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Linking Design Principles with Educational Research Theories to Teach Sound to Symbol Reading Correspondence with Multisensory Typea

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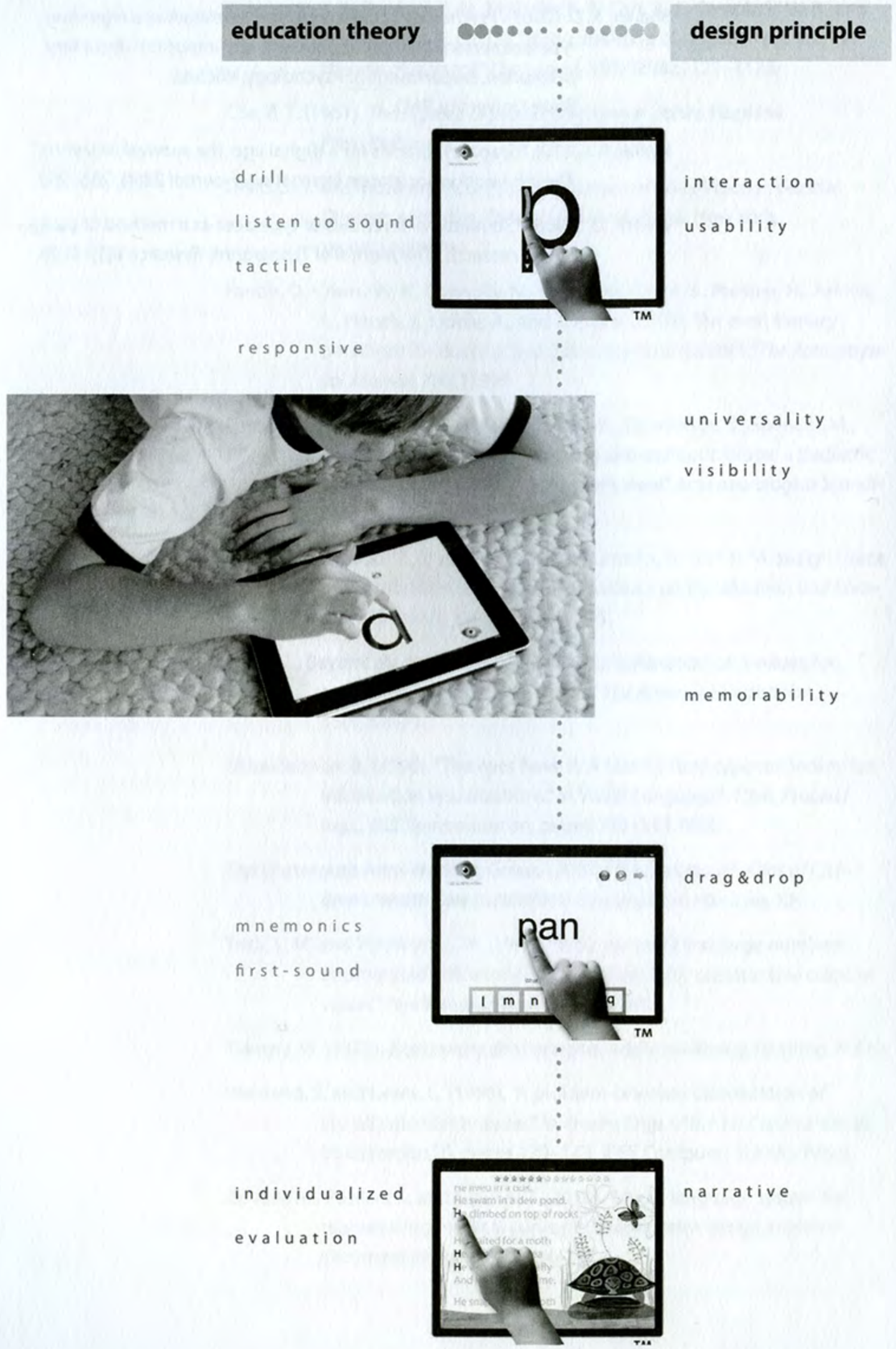


Linking Design Principles with Educational Research Theories to Teach Sound to Symbol Reading Correspondence with Multisensory Type

4

Renee Seward, Beth O'Brien, Allison D. Breit-Smith, Ben Meyer

ABSTRACT

Designing products that are considered easy to use and beautiful, yet also effectively addressing the communication problem, can be a difficult challenge for any designer. This paper explains the development of See Word Reading™, a digital tool that explores letterforms when teaching beginning reading principles to children at risk of reading difficulties. After conducting a pilot study with this tool, we assert that dynamic type within digital technologies can offer an even greater opportunity to master alphabetic consolidation by using the engagement of multiple senses.

KEYWORDS

typography; reading; multi-disciplinary; technology; multi-sensory

INTRODUCTION

Billy is a precocious 5 year old who loves books. He interacts with them every opportunity he gets, whether it be at home, in the car, or waiting in the hair salon while his mom is getting her hair washed and trimmed. His favorite story is Goldilocks and the Three Bears. Every time he sees the icon for this story on the Smartphone, he can't help but touch it. After touching the icon he becomes immediately engrossed in the story because of the illustrated images and the friendly voice that is telling him the story as words appear on the screen. For Billy what makes this story all the more engaging is the fact he can touch the images and letters in the story and get them to make noises as the story is being read. He particularly likes petting the bears' heads to make them roar. To him this is the experience of learning early reading skills; to most of us who are 20 years and older this is a very foreign experience.

New technologies have changed the way children are interacting with images and type in the early stages of learning to read. A study conducted by the Internet security company AVG found that 19% of children between the ages of 2 and 5 know how to use a Smartphone or a tablet application whereas only 11% can tie their own shoelaces. Leap Frog, computers, iPads, and Smartphones allow for a much more hands-on approach to reading experiences. Previously, children were introduced to reading by sitting with their parents while they read a hardbound book. While the parent-child interaction is still happening and is very necessary, today's parents are sometimes replacing the hardbound book with a digital tablet. In fact, "The ubiquitous quality of technology is nudging literacy instruction beyond its oral and print-based tradition to the embracing of digital tools that utilize typography, imagery, and interactivity" (Holum, 2001). The usage of digital technologies inside the classroom is an increasing trend in education as well (Li, Pow, Wong, & Fung, 2010). Unfortunately many of the tools and applications being developed for these digital technologies look beautiful and seem purposeful, but they lack the depth in educational research to adequately address issues in reading instruction.

While opportunities exist for new types of reading experiences, the US still faces staggering concerns regarding literacy among children. The National Assessment of Educational Progress found that 33% of fourth graders and 24% of eighth graders in the US are at or below a basic level reading skills (National Assessment of Educational Progress, 2007). This means that about a 1/3 of our children are reading at merely a functional level.

With the rise of new digital technologies, 21st Century children are greatly immersed in digital reading experiences. This paper will explain the development of See Word Reading, a digital tool that explores the impact of multisensory letterforms on teaching beginning reading principles to children considered at risk of reading difficulties. Essentially this case study describes the evolution of a product design that is grounded in educational theories on reading and comprehension.

BACKGROUND

DEFINING READING

Reading is a complex skill informed by multiple sources of knowledge gleaned over time (Scarborough, 2009). One early source of reading knowledge involves discovering that phonemes heard in oral language can be mapped onto graphemes written on a page or screen. It is this understanding that researchers have referred to as "cracking the alphabetic code" (Stanovich, 1986; Storch & Whitehurst, 2002). The process of cracking the code for young children can be arduous but once broken opens a world of opportunities for children to access information via a new mode of communication beyond spoken language. Cracking the code is one step in the stages of reading acquisition that culminates in comprehension of what is read. Although reading is a skill of many dimensions, theoretical models of reading using a simple view suggest that reading is the multiplicative factor of print decoding and oral comprehension (Gough & Tunmer, 1986; Vellutino, Tunmer, Jaccard, & Chen, 2007).

FOUR STAGES OF LEARNING TO READ

Research conducted by Ehri (1987, 2005) suggests that children experience four stages of learning to read new words including pre-alphabetic, partial alphabetic, full alphabetic, and consolidated alphabetic stages. Within the pre-alphabetic stage young children are very aware of print in their environment and will "read" signs such as "McDonald's" based on their designs (i.e.,golden arches) not by the letters in the name of the restaurant. The second stage of reading is the partial alphabetic stage in which children recognize some letters of the alphabet, typically those letters in their names, but cannot yet recognize all of the letters in words. The third stage Ehri terms the full alphabetic stage. With the full alphabetic stage, children recognize all letters and letter sounds of the alphabet and make the conceptual breakthrough that letters of the alphabet represent speech sounds. The fourth stage is referred to as the consolidated alphabetic stage in which children learn that letter combinations represent speech sounds and that there are consistent rules or phonics rules for the sequence and combination of letters in words (e.g., -ate, -ike, -tion).

HOW READING IS TAUGHT TODAY

Essentially, the successful development of reading hinges on a child's ability to master phonemic awareness or the ability to "hear" small segments or phonemes within spoken words and then use those phonemic awareness skills to map speech sounds to the graphemes in a written word (Ehri's consolidated alphabetic stage)(Hammill, 2004; Swanson, Trainin, Necoechea, & Hammill, 2003). In fact, a defining characteristic of school-age children identified with reading disorders is a deficit in phonemic awareness abilities

(Morris, et al., 1998; Snowling, 2001; Hulme, Snowling, Caravolas, & Carroll, 2005). Thus research examining the effectiveness of phonemic awareness instruction for young children has shown causal relations between increasing skills in this area and proficient reading (Lonigan et al., 2009; Wagner, Torgeson, & Rashotte, 1994). As a result, one essential component of early childhood literacy curriculums includes phonemic awareness and phonics instruction that pairs sounds with letterforms.

Traditional methods of teaching early reading skills typically include teacher instruction that is orally presented (e.g., The letter "m" says /m/) through direct instruction via games and/or drill-based worksheets. This type of instruction has been shown to be effective for many children (Boyer & Ehri, 2011; Piasta & Wagner, 2010); however, it ignores the natural inclination and interest of young children in the 21st Century to learn information from new technologies. Furthermore, for children who struggle to learn to read, traditional methods of early reading instruction often does not prove entirely successful for every child (Carson, Gillon, & Boustead, 2013; Noe, Spencer, Kruse, & Goldstein, 2013). Therefore, educators need access to new approaches for teaching these skills that have been shown through research to be effective.

Multi-sensory approaches to teaching early reading skills that include a tactile component, such as the use of manipulatives (e.g., letters tiles) or body tapping have been shown to be effective in increasing struggling readers' reading skills in some cases (Campbell, Helf, & Cooke, 2008; Ritchey & Goeke, 2006). The basis of Howard Gardner's Multiple Intelligence theory is that the more senses you can engage while learning the more memorable the learning experience will be (Gardner, 2006). Maria Montessori, a pioneer of multi-sensory learning stated, "The hands are the instruments of man's intelligence" (Montessori, 1964, p.27). Yet a consistent missing component of many multi-sensory approaches involves the use of technology for teaching early reading skills. Moreover, a drawback of traditional methods is that they introduce an additional step of pairing phoneme counting (via tapping different parts of the body) to sound matching, then to matching the separate sounds to letters within words. A more direct multi-sensory method that involves one step in the sound-print correspondence mapping is likely more efficient for teaching early reading skills. One such method would be a digital interactive tool that affords explicit presentations of sound/letterform correspondences (i.e., multiple, rich visual images to represent each sound/letter pairin) within meaningful contexts).

MULTI-SENSORY TYPE VERSUS STATIC TYPE

Educational researchers and practitioners alike assert that the potential of new technologies for learning is likely to be found not in the technologies themselves but in the way in which these technologies are used as tools for learning (Means & Olson, 1995; Owston, 1997; Valdez et al., 1999). Leveraging a designer's ability to synthesize visual, tactile, and auditory qualities

into learning experiences within new technologies holds potential for explicit presentations of sound/letterform correspondences to be taught within the context of reading.

When looking at the context of reading with traditional print there are two issues that present themselves as they pertain to beginning readers. First, the uniformed system of glyphs has proven to be challenging for beginning readers to distinguish several letters. (Walker, S., & Reynolds, L., 2003, Sanocki & Dyson, 2011; Fiset, et al., 2008). In any good typeface there are always commonalties of stroke thickness, line and curve language, and x-height, and width between letters. For example, the letters "p", "g", "b", "d" prove a challenge because they are mirrors of each other and so it is difficult to discriminate between these letters (Colberg, 1992). "Barring certain minor idiosyncrasies of typeface design, the four letters are identical in every respect, except orientation in space" (West, 2009, p. 82).

Second, in addition to learning variation between letter categories, children must learn to ignore variations across different fonts in the way they represent the same letter. In the development of a typeface there are several letterforms that do not have the same anatomy as the letterform being taught in the classroom to beginning readers. For example the two-story "a's" visual form is very different from the one-story glyph with which teachers instruct students, and the letter "q" in most typefaces is missing the curve on the descender. The discrepancy between the way letterforms are taught and their representation within typefaces has been a significant source of confusion for students while learning to read and write (Bennett, 2005, p. 255), and in fact the development of abstracted letter units from such variations in lower case forms shows a protracted developmental period (Thompson, 2009). These issues can impede early readers from achieving Ehri's consolidated alphabetic stage of reading.

There are several typefaces that have been developed to address these issues, two of which are Read Regular (a typeface suggested for dyslexic readers) and Myriad Pro. Read Regular is a typeface which has been carefully drawn to maximize differences among the 26 letters of our alphabet. This differentiation can be seen in the shapes of the letterforms, as well as their counterspaces. (See Figure 1.) Myriad Pro, while not specifically designed for beginner readers, has proven to be an effective typeface due to its having a significant length on ascenders and descenders and nice open counterspaces. (See Figure 2.) These typefaces may offer some aid in letter discrimination on the path to Ehri's consolidated alphabetic stage by linking visually distinct letterforms to distinct sounds. However, we assert that dynamic type within digital technologies can offer an even greater opportunity to master alphabetic consolidation by using the engagement of multiple senses. Type onscreen provides more than just a static representation of an abstract glyph. Nicolas Kunz & Michael Flückiger (2009) stated, "Why should a typeface be rigidly set, if it is not going to be printed? In a dynamic medium, why shouldn't the form and the character of the typeface be understood dynamically as well?"

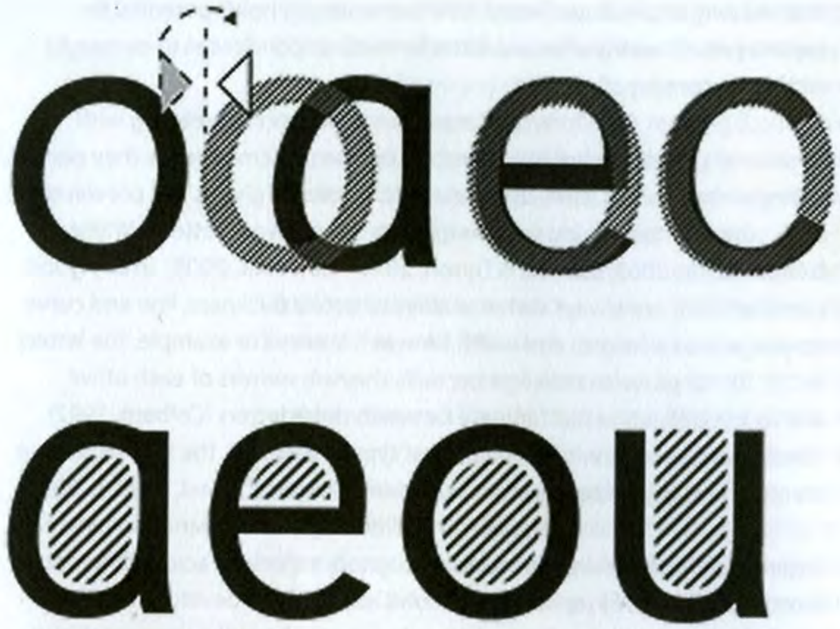


FIGURE 1

Read Regular has been carefully drawn to maximize differences among the 26 letters of our alphabet. This can be seen in the width of letters that are commonly the same like the a, e, o and c. The shape of the counterspaces in the bottom row, indicated through the diagonal line textures, have been careful drawn to appear as different as possible.

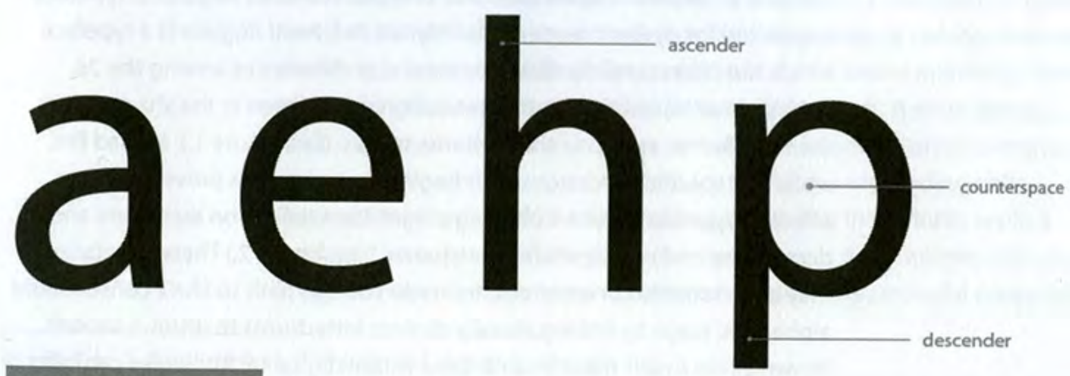


FIGURE 2

Myriad Pro has open counterpaces and the length of ascenders and descenders are very legible.

SEE WORD READING TOOL OVERVIEW

The See Word Reading tool, developed by School of Design and College of Education research faculty at the University of Cincinnati, is an experiential learning tool that explores the impact of multisensory letterforms on teaching beginning reading principles to children at risk of reading difficulties. There are three levels within See Word Reading™: Letter-sound Correspondence, Word Building Method, and See Word Reading Tool Overview. 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. (See *figure 3*.) For example, tracing the letter "p" initiates a sequence of images that appear embedded in the letterform, from peach to peppermint and then to pie, before the image resumes to the letterform alone. (see *figure 4*) Naming the images aloud cues readers to hear the common initial sound of the objects

FIGURE 3

This is a storyboard of the sequence of images that appear over time like after the letter has been traced.

FIGURE 4

These are screen shots of the four levels to the digital tools. From left to right there is: The Letter-sound correspondence level where readers trace letters and or letter pairs with their finger to initiate the visuals cues; the Word Building level where readers add a sound tile to the word family to create a new word; the Storybook level where readers identify the sounds in the story that they have been prompted to find.

displayed (or the medial sound for some vowels). Readers are then asked to answer questions about the letter, including its name, corresponding sound, and a word that begins with that sound. All responses are recorded to a database that teachers can access later.

Within the second level, Word Building, 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. (See Figure 4.) 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 sent to a database that teachers can access later. Teachers can pre-select a set of word families and onset letter choices for this level of the app.

Within the 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, students are prompted to find and touch letter(s) corresponding to a spoken phoneme. The letters here are dynamic, and if the correct letter and/or letter pairs are touched, the hidden cues associated with the letter and/or letter pairs reappear to reinforce the sound/ letter correspondences. (see *figure 4*)

LINKING DESIGN PRINCIPLES TO EDUCATIONAL RESEARCH

It was imperative that this tool fits like a glove for educators and their students. Many times designers make assumptions about a problem and fail to understand the pool of research existing on the problem yet still hope to create beautiful and fun artifacts. Many times these artifacts may be beautiful and fun but fail to truly address the problem they purport to address.

To avoid making such assumptions about this problem, as the See Word Reading prototype was being developed, rigorous critique sessions were conducted within the See Word Reading interdisciplinary team once to twice a month for a year to ensure that the tool was structured in a method supported by National Reading Standards. The interdisciplinary team consisted of two communication designers, a literacy specialist and an educational psychologist. The goal of the team was to pair graphic and interactive communication design principles with educational and cognitive research theories.

The pairing of graphic and interactive communication design principles with educational and cognitive research theories is seen in each level of the See Word Reading tool. Within the Letter-sound

Correspondence level, the series of visual image pairings to initial word sounds follows earlier cognitive research on the use of first-sound embedded picture mnemonics to relate phonemic sounds to the typographic letterform (See de Graaff, Verhoeven, Bosman & Hasselman, 2007.) Creating a memorable juxtaposition between the type and image by making formal connections helps readers to develop a mental model of the arbitrary sound-grapheme correspondences with letter-visuals pairings (Ehri, 2014). Thus at this Letter-sound Correspondence level of the tool, the method of image-symbol pairings is similar to what Ehri's pre-alphabetic readers do in the first stage of learning to read. They employ a similar strategy when they see the McDonald's golden arches logo and say the word "McDonald's". However for See Word Reading the strategically mapped images onto letterforms makes a direct connection between the image and type. According to Haber (1970) "memory for images is superior to memory for linguistic material" (cited in Colberg, 1992, p. 128). This was demonstrated in an experiment in which participants were able to recall 85 to 95% of 2,560 pictorial slides that they had viewed previously. Haber's research suggests the possibility that connecting images to linguistic material may effectively improve the recall of both. (See Standing, L., Conezio, J., & Haber, R. N. (1970).) These findings suggest that "images may aid retention…and maintain attention for (and interest in) meaningful linguistic material providing the visual relationship between the image and print [meaning letterform] are strong" (Colberg, 1992, p. 128).

Essentially, the See Word Reading tool consists of logotypes for all 44 sounds of the English language. Each image-to-letter pairing represents one logotype. (See *figure 5*.) The logotype system that was created for this tool is complex in that each sound within the English language can have as many as 4 different letter combinations to represent it; therefore there is a total of 78 letterform marks made to visualize the 44 sounds. The strength of the digital tool lies in the fact that each mark has been carefully crafted so that it carries the qualities that make for a good mark: distinctiveness, visibility, usability, memorability, universality, durability, and timelessness (Rand, 1994, Gernsheimer, 2008).

FIGURE 5

This figure show the logotypes developed for the /k/ sound.

Within the Word Building level readers are led to the processes used during Ehri's partial alphabet reading stage. In this stage readers know some letters but cannot recognize all the letters that would makeup a word. As students are engaging with the Word Building level they

can quickly build words with the letters they already know, and with the letters and/or letter pairs that they have not yet mastered they can access the hidden pre-alphabetic image cues then go on to build a word. The ability for children to still access the hidden image cues allows those between the developmental reading stages to still thrive. As readers become more established in the partial alphabet stage of reading they decrease the need to accessing the hidden images cues. Therefore, the cues serve as a scaffold (which is a cue that is given for a time then gradually taken away after students have mastered the concept) for learning at this level of the app, and the cues remain hidden when no longer needed. Readers learn at different paces; therefore, if readers need the additional cueing, they can use it while still being able to build words. The ability to access dynamically hidden cues within letterforms is a unique ability of digital interactive media.

The third Storybook level of See Word Reading is meant to support the transition from letter-sound learning to decoding within rich texts, and thus lead students toward Ehri's third and fourth stage of reading, the full alphabetic stage and the consolidated alphabetic stage. As noted above, in the full alphabet stage readers recognize that all letters of the alphabet represent speech sounds and in the consolidated alphabetic stage readers learn that letter combinations represent speech sounds and that there are consistent rules or phonics rules for the sequence and combination of letters in words (e.g., -ate, -ike, -tion). Within the fourth stage of the educational theory it is necessary that readers begin to decipher how learned letter-sound correspondences are consistent or differ across the contexts of different words. By searching for letter(s) that represent a given phoneme and only receiving positive feedback for correctly selected ones (e.g. the 'i' for /ĭ/ in the word 'big', but not in the word 'size'....), the Storybook level reinforces awareness of consistency beyond single letters to the letter pattern level.

In sum, See Word Reading capitalizes (1) on the educational and cognitive models of learning to read, (2) graphic and interactive communication design principles of embeding images as mnemonic devices within multiple levels of language (letter to word to text), (3) engaging tactile senses through tracing, touch and dragging behaviors to reveal new information overtime, and (4) engaging auditory senses through the audio sounds in order to draw readers through Ehri's four stages of reading development. Seeword Reading serves different types of learners by providing access to the pre-alphabetic image cues during all levels, thus providing a scaffolding so that all individuals can progress through the levels. The access to these hidden cues in all levels addresses the importance of children's ability to master and then in turn use those phonemic awareness skills to map speech sounds to the graphemes in a written word (Hammill, 2004; Swanson, Trainin, Necoechea, & Hammill, 2003).

Typically, assistive technology for reading simply tells students the sound a letter makes: however, with See Word reading

students are cued to recall the sound associated with the letter by the visual images and then prompted to produce the letter sound orally. Also, other programs (such as Hooked on Phonics) use a paired associate type of learning; however the associations are made through flashcards outside the context of reading text. In contrast, by embedding image cues within the letterforms in See Word Reading, readers can make letter-sound associations within the context of on screen reading further, by allowing the students to reveal the cues as needed with a touch, the learning process becomes scaffolded rather than assistive. Scaffolding is an educational technique of giving support to students during the learning process with the intention of helping students achieve their learning goals (Sawyer, 2006). As students begin to master the goal, the tool is gradually taken away. This allows for individualization of instruction where the children and also the teachers can realize which phonemes are difficult and require further instruction.

The Teacher's Backend Tool

In addition to providing support for readers, the See Word tool was developed to assist teachers in individualizing instruction. To this end, the tool collects data during the interactive learning sessions by tracking children's spoken and tactile interaction with the letters – and all data is accessible to the teacher through the backend interface. The backend capabilities that record all student interactions allows a teacher to learn where students are struggling so that further interventions can be establish to help the student learn. The tool tracks task completion times, and it records the children's verbal and tactile interactions at each level, providing information about various early literacy skills.

Grapho-motor and visual recognition is assessed at the letter level as children trace then visually match and sound out the letter. Level 1 tracks letter tracing time and records verbal and tactile responses to the questions being asked. Encoding is assessed at the word level as children build words and pronounce them. Level 2 tracks how many attempts it takes readers to build a word then goes on to record the children's verbal reading of the built words. Letter-sound decoding is assessed at the text level as children search for letters in a text that correspond to a given sound. Level 3 records the time it takes readers to find each sound they were prompted to find. Results from a pilot study (below) demonstrate how interactive digital text can serve as a pedagogical tool for tracking student progress.

A PILOT STUDY USING THE SEE WORD READING TOOL

OBJECTIVE

Once a prototype of the tool was developed, the interdisciplinary team col-

lectively wrote for grants and designed a pilot study as a proof of concept. This pilot study had two main objectives. First, to understand the usability of the tool for both the students and trained research teachers. The second objective was to gain some early preliminary data on how and in what way the tool aids in improving students' reading ability.

METHOD

The design of the pilot study was a randomized controlled design. Students enrolled in an urban after-school program were recruited into the study by the after-school coordinator and K-1 teachers sending home consent forms to parents. Then students with parental consent were randomly assigned to one of two groups. The See Word Reading group learned phonics with the ipad-based See Word Reading tool, whereas a control group used math, science and art focused applications on the ipads. Both groups received reading instruction during the school day with their classroom teachers, but after school the students in the See Word Reading group received additional reading instruction time whereas the control group did not. Matched pairs of students were randomly assigned to one of the two groups; students in pairs were matched on pre-test scores of letter-sound knowledge (Clay,2002).

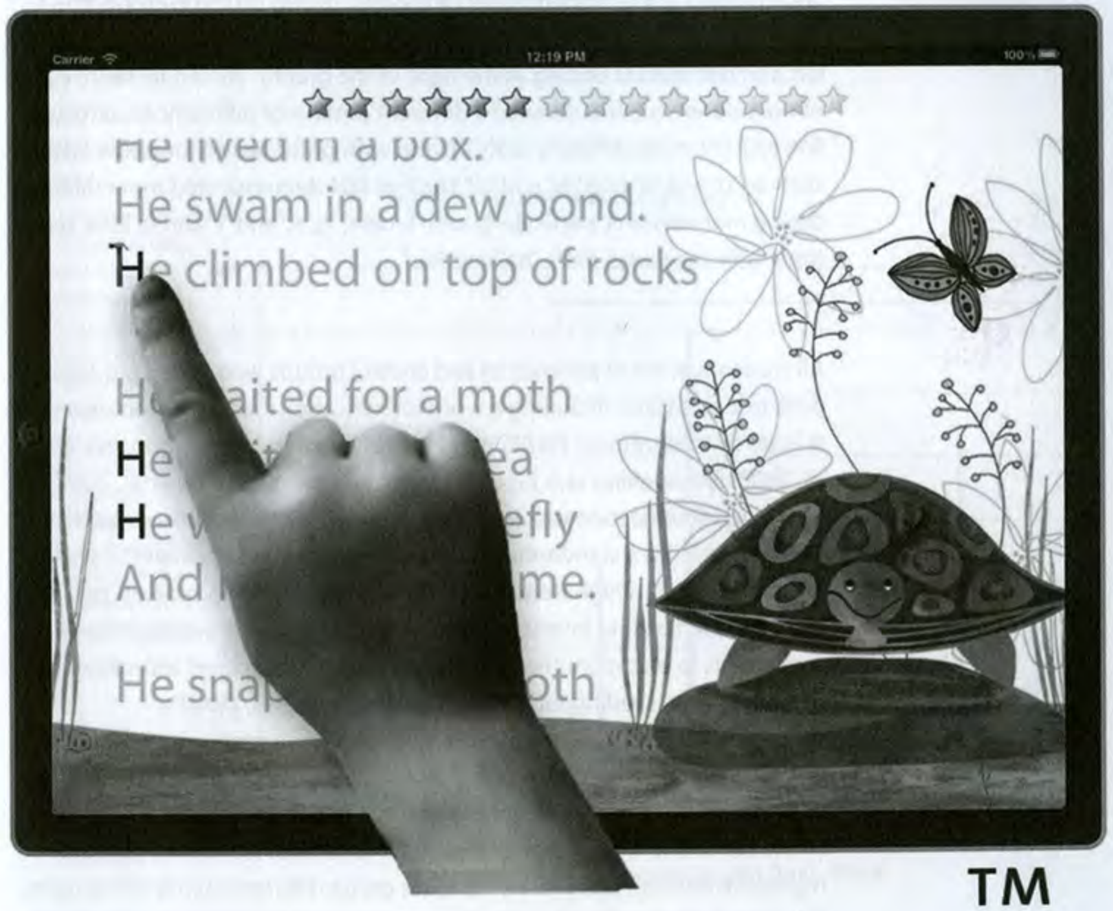
Groups met 3 times per week. Within the See Word Reading group children worked in small groups of 4 with trained research teacher (undergraduate students in education) for 30 minute lessons for a total of 10 lessons taught over 20 sessions. Each lesson was taught twice, included 10 minutes of instruction at each of the 3 levels of See Word Reading, and focused on 3-4 phonemes. Twenty-six phonemes were trained in total, wherein the most common consonants and vowels are taught first in the study (Common Core State Standards for English Language Arts and Literacy, Appendix A, p. 17). Within the control condition each session was led by a trained research teacher (undergraduate student in education) who introduced a series of math, science, and art focused applications on the iPad. These activities were unrelated to reading or pre-reading skills and were intended as a control for gains resulting from simply trying something new and working on the iPads. Without given the control access to applications on the iPad any gains in the measures could be considered as novelty effects, which would affect the validity of the outcomes. The novelty effect is the tendency for students to improve because of their increased interest and attention to the new technology introduced, not because they actually learned pre-reading and reading skills from the See Word Reading Tool (Clark & Sugrue, 1988).

During each testing session of the pilot study, an educator and a designer were present to make observations of how well the tool was functioning for both the educators and students. The interdisciplinary team met often throughout the 17 weeks, along with the trained research teachers, to address critical problems with the tool. Adjustments were then quickly made so that it functioned better for the teachers and the K-1 students in the following sessions.

One of the early usability issues found with the tool was the communication of the navigation button, which advanced readers through the series of questions being asked in the Phonemic Awareness level. The buttons were initially word-based buttons, but since the students could not read, icon-based buttons proved more functional. Within the Storybook level, we found it was helpful to install a timer to determine how long the students would search for a particular sound in a story. Without the timer, the students were easily frustrated when they couldn't find all sounds, and they wanted to quit looking. Subsequently, a progress bar made of stars was added to the Storybook level. (See Figure 6.) This bar let the children know how many instances of a particular sound they needed to find and it kept track of their progress. We found that frustration set in

FIGURE 6

The Storybook level progress bar is made of stars which helped readers to know how many sounds they needed to find.



TM

without this bar and there was not a clear incentive for them to keep looking for sounds. With the bar they were eager to be the first to find all the letters and get all the stars on their bar lit up.

Part of the tool is individualizing instruction and provides teachers with information about individual students regarding specific phonemes/graphemes they may struggle to learn. To assist teachers in this manner, the backend of the tool provides information about student interactions with the app. For example, in Level 1, the child responds to the question "What letter is this?" by selecting from a full keyboard the letter that matches the glyph that they had traced. The teacher can access stored data regarding how many attempts it took each student to identify each letter. With this information, the teacher can then focus on the letters with which each student is having difficulty. For example, in the two figures below (Figures 7 and 8), data were plotted from two more advanced students (102 and 103) compared with two weaker students (016 and 004) with regard to how many tries they needed to correctly match each letter. The weak students had very low baseline scores on a letter-sound test (2), whereas the stronger students had higher baseline letter-sound scores (10). Their performances were plotted across the entire set of lessons, shown on the x-axis as the graphemes that were taught each lesson (with first lessons beginning at the left and last lessons ending at the right of the graph). As can be seen, each of the poorer students showed a different pattern of difficulty. In particular, 016 had the most difficulty early on and with potentially confusable letters such as "p" and "q" and " b" and "d." Student 004 demonstrated more difficulty during mid-sessions, particularly with letters, "g, n," and "i" and in later sessions with the vowel pairs, "ea" and "oo."

RESULTS

All students in the experimental and control groups were given pre-test and post-test measures, including a word identification (Woodcock-Johnson III Tests of Achievement [WJIII] Word Identification subtest, Woodcock et al., 2007) and spelling task (Spelling Inventory measure, Bear et al., 2007). The word identification task included the Word Identification subtest from the WJII, which is a standardized, norm-referenced test of children's ability to read letters and high frequency words in isolation. The spelling task included the Spelling Inventory from Bear et al. (2007) in which children spell words to dictation. The spelling words are then scored according the developmental spelling model presented in Bear et al. (2007).

Average pre-to-post gain scores on each of these tasks are shown in Figure 9 and 10. According to ANCOVAs with gain score as the dependent measure and pre-test scores on the dependent measure and letter-sound knowledge entered as a covariates (to control for auto-regressive effects), there was a trend for group differences in spelling gains, $F(1, 19) = 3.78$, $p = .06$, $\eta 2 = .166$. Group means indicated that the See Word Reading group made somewhat greater gains overall (from pre- to post-test)

TABLE 1

Table 1 shows the number of errors made by pupils when matching a letter(s) to an audible dictated letter-sound. The errors are calculated by the number of attempts students made to correctly match the letter to the sound. The chart isolates individual data across different sessions for three students; one student with weaker skills (016) compared to two stronger students (103 and 102). The results of this chart show that as the weaker student (016) progressed through See Word Reading the number of errors made while matching sound to letters decreased and became similar to the stronger students.

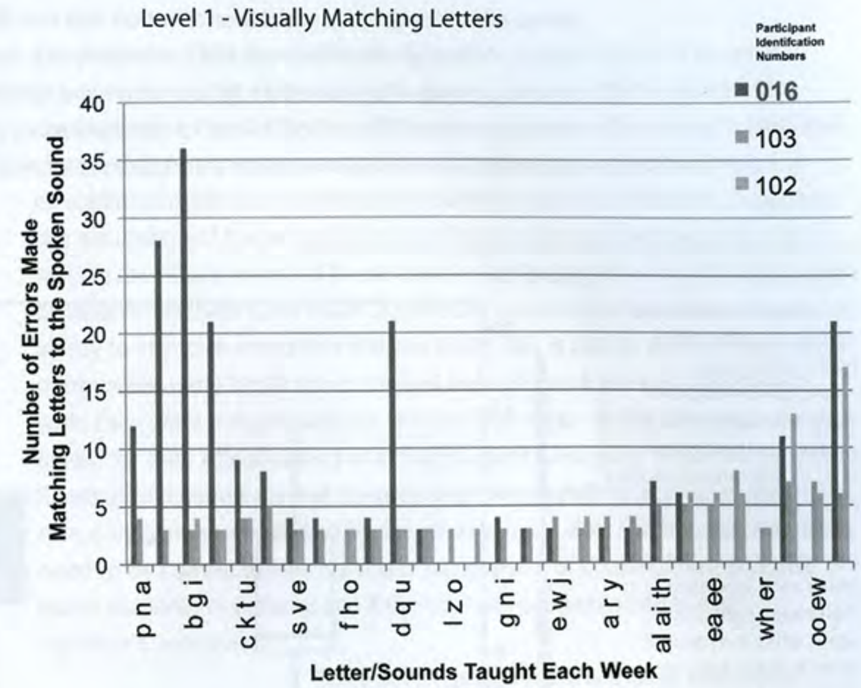
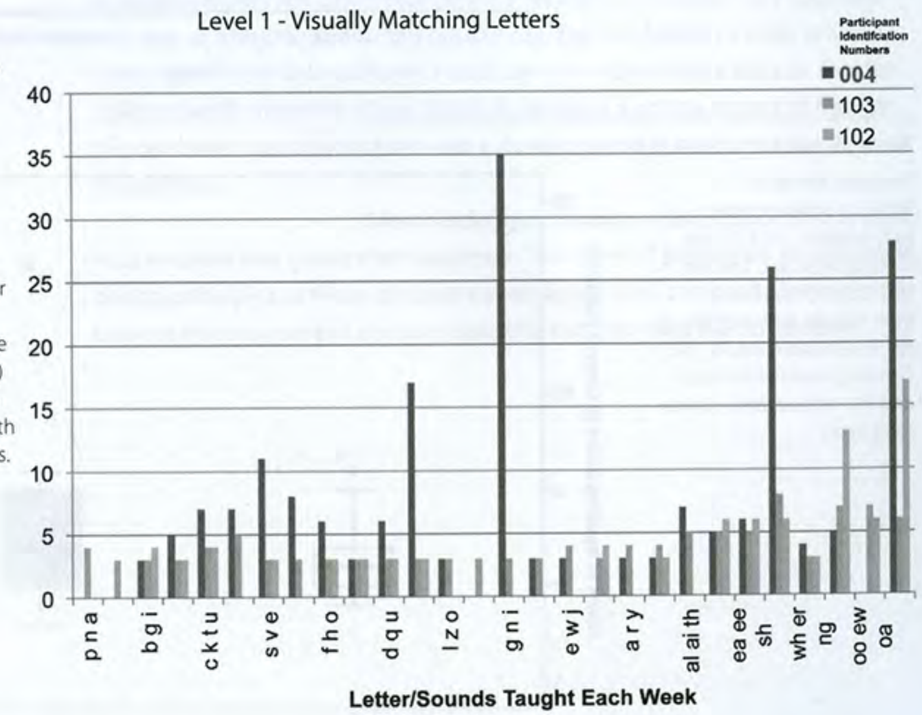


TABLE 2

Table 2 shows the same individual data on Level 1 visual letter matching as Table 1, except the comparison looks at the same two stronger students (103 and 102) compared to another weaker student (004). In this case, the weaker student (004) showed difficulty on particular lessons with specific letter-sounds.



in the number of correctly spelled word features (Msw=4.24, Mc=1.95). The group effect for gains in word identification was not significant, F(1, 21) = 0.56. Although the effect was not statistically significant, the See Word Reading group also showed a higher mean word identification gain across the intervention (Msw=5.50, Mc=3.71 standard score units). Given the small sample size and low power, such trends are still promising.

TABLE 3

The boxplots shown here represent performance by the two groups, control (white box) and experimental (grey box), on a word identification task. Performance is plotted as the gain in standard score units (change from pre- to post-test). The line inside each box represents the group's median gain score, while the top and bottom of the box represent the 3rd and 1st quartile scores, respectively, for the group. Whiskers show the minimum and maximum gain scores in each group.

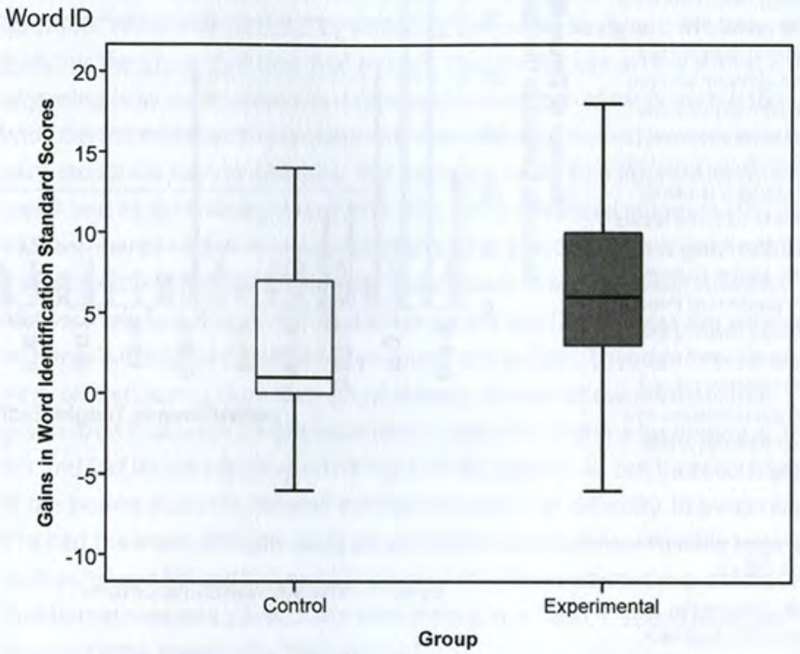
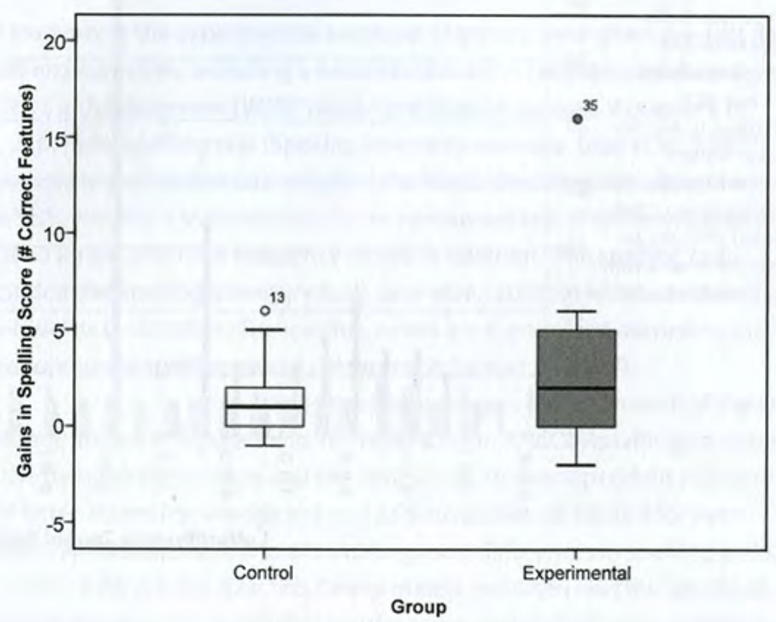


TABLE 4

Boxplots, similar to Table 3, represent group performance, here on the spelling measure. Median gain scores from pre- to post-test are indicated by the line in each box, for the control group (white box) and the experimental group (grey box).



CONCLUSION

The purpose of the development of See Word Reading tool is to serve as a case study that shows the evolution of a design that is grounded in educational research theories. While the landscape of learning to read has changed due to the influence of new digital technologies, the design of educational tools has to address the current needs of education, including the grounding of these tools in educational and cognitive theories and the testing the effectiveness of these tools in facilitating learning. To date many classroom teachers have much skepticism toward new educational tools' ability to improve education. It is our belief this is due to the fact that, while many of the early applications looked beautiful and were fun to interact with, they were not grounded in educational research theories and were not tested for their effectiveness in aiding student's learning. While the See Word Reading tool shows a trend towards improving spelling and word identification, conclusions are limited by the small sample size. Further investigations need to be conducted with a larger sample size of kindergarten and first grade students in order to see if the tool will produce statistically significant outcomes.

Currently in design there is a lot of discussion about the importance of user-centered design and how engaging in this process will result in stronger outcomes. Often this user-centered approach focuses solely on understanding the behaviors, motivation, and frustrations of a defined user set. Understanding the usability of a design is important and was an integral part of this pilot study, but also having a clear understanding on how to implement visual communication principles to the discipline specific theories of any given discipline is a critical aspect of design. It is our belief that this tool showed a positive trend in outcomes because of this pairing.

Most disciplines stand on a foundation that is built with theories that guide their existence. The value of pairing communication design principles to those discipline specific theories can produce outcomes that are not only easy to use and beautiful but also effective to educate.

REFERENCES

Bear, D.R., Invernizzi, M., Templeton, S. & Johnston,F. (2007). "Words their way: Word study for phonics, vocabulary, and spelling instruction (4th Ed.)." Upper Saddle River, NJ: Pearson Education.

Bennett, Audrey and Bridget Rice. (December 2005). "Bradbury Thompson's Alphabet 26: A Font System for Early Readers?" AIGA Design forum. Retrieved from http://designforum.aiga.org/content.cfm?ContentAlias=%5Fgetfullarticle&aid=1387503.

Birsh, Judith. (1999). *Multisensory Teaching of Basic Language Skills.* Baltimore: Paul H. Brookes Publishing Co.

Birsh, Judith and Suzanne Carreker. (1999) *Multisensory Teaching of Basic Language Skills.* Baltimore: Paul H. Brookes Publishing Co.

Boyer, N., & Ehri, L. C. (2011). "Contribution of phonemic segmentation instruction with letters and articulation pictures to word reading and spelling in beginners." *Scientific Studies of Reading*, 15, 440-470.

Campbell, M. L., Helf, S., & Cooke, N. L. (2008). "Effects of adding multisensory components to a supplemental reading program on the decoding skills of treatment resisters." *Education and Treatment of Children*, 31, 267-295.

Carson, K. L., Gillon, G. T., & Boustead, T. M. (2013). "Classroom phonological awareness instruction and literacy outcomes in the first year of school." *Language, Speech, and Hearing Services in Schools*, 44, 147.

Chiong, Cynthia & Shuler, Carly. (2010). "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*. 3-15

Clark, R. E. & Sugrue, B. M. (1988). "Research on instructional media, 1978-1988." In D. Ely (Ed.), *Educational Media Yearbook 1987-88*. Littletown, CO: Libraries Unlimited.

Clay, M.M. (2002). *An Observation Survey of Early Literacy Achievement, Second Edition.* Portsmouth, NH: Heinemann.

Colberg, Susan and Fern Snart. (1992) "Facilitation Instruction Through Interdisciplinary Efforts: The Role of Visual-Communication Design in Developing Instructional Materials for Reading." *B.C. Journal of Special Education*, Vol. 16, No. 2, 120-130.

De Graaff, S., Verhoeven, L., Bosman, A.M.T. & Hasselman, F. (2007). "Integrated pictorial mnemonics and stimulus fading: Teaching kindergartners letter sounds." *British Journal of Educational Psychology*, 77, 519–539.

Ehri, L. C. (1987). "Learning to read and spell words." *Journal of Literacy Research*, 19, 5-31.

Ehri, L. C. (2005). Learning to read words: Theory, findings, and issues. *Scientific Studies of Reading*, 9, 167-188.

Ehri, L. C. (2014). "Orthographic mapping in the acquisition of sight word reading, spelling memory, and vocabulary learning." *Scientific Studies of Reading*, 18(1), 5-21.

Fiset, D., Blais, C., Ethier-Majcher, C., Arguin, M., Bub, D. & Gosselin, F. (2008). "Features for identification of uppercase and lowercase letters." *Psychological Science*, 19(11), 1161-1168.

Fluckiger, Michael. (2009). Laika [website]. Retrieved from: http://laikafont.ch/About_eng.html.

Gardner, Howard. (2006) *Multiple Intelligences*. New York: Basic Book.

Gernsheimer, J. (2008). *Designing logos: The process of creating symbols that endure.* New York: Allworth Press.

Gough, P. B., & Tunmer, W. E. (1986). "Decoding, reading, and reading disability." *Remedial and Special Education*, 7, 6-10.

Hammill, D. D. (2004). "What we know about correlates of reading." *Exceptional Children*, 70, 453-469.

Holum, Ann, Gahala Jan. (2001). "Critical Issue: Using Technology to Enhance Literacy Instruction." The American Institutes for Research and Learning Point Associates, [Website]. http://www.ncrel.org/sdrs/areas/issues/content/cntareas/reading/li300.htm

Hulme, C., Snowling, M., Caravolas, M., & Carroll, J. (2005). "Phonological skills are (probably) one cause of success in learning to read: A comment on Castles and Coltheart." *Scientific Studies of Reading*, 9, 351-365.

Li, S. C., Pow, J. W. C., Wong, E. M. L., & Fung, A. C. W. (2010). "Empowering student learning through Tablet PCs: A case study." *Education and Information Technologies*, 15, 171-180.

Lonigan, C. J., Anthony, J. L., Phillips, B. M., Purpura, D. J., Wilson, S. B., & McQueen, J. D. (2009). "The nature of preschool phonological processing abilities and their relations to vocabulary, general cognitive abilities, and print knowledge." *Journal of Educational Psychology*, 101, 345.

Means, B., & Olson, K. (1995). Technology's role in education reform: Findings from a national study of education reform. Washington, DC:

Office of Educational Research and Improvement, U.S. Department of Education. Available online (requires Adobe Acrobat software): http://www.ed.gov/PDFDocs/techrole.pdf

(AM) Montessori, M. (1964) *The Montessori method*. New York, NY: Schocken Books, Inc. , 27

Morris, R. D., Stuebing, K. K., Fletcher, J. M., Shaywitz, S. E., Lyon, G. R., Shankweiler, D. P., Katz, L., Francis, D., & Shaywitz, B. A. (1998). "Subtypes of reading disability: Variability around a phonological core." *Journal of Educational Psychology*, 90, 347.

National Assessment of Educational Progress (2007). (NCES 2007-496). National Center for Education Statistics, Institute of Education Sciences, U.S. Department of Education. Washington, DC.

Noe, S., Spencer, T. D., Kruse, L., & Goldstein, H. (2013). "Effects of a Tier 3 phonological awareness intervention on preschoolers' emergent literacy." *Topics in Early Childhood Special Education*.

Piasta, S. B., & Wagner, R. K. (2010). "Learning letter names and sounds: Effects of instruction, letter type, and phonological processing skill." *Journal of experimental child psychology*, 105, 324-344.

Prensky, M. (2001). "Digital natives, digital immigrants." *On the Horizon*, 9(5), 1-2.

Available: www.marcprensky.com/writing/Prensky%20-%20Digital%20Natives,%20Digital%20Immigrants%20-%20Part1.pdf

Rand, Paul. (1994). "Logos, Flags and Escutcheons." In Michael Bierut, William Drenttel, Steven Heller and D.K. Holland (Eds.). *Looking Closer: Critical Writings on Graphic Design*. New York: Allworth Press. 88-90.

Ritchey, K.D. & Goeke, J.L. (2006). "Orton-Gillingham and Orton-Gillingham—Based Reading Instruction: A Review of the Literature." *Journal of Special Education*. 40(3), 171-183.

Sanocki, T. & Dyson, M.C. (2011). "Letter processing and font information during reading: Beyond distinctiveness, where vision meets design." *Attention, Perception & Psychophysics*, in press.

Sawyer, R. Keith. (2006). *The Cambridge Handbook of the Learning Sciences*. New York: Cambridge University Press.

Scarborough, H. (2009). "Connecting early language and literacy to later reading (dis)abilities: Evidence, theory, and practice (pp. 23-38)." In Felicity Fletcher-Campbell, Janey Soler, and Gavin Reid. *Approaching Difficulties in Literacy Development: Assessments, Pedagogy, and Programmes*. Sage Publications: Thousand Oaks, CA.

Snowling, M. J. (2001). "From language to reading and dyslexia1." *Dyslexia*, 7, 37-46.

Standing, L., Conezio, J., & Haber, R. N. (1970). "Perception and memory for pictures: Single-trial learning of 2500 visual stimuli." *Psychonomic Science*, 19(2), 73-74.

Stanovich, K. E. (1986). "Matthew effects in reading: Some consequences of individual differences in the acquisition of literacy." *Reading research quarterly*,21(4), 360-407.

Storch, S. A., & Whitehurst, G., J. (2002). "Oral language and code –related precursors to reading: Evidence from a longitudinal structural model." *Developmental Psychology*, 38, 934-947.

Swanson, H. L., Trainin, G., Necoechea, D. M., & Hammill, D. D. (2003). "Rapid naming, phonological awareness, and reading: A meta-analysis of the correlation evidence." *Review of Educational Research*, 73, 407-440.

Thompson, G.B. (2009). "The long learning route to abstract letter units." *Cognitive Neuropsychology*, 26(1), 50-69.

Vellutino, F. R., Tunmer, W. E., Jaccard, J. J., & Chen, R. (2007). "Components of reading ability: Multivariate evidence for a convergent skills model of reading development." *Scientific Studies of Reading*, 11(1), 3-32.

Walker, S., & Reynolds, L. (2003). "Serifs, sans serifs and infant characters in children's reading books." *Information Design Journal*, 11(3), 106-122.

Wagner, R. K., Torgesen, J. K., & Rashotte, C. A. (1994). "Development of reading-related phonological processing abilities: New evidence of bidirectional causality from a latent variable longitudinal study." *Developmental psychology*, 30, 73.

West, Thomas G. (1997). *In The Mind's Eye: Visual Thinkers, Gifted People With Dyslexia And Other Learning Difficulties, Computer Images, and the Ironies of Creativity*. Amherst: Prometheus Books.

Woodcock, R.W., McGrew, K.S. & Mather, N. (2007). *Woodcock-Johnson III Tests of Achievement with Normative Update*. Rolling Meadows, IL: Riverside Publishing.