assessed in English with the RAN/RAS letters subtest ([69], test-retest reliability = 0.90). The time to complete naming all items is reported (sec).

2.3.3. Repeated Measures

Word Reading was again assessed with the sight word subtest of the TOWRE-2 [69] three more times after baseline.

Decoding skill was assessed three times with the word attack subtest of the Woodcock-Johnson III Tests of Achievement (WJIII [70], test-retest reliability = 0.87). This task involves reading nonwords aloud and is scored for accuracy in terms of number of correct responses.

Spelling (or encoding) was assessed three times with the primary spelling inventory in Words Their Way [71]. The task involves spelling dictated CVC and CCVC words, and spellings are scored based on the number of features written correctly—for example, initial and final letters, and short and long vowels. Children in kindergarten (around 5 years of age) begin to use the alphabetic principle to spell, beginning with consonants, followed by medial vowels [71]. Therefore, children could earn points by representing single letters, or partial spellings associated with the word. The total features score across all the items (total possible points = 74) was entered into group comparison analyses.

2.3.4. Lesson-by-Lesson Performance

A separate set of data was collected through the iPad app during the lesson activities; these data differed from the pre- and post-test measures and were more specifically tied to the items and performance during the learning activities as opposed to a more general summative test. This included the time it took children to trace the given letter (from Level 1); the accuracy with which they could spell a dictated word (from Level 2); and their search times for graphemes within a story that corresponded to a said phoneme (from Level 3). Tracing time was the total time to accurately trace the letter shape, in seconds. For the spelling task, accuracy was used because we did not record response time. Accuracy was the number of graphemes spelled correctly within the given word. Words in the lessons were either CVC, CVCV or CVCC structures. For the story search task, search time was the time, in seconds, to find each instance of a target grapheme (total time/correct responses).

2.4. Intervention

Small groups of 4–5 children within each of the kindergarten centers were randomly assigned to conditions with iPad-based interventions: (1) the "experimental reading" condition, which received the phonics intervention + classroom phonics, or (2) the "control" condition, which received the iPad control sessions + classroom phonics. Both the experimental and control groups received 12 weeks of small group instruction, 90 min per week, led by a research teacher. There were 2 additional weeks dedicated to introductions and warm-up activities at the beginning of the program, and a week for review and catch-up after the between-term break, bringing the total to 14 weeks of instruction. Each child had an iPad and headphones with which to perform the lesson's activities, but each lesson began with the research teacher preteaching, demonstrating and modeling the lesson.

2.4.1. Experimental Condition: Phonics Intervention and classroom phonics

The *See Word Reading*® app [21] was used for the phonics lessons. This app was developed through a user-centered design process for L1 learners, with several prototypes made between the developer and a classroom teacher, followed by an interdisciplinary team of a literacy specialist, an educational psychologist, and two communication designers that rooted the tool in educational theory and methodology [21]. This team took the prototype and developed a tool that visualizes the 44 sounds of the English language and that works around a framework of the reading curriculum aligning with US National Reading Standards. The tool was then user-tested and revised, then implemented in after-school programs within urban schools in the US, and found to have a positive impact on children's learning. The version used for the current study was further adapted by screening and revising the picture cues to be relevant to the local context.

The iPad tool uses a picture-supported first-sound mnemonic device [22,30] that pairs letter forms with pictures whose name contains the letter sound. Each lesson consisted of activities at 3 levels (10 min per level). Instructions at each level were given through the app, and children used headphones to listen. The research teacher also provided some additional information before the children worked through the iPad-based lesson, such as previewing the names of the imaged objects, word family rime patterns, and vocabulary words for the stories. During each phase of the lesson, children had access to the image cues for that lesson's phonemes with the touch screen device.

The children interact with the multisensory font that, when traced properly on the touch screen, presents a series of embedded images per letter/grapheme to serve as first-sound cues. The font is delivered inside the experiential tablet-based learning tool that consists of three levels: Letter-sound Correspondence, Word Building, and Storybook levels. Each level records student audio and kinesthetic interactions. Within the Letter-Sound Correspondence level, readers are introduced to individual letters and visual cues that are paired with them to aid in remembering their sound correspondences. Students are presented with the letter "p", for instance, and first, trace the letterform with their fingers in the direction they have been taught to write. Upon successful tracing, the tool initiates a series of photographic images that begin with the letter's sound. For example, tracing the letter "p" initiates a sequence of images that appear embedded in the letterform, from peapod, peach, and peppermint, before the image resumes to the letterform alone. Naming the images aloud cues readers to hear the common initial sound of the objects displayed (or the medial sound for some vowels). Readers are then prompted to answer questions about the letter, including its name, corresponding sound and a word that begins with that sound. All trace times and audio responses are recorded to a database that teachers can access to help pinpoint problem areas, that then they can go back and work with the child to improve their issues.

Additionally, the audio recording also serves as immediate feedback or self-evaluation to the children so that they can hear their recordings and choose to re-record if they do not think they spoke it correctly. Within the second level, Word Building-Word Family, readers begin to make words that utilize the sounds they are learning in the Letter-sound Correspondence level. A word rhyme pattern ("an") appears with a blank at the beginning, and students can select and drag a letter tile from the bottom of the screen to the word onset to fill in the blank and make a word. Choosing a letter that does not make a word results in the letter tile falling back down to the letter tile bank at the bottom of the screen. If they cannot recall the sound that belongs to a letter and/or letter pairs, they can tap the letters to dynamically initiate the visual cues. Once a new word has been built, readers are prompted to verbally record themselves reading the word, and the verbal recording is played back for the child to hear and sent to a database that teachers can access later. After this, the Word Building-Spelling activity is given, where the child hears a dictated word, and they have to drag letter tiles into the blank spaces to spell the whole word.

Within the third Storybook level, a story is read to the students and the print is highlighted word by word as the children follow along with the reading. After the short story is read, children are prompted to find and touch letter(s) corresponding to a spoken phoneme. The letters here are dynamic, and if the correct letter/graphemes are touched, the hidden cues associated with the letter/graphemes re-appear to reinforce the sound/letter correspondences (see Figure 2).

Figure 2. Activities within the *See Word Reading*® tool. The digital text is incorporated into lessons that train letter-sound correspondences through interactive activities drawing on letters, words, text and levels. Each level of activity is practiced within the same lesson introducing new graphemes.

2.4.2. Control Condition: Classroom phonics only

This condition served as a classroom-instruction-alone comparison to the experimental group while ensuring control for the novelty effects of working in small groups with tablets. As with the experimental group, the control group participated in small group instruction led by a research teacher for the same amount of time (90 min per week for 14 weeks of instruction = 21 h of instruction), where each child used an iPad equipped with headphones. The small-group teacher introduced concepts verbally and modeled how to play the app activities. The amount of direct instruction and modeling from the group teacher was equivalent to that in the experimental condition and included verbal directions in English, such as, "Drag the frog with the numbers to the number line where it belongs. If you drag the wrong number, the number will not be accepted into the number line and the frog will remain in the wrong place. If you drag it to the correct place, the frog will turn into a green circle in the number line". As students engaged with the app, the teacher guided them and offered verbal instructions as needed. Thus, children in this condition completed a series of lessons using iPad applications chosen to develop their concepts of number, shape, pattern, logic, measurement, or space; these activities were structured and focused on developing concepts following *Big Math for Little Kids* [72]. Their program is based on playful activities that focus on each of the concepts in a sequenced way. Publicly available iPad apps were used to exercise children's play with the concepts from week to week, such as *Montessori Math* (L'Escapadou Apps), *Math Zoom* (Motion Math, Inc), and *Play Lab123* (CJ Educations). Skills are developed over the 12 weeks of lessons by providing more challenging levels and tasks over time, following the premise of Greenes et al. [72] for revisiting ideas that are introduced earlier on to enhance understanding and learning. This ensured their continued engagement with the app-based activities throughout the intervention phase.

2.4.3. Instruction Fidelity

Observational ratings of instruction were conducted by two raters, at the beginning and end of the intervention. A checklist was used for observing the following facets of implementation: whole group vs. individual instruction time, time for student practice, teacher support and reinforcement during practice, quality of student engagement, and teacher responsiveness. The raters showed good agreement overall (Cohen's kappa= 0.77, considered to be in the substantial agreement range [73]). Given the non-normal distributions of the ratings, comparisons were made with Kolmogorov-Smirnov independent samples tests. No differences in any of the ratings were found between the research teachers. There also were no significant differences observed between the experimental and control conditions for the provision of the whole group compared with individual instruction time, teacher vs. student-centeredness, and quality of student engagement and teacher responsiveness. For both intervention conditions, the same amount of time was given for direct instruction/modeling, and student practice on the iPads. Teacher logs also showed no significant differences in median ratings between the control and experimental reading intervention conditions with regard to student engagement, engagement of the activities, effectiveness, and duration of the activities.

3. Results

3.1. Analytic Approach

To first ensure that the groups formed by random assignment were similar prior to the intervention, group differences in potential confounding variables were checked with between-group analyses of variance. ANOVAs were run for baseline measures of cognitive, language and literacy measures, as well as parent-reported SES.

Following this, the first research question was addressed with mixed effects regression models using the MIXED procedure in SPSS. Models were run for decoding, word reading, and encoding outcomes, with a random variable of participants and fixed variables of intervention condition and time. This tested the prediction that there would be an interaction of conditions over time, such that the experimental group would show better performance across the intervention period than the control group. Besides testing whether this prediction was statistically significant, we also wanted to examine the size of any significant effects. Thus, an effect size was calculated by subtracting the gain score of the control group from that of the reading group and dividing this difference by the standard deviation of the control group [74]. This was done for each of the three outcome variables.

To address the second research question, that particular grapheme-phoneme pairs would be more challenging to learn, we examined data from the lesson-by-lesson performance, involving the letter-level tracing time, word-level spelling, and text-level search time. Three types of graphemes were compared in repeated measures ANOVAs to see whether they elicited differences in tracing time, spelling, and search time.

3.2. Descriptive Statistics

The average scores taken at baseline, as well as items from the parent survey, are shown in Table 2 for the two experimental groups. (Sample size differences per measure are due to child absences or missing data from the parent-report survey). One-way ANOVAs showed that the groups (experimental and control) did not differ on any of these measures prior to the intervention (all p's > 0.61). This indicates that the groups were similar in regard to SES, cognitive ability, and both English and Chinese vocabulary. Further, the groups did not differ on the literacy, or phonological awareness measures taken at the pretest (all p's > 0.55); it is also notable that the children in both groups obtained similar Chinese vocabulary scores as peers who are considered Chinese L1 speakers [57]. From the parent reports, there was also no difference between the groups in the frequency of outside tutoring in English reading or writing ($F(1, 86) = 0.585$, $p = 0.45$).

Table 2. Descriptive Statistics for Measures at Baseline.

	Experimental Group			Control Group		
Baseline Measure	***n***	***M***	***SD***	***n***	***M***	***SD***
Mother's Education	48	3.30	1.64	42	3.17	1.65
Living Quarters	47	3.53	1.33	40	3.65	1.93
Cognitive ability (Ravens CPM)	48	108.02	17.83	41	107.80	18.41
English Vocabulary (PPVT)	48	53.58	16.39	42	54.69	16.03
Chinese Vocabulary (BLAB)	48	34.96	10.38	42	34.26	10.02
English Word Reading (TOWRE)	44	8.61	12.37	34	7.09	13.54

Note. Raw scores are reported, except for Raven's CPM, which are standard scores. Mother's Education is based on a scale from 1–5 (lower to higher degrees), and Living Quarters is based on a scale of 1–9 (less to more expensive).

3.3. Differences across Randomized Groups

To account for the hierarchical nature of the data, with participants nested within small treatment groups, and to handle missing data points, we used mixed effects models to examine each of the dependent measures: word reading, decoding, and spelling. For each measure, data across three time points (pretest, posttest, and follow-up) were submitted to a mixed effect model with maximum likelihood estimation. Each model included a fixed variable of condition (experimental vs. control group), and a random variable of participants within small groups. Time (pretest, posttest, and follow-up) was entered as a repeated measures factor, and cognitive ability and phonological awareness were entered as covariates. For word reading, baseline scores on the TOWRE test were also covaried.

Time by condition effects were significant for each of the literacy measures, indicating greater growth in the experimental group: for word reading $F(6, 24.8) = 24.83$, for decoding $F(5, 238.8) = 35.93$, and for spelling $F(5, 112.7) = 38.91$ (all p's < 0.01). Post hoc comparisons (with Sidak adjustment for multiple comparisons) showed trends for group differences in word reading and decoding measures at post-test (p's = 0.07), with the experimental group performing better. There was also a significant group difference in word reading at the follow-up time point ($p < 0.01$) (see Figure 3).

To estimate the extent to which the technology-based tool affected the literacy gains relative to the control group we calculated effect sizes for each of the outcome variables. Medium effect sizes were found for decoding and word reading (d's = 0.48 and 0.40, respectively), and the effect remained for word reading at follow-up ($d = 0.40$), but the effect size for spelling was small ($d = 0.23$).

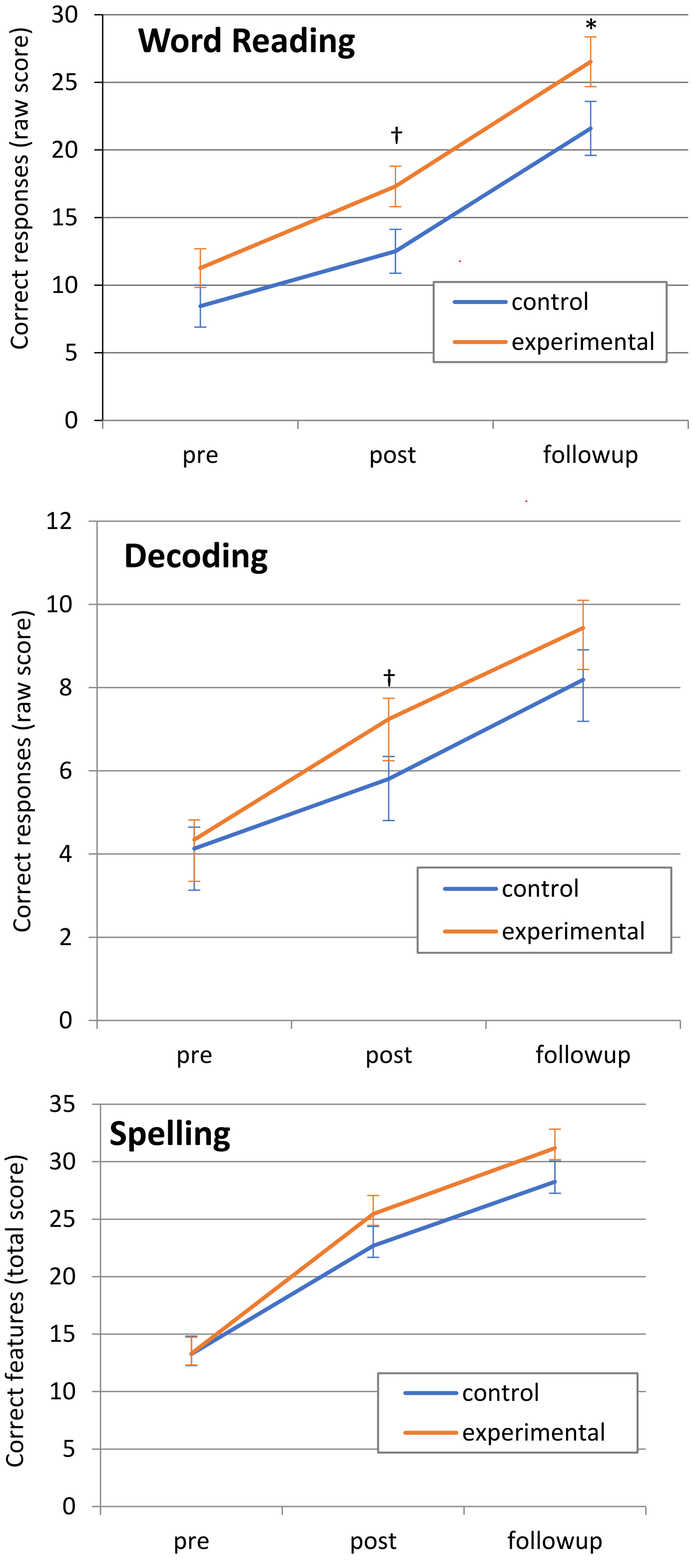

Figure 3. Mean performance on literacy measures by the reading intervention and control groups. Word reading (TOWRE sight words), Decoding (WJIII word attack), and spelling (WTW) scores at each time point. Total number correct are presented as raw scores for nonwords and words read, and total number of correctly spelled features, respectively. Reading intervention group (orange lines) and control group (blue lines) means are displayed, and differences in group means are indicated with * ($p < 0.01$) and † ($p < 0.10$).

3.4. Differences across Types of Graphemes

A closer examination of lesson-by-lesson performance was made using the data that was collected through the iPad app during the lesson activities. Three types of data were examined for different types of graphemes, including: those with consistent letter-sound pairings (Consistent), those with more than one possible pronunciation (Inconsistent), and letters representing phonemes unique to English compared with Chinese (English specific). Examples of each of these three grapheme types are shown in Figure 4. The different grapheme types were given throughout the intervention and did not appear in a given sequence. That is, each type appeared in earlier as well as later lessons over the 14-week period.

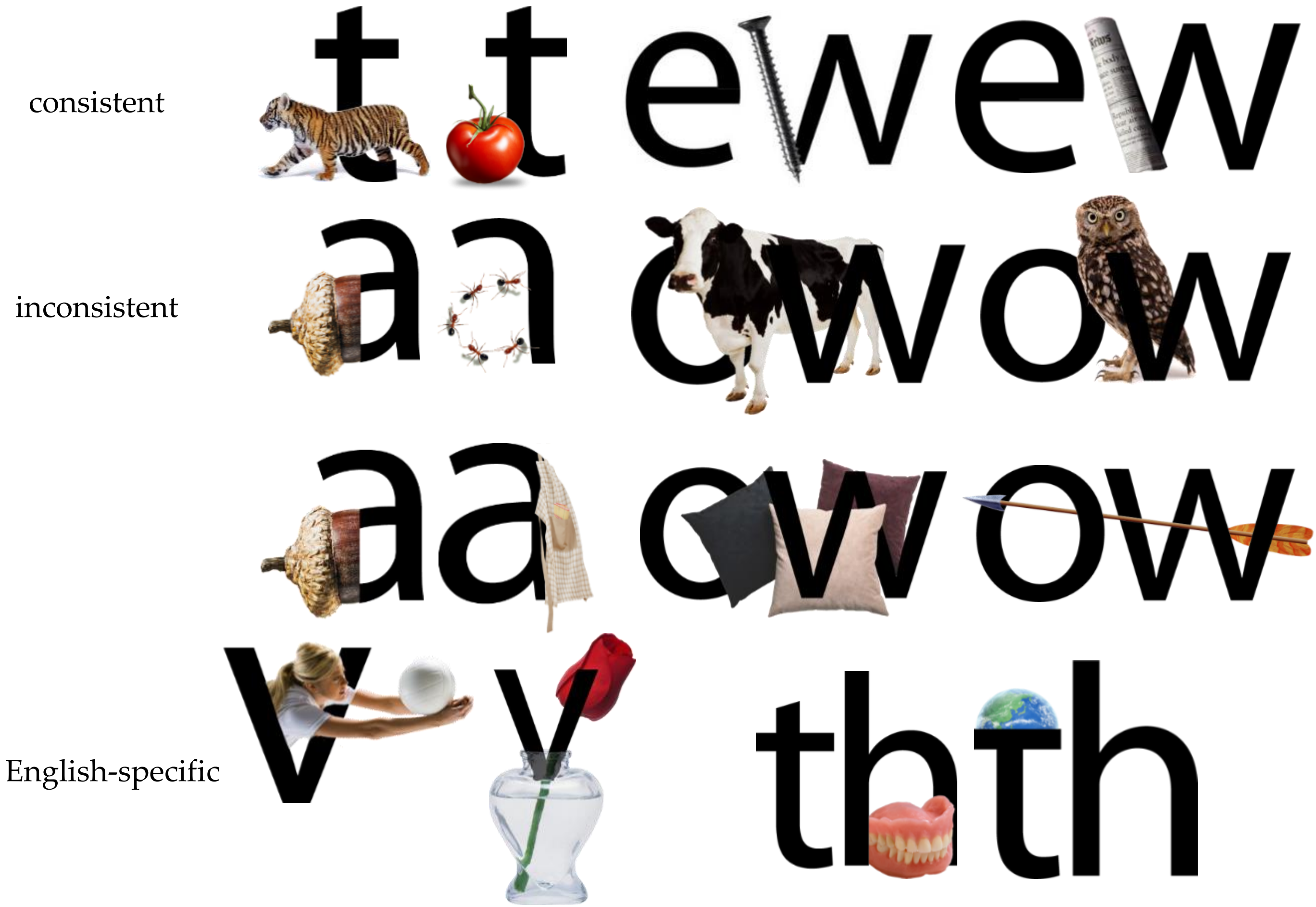

Figure 4. Examples of three different types of graphemes. Across the training session, reading lessons included training on different types of graphemes. Examples of consistently pronounced graphemes are presented in the top row. The middle row shows examples of graphemes that can be pronounced in more than one way, with different sets of picture cues given for each pronunciation. Examples of phonemes represented in English but not in Chinese are presented in the bottom row.

Figure 5 shows plots of children's performance on 3 tasks (at the letter, word level, and text level) across the three types of graphemes. Within each grapheme type, children's median response times (in seconds) were calculated for tracing and story search, and the proportions of correct responses were calculated for the spelling task; these data were compared in repeated measures ANOVAs. The data showed that spelling and letter search were affected by the types of graphemes being learned, $F(2, 56) = 7.16$, $p < 0.01$, and $F(2, 60) = 12.38$, $p < 0.01$, respectively. Graphemes corresponding to more than one pronunciation or specific to the English language were more challenging to learn for this group of children. Spelling was less accurate for inconsistent graphemes (adjusted LSD contrast p's <0.01), and letter search was faster with consistent graphemes than either English-specific ones ($p = 0.04$) or inconsistent graphemes ($p < 0.01$). On the other hand, the tracing activity (letter level of the program) showed no effect of grapheme type, $F(2, 69) = 0.49$, $p = 0.56$, as would be expected since this was purely a motor skill; these findings highlight the use of technology-based methods to gain online information about student performance during learning activities.

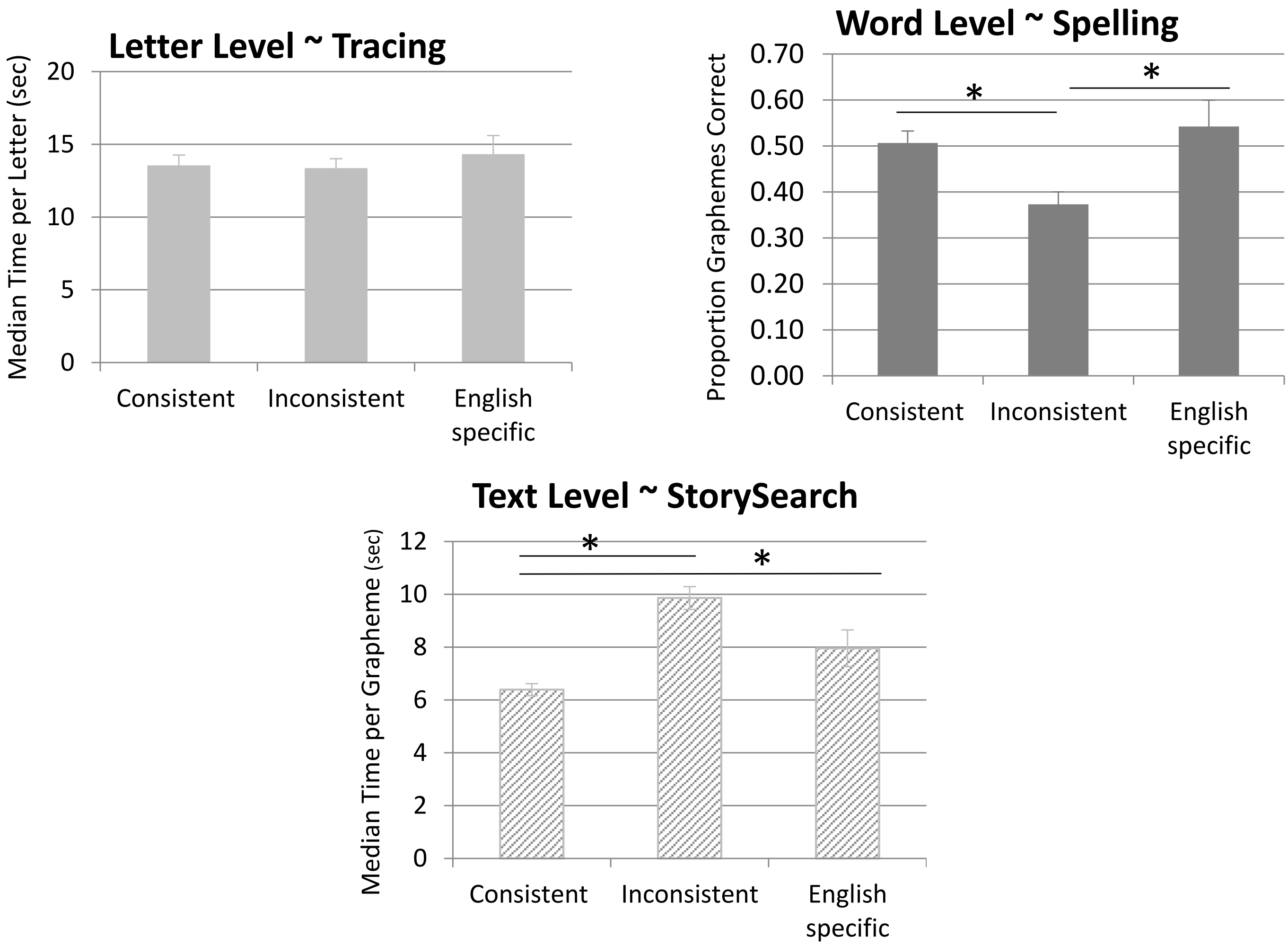

Figure 5. Performance on *See Word* activities for three types of graphemes. Average performance by children in the reading intervention group on different activities. The top plot shows times for tracing the letter (in seconds) in Level 1 of the *See Word* tool. The bottom left plot shows the proportion of correctly spelled phonemes within the given word in Level 2. The bottom right plot shows the time for searching for graphemes representing a given phoneme (median seconds per instance). Bars represent average performance across grapheme types. Significant differences between conditions are indicated with * ($p < 0.01$).

4. Discussion

We examined the effects of a technology-based tool, *See Word Reading®*, for teaching early reading skills in English letter-sound correspondence to developing readers. Literacy outcomes were generally positive, and the study made several novel contributions. This study focused on young bilingual learners with a language background typologically different from English, utilizing a randomized-controlled design and extended previous research on mnemonic techniques for teaching phonics by using a technology-based platform.

The reading intervention for teaching phonics used in this study builds on and extends the previous work using picture-cue mnemonics for teaching letter-sound correspondences [25,30,31]. We incorporated features found to be key to learning in the earlier set of results; including picture cues that are well-integrated with the letter forms and fading out of the cues to make the bare letter form's shape more salient, within each presentation of the series of photographic image cues. We trained a more extensive set of grapheme-phoneme pairings (45) over a longer training period (14 weeks), and each lesson included training of the grapheme-phoneme pairings in isolation as well as in the context of words and text, with the intent to draw children's attention to how phonics is applied to decoding of words and reading of the text. Our outcome measures focused on this aim by using general tests of word reading and decoding rather than a limited set of trained items. Similar to Shmidman and Ehri's [31], we found that training effects extended to word reading performance.

By implementing the intervention on tablets, we were also able to incorporate other features that have been found advantageous in technology-based educational applications. Interactive features, for example, are a major difference between touchscreen devices and paper-based platforms for learning. The activities within the *See Word Reading*® app included multiple opportunities for children to interact with the content, including letter tracing, dragging, and tapping to learn letter shapes, build words, and seek letters within words. Children also interacted with voice-directed queries about the letters and words that they were working with. Their responses to the questions were recorded and played back to them, and they could re-record if they wished. Responding to questions was also found to help children's vocabulary learning within technology-based apps [75]. The use of interactive and adaptive games was reported to improve learning for phonological awareness, reading, and spelling by kindergarten-aged children in other studies using iPod/iPad touch devices [76,77] and computers as well [78–80]. For their average learners, Macaruso and Walker [79] reported an overall effect size comparable to the present study (0.48), while larger gains were reported for their low-performing students. The effect size for our literacy measures, comparing the reading group relative to the control group, was in the medium range for decoding at post-test (d = 0.48), and for word reading at post- and follow-up-test (d's = 0.40). While such effects are generally considered moderate, in the reading intervention literature, they compare favorably to findings for other interventions considered effective (e.g., with effect sizes ranging from 0.13 to 0.23, [81,82]). The differential effect for spelling was small (d = 0.23), however. This finding seems to be in line with the well-known asymmetry between spelling and reading competence in that spelling is a more challenging skill to acquire than reading [83]; it suggests that spelling may require more direct instruction or focused practice with applying letter-sound knowledge to sound-symbol encoding, as only some of the lessons included the spelling activity for words.

Other features unique to electronic device platforms for learning include a multimodal presentation and timely feedback. The vivid photographic images flashed along with auditory labelling of the image names in this app ensured consolidation of visual-aural coupling, and spoken stories accompanied by highlighted read text ensured capturing of children's attention to the text. In a study with second-language learners in kindergarten, Verhallen et al. [19] also found positive effects on story comprehension and vocabulary when e-storybooks were presented with animated multimedia. Like some of these other applications, *See Word Reading*® also contained feedback at each lesson level for children's performance: from accurate tracing that begins the lesson at level 1, to dropped incorrect letters in level 2, and progress stars for correct letters found in level 3. In addition, technology-based applications can assist teachers by providing insights into the children's online performance, highlighting an advantage of technology for monitoring student progress in an unobtrusive way.

In the current study, we focused on how *See Word*'s picture embedding methods affected English literacy for bilingual children. This fills an important gap in the literature because both the inconsistencies in English orthography and the children's language background present challenges in learning to read English. The former factor was reflected in the participants' performance on the *See Word* reading activities during the lessons. For example, when learning graphemes that could be pronounced more than one way, the children in the reading intervention were less accurate in spelling words with these inconsistent graphemes; they also took longer to search within a story text for such graphemes when asked to find letters that matched a given phoneme. The group performed better on spelling and letter-searching activities across lessons when the learned graphemes were consistent in their sound correspondence.

Regarding the bilingual children's language background, they had extensive experience with both Chinese and English; they came from bilingual backgrounds where Chinese was spoken most of the time or equally as often as English, and their Chinese vocabulary scores were at a level commensurate with similarly aged bilinguals in prior research in Singapore [57]. Furthermore, these children who are learning two scripts simultaneously follow a Chinese language curriculum emphasizing holistic processing for character reading; they are not introduced to the pinyin system for coding Chinese at the phoneme level until primary school. Previous work has shown that while syllable level awareness develops "naturally" from speech [84], instruction in pinyin gives an advantage for onset and coda level phonological awareness (e.g., [85–87]); these factors may have rendered the children in this study less sensitive to the phonemic level of processing necessary for learning to read an alphabetic language. Indeed, their average phonological deletion scores showed the expected advantage of syllable awareness (5.9 out of 9 or 66% correct) compared with phoneme awareness (1.3 of 25, or 0.05% correct) (e.g., [55]).

The influence of the language background factor was also evident in children's *See Word* performance. For example, the children were slower when searching for grapheme matches to phonemes that are unique to English versus Chinese. Given their exposure to the Chinese language in the home, they may have less familiarity with phonemes that are not expressed in Chinese, just as previous studies found that Chinese ESL and bilingual kindergarteners had more difficulty spelling these phonemes [58,59]; these findings perhaps suggest that additional methods would be necessary to augment *See Word* for addressing those learning challenges induced by intra-lingual complexities (i.e., irregularities in letter-sound correspondences in English) and inter-lingual variations (i.e., phonemes and phonological representations in English vs. in Chinese) for bilingual children.

5. Conclusions

Techniques with pictures embedded have been found to promote early literacy development in English-speaking children by drawing their attention to letter-sound correspondences. Limited intervention studies, however, have aimed to test how technological tools utilizing these techniques could similarly promote literacy learning in young bilingual children, particularly those whose ethnic language is typologically disparate from English. Chinese-English bilingual children, the focus of the present study, offered a valuable opportunity to test the effectiveness of learning such technological tools as the *See Word Reading*®, because of cross-linguistic variations between the two languages in phonemes and phonological representations in print.

The findings of this study have enhanced current understandings about teaching English literacy to bilingual children, and children in general, using innovative technologies. *See Word Reading*® was considered engaging, according to a student survey, and the tablet format offers features distinct from other classroom activities: including more consistent pronunciations of the target language than teachers might offer. The effects on word reading performance support the contention that drawing attention to letter-sound correspondence within word and text levels facilitates the transition from phonics to decoding. The present results suggest that technology-based approaches to phonics, using digital text and embedded cues, may help overcome obstacles to children's learning. In multilingual societies within which influences from different languages bear on conversation and talk [88,89], such variations can be especially challenging for the teacher to accommodate for students' effective learning of phonemes and phonics. In this respect, apps and activities such as those of *See Word Reading*® may be particularly useful for supplementary learning purposes.

While the present results are promising, there are several limitations to the study. Primarily, the study is limited to the activities tested in the design of the app. That is, even though the first 5–8 min per lesson of each group was spent with verbal instructions and modeling with teacher self-talk on the activities for the day, the experimental group spent time working specifically with graphemes and sounds, while the control group worked with numerical and shape processes. Thus, working with apps that emphasize language, in general, could be just as beneficial as working with GPC-based activities. However, it is noted that the pre- and post-test measures utilized in this study were not directly taught within the GPC lessons—rather, they were extensions of these lessons to word reading, decoding, and spelling of an independent set of words that were predefined in the standardized assessments. Thus, students transferred the trained knowledge and applied this to new words. Further, we did not observe the effects of the intervention on spelling as earlier findings did [31], and our effect on word reading, though significant, was not large, although not uncommon for these types of intervention studies. This could be due to a number of factors, including treatment intensity and the curriculum design, which would require further study.

Author Contributions: Conceptualization, B.A.O., R.S. and D.Z.; methodology, B.A.O.; software, R.S.; formal analysis, B.A.O.; resources, R.S.; data curation, B.A.O.; writing—original draft preparation, B.A.O. and D.Z; writing—review and editing, B.A.O., R.S. and D.Z.; visualization, R.S.; project administration, B.A.O.; funding acquisition, B.A.O. All authors have read and agreed to the published version of the manuscript.

Funding: This study was funded by the Education Research Funding Programme, National Institute of Education (NIE), Nanyang Technological University, Singapore, project no. OER 5812OBA.

Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki, and approved by the Institutional Review Board of Nanyang Technological University (IRB-2013-05-023).

Informed Consent Statement: Informed consent was obtained from all participants' parents and assent was obtained from the children involved in the study.

Data Availability Statement: The data presented in this study are available on request from the corresponding author.

Conflicts of Interest: The authors declare no conflict of interest at the time the study was conducted. Subsequently, the second author co-founded a start-up company, See Word Design LLC, which along with the University of Cincinnati holds ownership of the application.

References

1. Montag, J.L.; Jones, M.N.; Smith, L.B. The words children hear: Picture books and the statistics for language learning. *Psychol. Sci.* **2015**, *26*, 1489–1496. [CrossRef] [PubMed]
2. National Early Literacy Panel. *Developing Early Literacy: Report of the National Early Literacy Panel*; National Institute for Literacy: Washington, DC, USA, 2009.
3. Ehri, L.C.; Nunes, S.R.; Stahl, A.S.; Willows, D.M. Systematic phonics instruction helps children to read: Evidence from the National Reading Panel's meta-analysis. *Rev. Educ. Res.* **2001**, *71*, 393–447. [CrossRef]
4. Johnston, R.S.; McGeown, S.; Watson, J.E. Long-term effects of synthetic versus analytic phonics teaching on the reading and spelling ability of 10 year old boys and girls. *Read. Writ.* **2012**, *25*, 1365–1384. [CrossRef]
5. 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: Bethesda, MD, USA, 2000.
6. Bowyer-Crane, C.; Snowling, M.J.; Duff, F.J.; Fieldsend, E.; Carroll, J.M.; Miles, J.; Hulme, C. Improving early language and literacy skills: Differential effects of an oral language versus a phonology with reading intervention. *J. Child Psychol. Psychiatry* **2008**, *49*, 422–432. [CrossRef] [PubMed]
7. Hatcher, P.J.; Hulme, C.; Snowling, M.J. Explicit phoneme training combined with phonic reading instruction helps young children at risk of reading failure. *J. Child Psychol. Psychiatry* **2004**, *45*, 338–358. [CrossRef] [PubMed]
8. Hulme, C.; Bowyer-Crane, C.; Carroll, J.M.; Duff, F.J.; Snowling, M.J. The causal role of phoneme awareness and letter-sound knowledge in learning to read: Combining intervention studies with mediation analyses. . *Psychol. Sci.* **2012**, *23*, 572–577. [CrossRef]
9. Swanson, H.L.; Trainin, G.; Necoechea, D.M.; Hammill, D.D. Rapid naming, phonological awareness and reading: A meta-analysis of the correlation evidence. *Rev. Educ. Res.* **2003**, *73*, 407–440. [CrossRef]

10. August, D.; Shanahan, T. *Developing Literacy in Second–Language Learners: Report of the National Literacy Panel on Language Minority Children and Youth*; Lawrence Erlbaum Associates: Mahwah, NJ, USA, 2006.
11. Seward, R. See Word Reading Teaching Tool [Mobile application software], 2015a. Available online: http://itunes.apple.com (accessed on 19 October 2022).
12. Seward, R. See Word Reading Student App [Mobile application software], 2015b. Available online: http://itunes.apple.com (accessed on 19 October 2022).
13. Li, S.C.; Pow, J.W.C.; Wong, E.M.L.; Fung, A.C.W. Empowering student learning through tablet pcs: A case study. *Educ. Inf. Technol.* **2010**, *15*, 171–180. [CrossRef]
14. Hirsh-Pasek, K.; Zosh, J.M.; Golinkoff, R.; Gray, J.; Robb, M.; Kaufman, J. Harnessing the science of learning to promote real educational apps. *Psychol. Sci. Public Interest* **2015**, *16*, 3–34. [CrossRef]
15. Northrop, L.; Killeen, E. A framework for using iPads to build early literacy skills. *Read. Teach.* **2013**, *66*, 531–537. [CrossRef]
16. International Reading Association. *New Literacies and 21st-Century Technologies: A Position Statement of the International Reading Association*; International Reading Association: Newark, DE, USA, 2009.
17. Doty, D.E.; Popplewell, S.R.; Byers, G.O. Interactive CD-ROM storybooks and young readers' reading comprehension. *J. Res. Comput. Educ.* **2001**, *33*, 374–384. [CrossRef]
18. Korat, O.; Shamir, A. The educational electronic book as a tool for supporting children's emergent literacy in low versus middle SES groups. *Comput. Educ.* **2008**, *50*, 110–124. [CrossRef]
19. Verhallen, M.; Bus, A.G.; de Jong, M.T. The promise of multimedia stories for kindergarten children at risk. *J. Educ. Psychol.* **2006**, *98*, 410–419. [CrossRef]
20. Sandvik, M.; Smørdal, O.; Østerud, S. Exploring iPads in practitioners' repertoires for language learning and literacy practices in kindergarten. *Nord J. Digit. Lit.* **2012**, *3*, 204–221. [CrossRef]
21. Seward, R.; O'Brien, B.; Breit-Smith, A.D.; Meyer, B. Linking design principles to educational research theories to teaching sound to symbol reading correspondence with multisensory type. *Visible Language* **2014**, *48*, 87–108.
22. Ehri, L.C. Orthographic mapping in the acquisition of sight word reading, spelling memory and vocabulary learning. *Sci. Stud. Read.* **2014**, *18*, 5–21. [CrossRef]
23. Foulin, J.N. Why is letter-name knowledge such a good predictor of learning to read? *Read. Writ.* **2005**, *18*, 129–155. [CrossRef]
24. Colberg, S.; Fern, S. Facilitation Instruction through interdisciplinary efforts: The role of visual-communication design in developing instructional materials for reading. *J. Spec. Educ.* **1992**, *16*, 120–130.
25. Ehri, L.C.; Deffner, N.D.; Wilce, L.S. Pictorial mnemonics for phonics. *J. Educ. Psychol.* **1984**, *76*, 880–893. [CrossRef]
26. Agramonte, V.; Belfiore, P.J. Using mnemonics to increase early literacy skills in urban kindergarten students. *J. Behav. Educ.* **2002**, *11*, 181–190. [CrossRef]
27. DiLorenzo, K.E.; Rody, C.A.; Bucholz, J.L.; Brady, M.P. Teaching letter-sound connections with picture mnemonics: *Itchy's Alphabet* and early decoding. *Prev. Sch. Fail. Altern. Educ. Child. Youth* **2011**, *55*, 28–34. [CrossRef]
28. O'Brien, B.A.; Habib, M.; Onnis, L. Technology-based tools for English literacy intervention: Examining intervention grain size and individual differences. *Front Psychol* **2019**, *10*, 2625. [CrossRef]
29. Roberts, T.A.; Sadler, C.D. Letter sound characters and imaginary narratives: Can they enhance motivation and letter sound learning? *Early Child Res. Q.* **2019**, *46*, 97–111. [CrossRef]
30. de Graaff, S.; Verhoeven, L.; Hasselman, F.; Bosman, A.M.T. Integrated pictorial mnemonics and stimulus fading: Teaching kindergartners letter sounds. *Br. J. Educ. Psychol.* **2007**, *77*, 519–539. [CrossRef] [PubMed]
31. Shmidman, A.; Ehri, L. Embedded picture mnemonics to learn letters. *Sci. Stud. Read.* **2010**, *14*, 159–182. [CrossRef]
32. Sener, U.; Belfiore, P. Mnemonics strategy development: Improving alphabetic understanding in Turkish students, at risk for failure in EFL settings, *J. Behav. Educ.* **2005**, *14*, 105–115. [CrossRef]
33. Manalo, E.; Uesaka, Y.; Sekitani, K. Using mnemonic images and explicit sound contrasting to help Japanese children learn English alphabet sounds. *J. Appl. Res. Mem. Cogn.* **2013**, *2*, 216–221. [CrossRef]
34. McBride-Chang, C. *Children's Literacy Development*; Routledge: New York, NY, USA, 2004.
35. López, O.S. The digital learning classroom: Improving English Language Learners' academic success in mathematics and reading using interactive whiteboard technology. *Comput. Educ.* **2010**, *54*, 901–915. [CrossRef]
36. Wolgemuth, J.R.; Savage, R.; Helmer, J.; Harper, H.; Lea, T.; Abrami, P.C.; Louden, W. ABRACADABRA aims indigenous and non-indigenous early literacy in Australia: Evidence from a multisite randomized controlled trial. *Comput. Educ.* **2013**, *67*, 250–264. [CrossRef]
37. Zheng, B.; Warshauer, M. Participation, interaction, and academic achievement in an online discussion environment. *Comput. Educ.* **2015**, *84*, 78–89. [CrossRef]
38. Seymore, P.H.K.; Aro, M.; Erksine, J.M. Foundation literacy acquisition in European orthographies. *Br. J. Psychol.* **2003**, *94*, 143–174. [CrossRef]
39. Alegria, J.; Mousty, P. The development of spelling procedures in French-speaking normal and reading-disabled children: Effects of frequency and lexicality. *J. Exp. Child Psychol.* **1996**, *63*, 312–338. [CrossRef]
40. Andrews, S.; Woollams, A.M.; Bond, R. Spelling-sound typicality only affects words with digraphs: Further qualifications to the generality of the regularity effect on word naming. *J. Mem. Lang.* **2005**, *53*, 567–593. [CrossRef]

41. Lété, B.; Peereman, R.; Fayol, M. Consistency and word-frequency effects on spelling among first- to fifth-grade French children: A regression-based study. *J. Mem. Lang.* **2008**, *58*, 952–977. [CrossRef]
42. Weekes, B.S.; Castles, A.E.; Davies, R.A. Effects of consistency and age of acquisition on reading and spelling in developing readers. *Read. Writ.* **2006**, *19*, 132–169. [CrossRef]
43. Ziegler, J.C.; Goswami, U. Reading acquisition, developmental dyslexia, and skilled reading across languages: A psycholinguistic grain size theory. *Psychol. Bull.* **2005**, *131*, 3–29. [CrossRef]
44. Ho, C.S.H.; Bryant, P. Development of phonological awareness of Chinese children in Hong Kong. *J. Psycholinguist. Res.* **1997**, *26*, 109–126. [CrossRef]
45. Hu, C.F.; Catts, H.W. The role of phonological processing in early reading ability: What we can learn from Chinese. *Sci. Stud. Read.* **1998**, *2*, 55–79. [CrossRef]
46. Huang, H.S.; Hanley, J.R. Phonological awareness and visual skills in learning to read Chinese and English. *Cognition* **1994**, *54*, 73–98. [CrossRef]
47. McBride-Chang, C.; Ho, C.S.-H. Developmental issues in Chinese children's character acquisition. *J. Educ. Psychol.* **2000**, *92*, 50–55. [CrossRef]
48. O'Brien, B.A.; Mohamed, H.M.; Yussof, N.T.; Ng, S.C. The phonological awareness relation to early reading in English for three groups of simultaneous bilingual children. *Read. Writ.* **2019**, *32*, 909–937. [CrossRef]
49. Gottardo, A.; Pasquarella, A.; Chen, X.; Ramirez, G. The impact of language on the relationships between phonological awareness and word reading in different orthographies: A test of the psycholinguistic grain size theory in bilinguals. *Appl. Psycholinguist.* **2016**, *37*, 1083–1115. [CrossRef]
50. Muljani, D.; Koda, K.; Moates, D.R. The development of word recognition in a second language. *Appl. Psycholinguist.* **1998**, *19*, 99–113. [CrossRef]
51. Wang, M.; Koda, K.; Perfetti, C.A. Alphabetic and nonalphabetic L1 effects in English word identification: A comparison of Korean and Chinese English L2 learners. *Cognition* **2003**, *87*, 129–149. [CrossRef]
52. Caravolas, M.; Bruck, M. The effect of oral and written language input on children's phonological awareness: A cross-linguistic study. *J. Exp. Child Psychol.* **1993**, *55*, 1–30. [CrossRef]
53. Cheung, H.; Chen, H.C.; Lai, C.Y.; Wong, O.C.; Hills, M. The development of phonological awareness: Effects of spoken language experience and orthography. *Cognition* **2001**, *81*, 227–241. [CrossRef]
54. Taylor, I. Phonological awareness in Chinese reading. In *Chinese Children's Reading Acquisition: Theoretical and Pedagogical Issues*; Li, W., Gaffney, J.S., Packard, J.L., Eds.; Kluwer Academic: Boston, MA, USA, 2002; pp. 39–58.
55. McBride-Chang, C.; Bialystok, E.; Chong, K.K.Y.; Li, Y. Levels of phonological awareness in three cultures. *J. Exp. Child Psychol.* **2004**, *89*, 93–111. [CrossRef]
56. Newman, E.H.; Tardiff, T.; Huang, J.; Shu, H. Phonemes matter: The role of phoneme-level awareness in emergent Chinese readers. *J. Exp. Child Psychol.* **2011**, *108*, 242–259. [CrossRef]
57. Yeong, H.-M.S.; Rickard Liow, S.J. Development of phonological awareness in English–Mandarin bilinguals: A comparison of English–L1 and Mandarin–L1 kindergarten children. *J. Exp. Child Psychol.* **2012**, *112*, 111–126. [CrossRef]
58. Wang, M.; Geva, E. Spelling performance of Chinese ESL children: Lexical and visual-orthographic processes. *Appl. Psycholinguist.* **2003**, *24*, 1–25. [CrossRef]
59. Yeong, H.-M.S.; Rickard Liow, S.J. Phonemic representation and early spelling errors in bilinguals. *Sci. Stud. Read.* **2010**, *14*, 387–406. [CrossRef]
60. Gernsheimer, J. *Designing Logos: The Process of Creating Symbols that Endure*; Allworth Press: New York, NY, USA, 2008.
61. Connor, C.M.; Morrison, F.J.; Fishman, B.; Crowe, E.C.; Al Otaiba, S.; Schatschneider, C.A. Longitudinal cluster-randomized controlled study on the accumulating effects of individualized literacy instruction on students' reading from first through third grade. *Psychol. Sci.* **2013**, *24*, 1408–1419. [CrossRef]
62. Morris, R.D.; Lovett, M.W.; Wolf, M.; Sevcik, R.A.; Steinbach, K.A.; Frijters, J.C.; Shapiro, M.B. Multiple-component remediation for developmental reading disabilities: IQ, socioeconomic status, and race as factors in remedial outcome. *J. Learn. Disabil.* **2012**, *45*, 99–127. [CrossRef]
63. Zhao, S.; Liu, Y. Home language shift and its implications for language planning in Singapore: From the perspective of prestige planning. *Asia Pac. Educ. Res.* **2010**, *16*, 112–126. [CrossRef]
64. Raven, J.; Raven, J.C.; Court, J.H. *Manual for Raven's Progressive Matrices and Vocabulary Scales, Section 3: The Standard Progressive Matrices*; Harcourt Assessment: San Antonio, TX, USA, 2004.
65. Dunn, L.M.; Dunn, L.M. *Peabody Picture Vocabulary Test–IV*; American Guidance Service: Circle Pines, MN, USA, 2007.
66. Liow, S.J.R.; Sze, W.P. *Bilingual Language Assessment Battery (BLAB)*; National University of Singapore, Department of Psychology and Division of Graduate Medical Studies: Singapore, 2008.
67. Torgesen, J.K.; Wagner, R.K.; Rashotte, C.A. *Test of Word Reading Efficiency-2*; Psych-Corp: San Antonio, TX, USA, 2012.
68. Wagner, R.K.; Torgesen, J.K.; Rashotte, C.A.; Pearson, N.A. Comprehensive Test of Phonological Processing-2. Psych-Corp: Hudson, NY, USA, 2013.
69. Wolf, M.; Denckla, M.B. *Rapid Automatized Naming and Rapid Alternating Stimulus Tests (RAN/RAS)*; PRO-ED: Austin, TX, USA, 2004.

70. Woodcock, R.W.; McGrew, K.S.; Mather, N. *Woodcock-Johnson III Tests of Achievement with Normative Update*; Riverside Publishing: Rolling Meadows, IL, USA, 2007.
71. Bear, D.R.; Helman, L.; Invernizzi, M.; Templeton, S.; Johnston, F. *Words Their Way: Word Study for Phonics, Vocabulary, and Spelling Instruction*, 4th ed.; Pearson Education: Upper Saddle River, NJ, USA, 2007.
72. Greenes, C.; Ginsburg, H.P.; Balfanz, R. Big math for little kids. *Early Child Res. Q.* **2004**, *19*, 159–166. [CrossRef]
73. Landis, J.R.; Koch, G.G. The Measurement of Observer Agreement for Categorical Data. *Biometrics* **1977**, *33*, 159–174. [CrossRef]
74. Hatcher, P.J. Reading intervention need not be negligible: Response to Cossu (1999). *Read. Writ.* **2000**, *13*, 349–355. [CrossRef]
75. Smeets, D.J.; Bus, A.G. Interactive electronic storybooks for kindergartners to promote vocabulary growth. *J. Exp. Child Psychol.* **2012**, *112*, 36–55. [CrossRef]
76. Bebell, D.; Pedulla, J. A quantitative investigation into the impacts of 1:1 iPads on early learner's ELA and math achievement. *J. Inf. Technol. Educ. Innov. Pract.* **2015**, *14*, 191–215. [CrossRef]
77. Chiong, C.; Shuler, C. *Learning: Is there an App for that? Investigations of Young Children's Usage and Learning with Mobile Devices and Apps*; The Joan Ganz Cooney Center at Sesame Workshop: New York, NY, USA, 2010; Available online: https://clalliance.org/wp-content/uploads/files/learningapps_final_110410.pdf (accessed on 19 October 2022).
78. Macaruso, P.; Rodman, A. Efficacy of computer-assisted instruction for the development of early literacy skills in young children. *Read. Psychol.* **2011**, *32*, 172–196. [CrossRef]
79. Macaruso, P.; Walker, A. The efficacy of computer-assisted instruction for advancing literacy skills in kindergarten children. *Read. Psychol.* **2008**, *29*, 266–287. [CrossRef]
80. van Daal, V.H.P.; Reitsma, P. Computer-assisted learning to read and spell: Results from two pilot studies. *J. Res. Read.* **2000**, *23*, 181–193. [CrossRef]
81. Kyle, F.; Kujala, J.V.; Richardson, U.; Lyytinen, H.; Goswami, U. Assessing the effectiveness of two theoretically motivated computer-assisted reading interventions in the United Kingdom: GG Rime and GG Phoneme. *Read. Res. Q.* **2013**, *48*, 61–76. [CrossRef]
82. Torgesen, J.K.; Alexander, A.W.; Wagner, R.K.; Rashotte, C.A.; Voeller, K.K.S.; Conway, T. Intensive remedial instruction for children with severe reading disabilities. *J. Learn. Disabil.* **2001**, *34*, 33–58. [CrossRef]
83. Bosman, A.M.T.; Van Orden, G.C. Why spelling is more difficult than reading. In *Learning to Spell: Research, Theory, and Practice across Languages*; Perfetti, C.A., Rieben, L., Fayol, M., Eds.; Lawrence Erlbaum Associates: Hillsdale, NJ, USA, 1997; pp. 173–194.
84. Shu, H.; Peng, H.; McBride-Chang, C. Phonological awareness in young Chinese children. *Dev. Sci.* **2008**, *11*, 171–181. [CrossRef]
85. Cheung, H.; Chen, H.-C. Early orthographic experience modifies both phonological awareness and on-line speech processing. *Lang. Cogn. Process.* **2004**, *19*, 1–28. [CrossRef]
86. Leong, C.K.; Cheng, P.W.; Tan, L.H. The role of sensitivity to rhymes, phonemes and tones in reading English and Chinese pseudowords. *Read. Writ.* **2005**, *18*, 1–26. [CrossRef]
87. Siok, W.T.; Fletcher, P. The role of phonological awareness and visual-orthographic skills in Chinese reading acquisition. *Devel. Psychol.* **2001**, *37*, 886–899. [CrossRef]
88. Deterding, D. *Singapore English*; Edinburgh University Press: Edinburgh, UK, 2007.
89. Leimgruber, J.R.E. Singapore English. *Lang. Linguist. Compass* **2011**, *5*, 47–62. [CrossRef]