Increasing Vocabulary and Comprehension with the use of a Reading Pen

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Abstract

Six reading disabled students were given an assistive technology to see the impact it would have on their reading comprehension. The Reading Pen, a small hand held device, scans and reads words students have difficulty with. Students were given two reading passages to read. The first was read without the apparatus and the second passage was read with assistance of the Reading Pen. Miscues, reading rate, comprehension and word recall were measured. Students' time and comprehension of stories decreased with the use of the pen. However, students were able to recall and pronounce many of the words they had scanned with the Reading Pen, words which they previously could not pronounce. Students showed great enthusiasm for the tool and the Pen holds promise for schools wanting to integrate technology and comprehension instruction.

1.0 Introduction

The correlation between vocabulary skills and students' comprehension skills is well established (RAND 2002). However, students with reading difficulties often have lower vocabulary knowledge than their peer groups which makes comprehension of text difficult and reading more of a chore rather than pleasurable. Indeed, many disabled readers become frustrated and avoid reading altogether. Assistive technologies have been used in the past to help students with reading difficulties overcome some of these hurdles and they have been particularly effective with children with phonological deficits in early grades (McCullough 1995). What has been more elusive, however, is getting successful decoders to become effective comprehenders of text. To date, few studies have focused on using technology to improve students' reading comprehension.

The present study looks at how students with reading disabilities use a reading pen (will be called the Reading Pen or "Pen" throughout text) to assist them comprehending text they have difficulty with. Computer miniaturization has been one of the more exciting

advances in recent years. What previously took a lot of desktop space, computer memory and scanning technology, now fits neatly into the size of a highlighter pen. This report will first summarize the background literature as it applies to technology and literacy. The report will then present a ministudy experiment with the Reading Pen with six, upper elementary school children. Finally, results will be reported about the effect of Reading Pen on subjects' reading accuracy, reading rate and comprehension skills. A discussion will follow.

2.0 **Literature Review**

2.1 *Historical context for technology and education*

In 1995 a Panel on Educational Technology was organized to provide independent advice to the President on matters of science and technology. The Panel, the President's Committee of Advisors on Science and Technology (PCAST), made a number of recommendations that accelerated the rate of computers being put into classrooms and increased the amount of training for teachers to take advantage of the technology in their classroom. As a result of the PCAST report, large numbers of teachers have had computers at their disposal and many have participated in some kind of professional development to learn ways to integrate these tools into classrooms.

The technological revolution that took place in schools seems to have stalled in recent years. Policymakers, determined to justify the expense of technology, questioned whether these large investments were worthwhile and looked toward student achievement for evidence. Some schools and districts have shown some academic progress, increased student motivation and increased engagement, but generally speaking policymakers were not convinced that computer technology was closing the achievement gap. [1]What's more, the pressure of the No Child Left Behind Act has made teachers and administrators focus their attention on student achievement with a particular focus on reading instruction. It is within this context that schools are now looking toward technology solutions that are more affordable and that will help students become more proficient readers. Until recently there has been limited research on reading instruction and computer technology, however, our

[1] See PCAST March 1997, includes a list of successful schools and districts that have solid increase of student achievement due to the appropriate integrations of the technology. Some of the districts include: Union City, New Jersey, and the Carrolton, GA. school districts.

nation's new interest in literacy and instruction has spurred a number of policy shifts and large-scale research reviews.

In a recent review of computer technology and reading instruction, the National Reading Panel determined that there has been little research on reading and technology because: a) many reading researchers do not consider technology to be a mainstream topic; b) computers did not have all of the capabilities that were needed to implement a complete program of reading instruction and many computers do not have the capability to judge oral reading accurately. This lack of capability meant that the technology was used to supplement typical instruction; c) the cost of computers were prohibitive, but now many of the computers cost a few hundred dollars and have more capabilities than the older models. Newer models are making it more cost effective to have computers in the classrooms and this will make it more possible to do research; d) there has been resistance in the field as to whether computers could deliver appropriate reading instruction (National Reading Panel report, 2002).

The literature on technology and reading is sparse, but there have been a number of studies that show that integrating technology into reading has some benefits for students with learning difficulties (Baker & Torgesen, 1995; Meyers and Rose, 1998). Much of the work in reading and technology focus on students in earlier grades where decoding has been problematic (Bruce 2002, Olson et al., 1986, Olson et al.1997, Reinking & Labbo 1998). Integrated learning systems (computer-based systems that deliver curriculum material) such as the Waterford Early Reading Program have been popular in recent years. Such programs are expensive and lack the flexibility needed to accommodate styles and individual learner needs (Meyers and Rose). While technical reports of the Waterford system discuss its benefits (http://www.waterford.org/corporate_pages/Research_Background.jsp) other researchers found that the program does not encourage teachers to interact with student which is necessary for growth in early emergent reading (Paterson et al. 2003).

2.2 *Studies with comprehension and speech recognition*

There are two studies that most resemble the current study. Freese (1997) presents findings from recent research on reading rate, comprehension and subvocal speech. Freese worked with 25 children between the ages of eight and fifteen years of age. All of the participants in the study read at the fourth grade level. Two passages were used for the study-

-a regular passage and an experimental homophone. Passages were on average 240 words in length and a readability of 4.0 to 4.3 (Dale Chall Readability Scale). Each participant was asked to read either the standard passage or the experimental passage. Students were to answer a series of comprehension questions after they read their passage silently. It was hypothesized that the participants would increase their level of subvocal speech when reading the homophone passage, thus decreasing their reading rate (homophone passage was considered to be more difficult). The goal of the study was to have students read the passages with understanding. The homophone passages were an indicator as to whether the participants integrate the individual units (homophones) to gain meaning from text. Results indicated that students adjusted their reading rate with more difficult text reading fewer words per minute. Low comprehenders did not adjust their reading rate while high comprehenders did adjust their reading rate.

Olson (1986) and his colleagues used speech synthesizing systems to read aloud text which was displayed on computer screens. For example, a student would see an unrecognizable word on the screen and using a pointing device, highlight the word which would then be pronounced by the computer. Text could be read by word, by line, or by paragraph. This was one of the earlier studies done with speech recognition software, DECtalk, which was rated as having the highest "intelligibility" when compared to digitized human speech (Mineo & Cavalier, 1990 from McCullough, 1995). Olson and his colleagues gave fifteen subjects a word recognition test at the beginning of each session to select appropriate reading level material. Students sat in front of a computer and listened to DECtalk give instructions. Subjects were then told to read the stories for meaning and to target each word that they did not recognize. They were told that they would later be tested on the words they targeted, along with other difficult words in the text, and they would be asked some comprehension questions after each of the stories. The instructions emphasized that the subjects should attempt to decode difficult words before targeting them for feedback. After students read stories they were asked four comprehension questions. Then the computer presented a word recognition test that included a randomized list of all the words that were targeted, plus six of the most difficult words in the text. Students were either assigned a mouse or a light pen that they used to highlight for speech feedback (after they tried to

decode the word). A control group had no assistance to from the speech synthesizer. Olson and his colleagues found that disabled readers preferred to use this speech system and it aided subjects' comprehension and their word recognition level also increased. For example, Olson's subjects correctly repeated 95% of 120 unrelated words presented by synthesized speech and 98% for digitized recorded human speech.

Disabled Readers use of the Reading Pen to assist in their reading comprehension

The present study focused on students with reading difficulties using an innovative assistive technology called the Reading Pen. The Reading Pen was designed so that when scanned over a word the pen "reads" the word and pronounces it through its small speaker. The Pen can also give the word's definition and syllabicate the word sounds. The hypothesis: students who use the Reading Pen on difficult passages will perform better on a comprehension assessment than reading a difficult passage without the Reading Pen. Other questions that were addressed: a) at what point do students use the Reading Pen and on what kinds of words? b) Do students try to decode words or just use the pen? c) Can subjects recognize and recall how to pronounce words that hey previously scanned? d) How do students feel about the pen? Did they think it was useful?

3.0 Methods

3.1 Subjects

Six children who attend a school that focuses on reading disability were used for the study. Children were ten and eleven years of age and there were three were boys and three girls. Five of the students have been going to the school for two years. One of the students is new to the school as of last September. Given the students were in this particular school, the investigator inferred that students were reading below grade level, but the severity of their reading disability was unknown (the teacher was not interviewed for this study, but she could have provided some data on students' reading level). Besides varying reading levels, there were a number of other factors that could have differentiated students: for example, children's verbal and language ability, lack of strong memory, hearing and neurological disorders.

It is important to note that children who attend this school spend at least an hour and half a day on explicit instruction using either the Orton-Gillingham or Wilson reading methods. Many of the students were strategic decoders. That is, they had become proficient at phonemic segmentation and applying those skills when they worked with vocabulary words. In addition, a number of children have received occupational therapy to help with graphomotor skills (how to hold a pen or pencil properly) and how best to organize their notes and assignments. Throughout the experiment students were asked to hold a new apparatus in a completely different way than they were taught to hold their pens (some students who had graphomotor problems had particularly difficult time holding the Reading Pen). All students were average IQ because the school only accepts students with average to above average IQ into the school. According to the schools' website "Selection of Stephen Gaynor students is limited to children of average or above average intellectual functioning who have difficulties with reading, writing, language, or math skills." (http://www.sgaynor.com/).

3.2 *Apparatus*

The Reading Pen has been described as a tool for dyslexic students to support their learning. The Reading Pen displays scanned text and can also display syllable breaks. The Pen is 6.5 inches long and at its thickest point is 4 inches in diameter. The Pen has an internal speaker and a 1 inch by 3 inch screen that displays words when scanned. An "enter" button allows the user to repeat the scanned words and arrow keys allow the user to look up and read definitions of words. The Pen reads a wide variety of text, but it is important for the novice user to have plenty of white space in between words so they can scan words easily.

3.3 *Text and Materials*

Boder Test of Reading- Spelling Patterns: All children were given the Boder Test of Reading - Spelling to determine appropriate/challenging reading level. Boder developed a diagnostic screening tool for developmental dyslexia from which she divided into three subtypes: dysphonetic, disability in associating symbols with sounds; dyseidetic, deficits in vision and memory of letters and word shapes; alexic or mixed dyseidetic and dysphonetic, this subtype combines the deficit of the first two groups. (http://www.macalester.edu/~psych/whathap/UBNRP/Dyslexia/types.html)

Qualitative Reading Inventory-III (QRI-III): The passages and comprehension measures were used from this informal reading text. In addition, the oral miscue analysis was also used (the "oral reading rates of students reading at instructional level formula" as measured in oral words per minute). This was useful to understand whether students were reading at an independent level, instructional level or at the frustration level. Passages have five, six, eight or ten comprehension questions depending on their level of difficulty.

Reading pen training manual: This was a reference guide to the Reading Pen book and was used for students to practice exercises with the reading pen. Students spent between 5-10 minutes scanning a number of words to make them proficient at scanning.

4.0 **Design and Procedures**

Each of the students was told they were going to be reading two stories and they were going to be asked comprehension questions afterward. They were also told that in between stories a tool would be demonstrated that they would be able to use on the second story. In order to find the appropriate level story for the students they were first asked to read a word list.

Each of the subjects was first given the Boder Test of Reading-Spelling. Students began with the 2nd grade level and worked their way up grade levels. In consultation with Professor Linnea Ehri, appropriate leveled story was chosen when students were struggling with at least 40%-50% of the words on the list. When the appropriate reading level was determined, students were asked to read a story out loud from the QRI-III (Leslie and Caldwell 2001). The investigator also made an explicit choice to give students narrative stories as opposed to expository stories from the QRI-III.

In addition, the investigator recorded miscues for each of the reading sessions. The following were recorded as miscues: omission, misread words, sounding out words, insertions and repetitions. Misread pronouns were counted as one miscue in a story. If entire sentences were skipped each of the words were counted. In addition, words that were "scanned" with the Reading Pen were counted as a miscue. As children read stories the investigator recorded the time it took to read each of the stories

After reading their first story and completing their comprehension questions, students were introduced to the Reading Pen. Students were first asked if they had ever seen the Reading Pen before (only one child reported they had seen something like it in the past). Children were then given instructions as to how to hold the pen and they were given instructions on how to scan the Pen over words. The investigator used the *Reading Pen Training Manual* to practice over a number of words. Children first practiced on a bold lettered "College" that was boxed and had plenty of white space around it. After several trials with this word and practice on how to hold the Pen, children practiced on a number of words from the Reading Pen practice guide. Students recognized some of the words and others they found difficult. For example: *complete; interest; magazine; replace; character; critical; redundant; ingratiate; circumspect; soporific; enhance; aberration; susceptible; expedite; litigate; prodigious; incisive; meandering; attraction; pragmatic* and *voracious*.

Subjects were asked to repeat each of the words after the word was scanned successfully and announced by the Pen. If they mispronounced the word they were asked to hit the "enter" key to listen to the word again. Some of the subjects were interested in seeing the definitions of the words and were allowed to hit the "down arrow" to see the definition of the word. When students appeared to be having minimal errors with the Pen and appeared to be using it with some proficiency, students were given a second story at the same reading level as the first. Subjects were told to use the Pen on words they were not familiar with or had problem pronouncing.

Like the first story, students were also asked to read the second story aloud. Subjects were also timed for story 2 and miscues were also recorded. Words that were scanned were counted as miscues, but were also noted on by the investigator to see if students could recall the words later. After the second reading, students were asked to answer QRI-III comprehension questions. Subjects were allowed to hold onto the pen while answering comprehension questions in case they didn't understand some of the words on the comprehension assessment. After the second comprehension assessment students were asked how they felt about the Reading Pen in general. All sessions were audio recorded and each session took approximately 45 minutes to complete.

Adjustment to text: Because students were novice users of this technology, it was

easier for students to scan the information with more white space around the words. For this reason, the investigator made copies of each of the stories and increased its size by 15% so that more white space could be accommodated between words. Hypothetically, this should have allowed for easier scanning of words from the text.

4.0 **Results**

Dependent variables included: the total number of miscues in each of the passages (miscue 1 pre-test and miscue 2 in the post test), percentage correct on the pre and post test comprehension; total time, as reported in seconds, in the first versus second story; as well as words per minute. The means in Table 1 are based on the 6 subjects as results for pre and post test, time on task with and without the pen, words read per minute.

A matched pair t-test was done to compare the means of several variables (example, comprehension with the Pen and without the Pen). This was done for four dependent measures (miscue, time, words per minute and comprehension). Significance was found for pair 2 (Time 1 and Time 2) as well as Comprehension 1(without the Pen) and Comprehension 2 (with the Pen). There was significance beyond the $p < .05$. That is, students took a longer time reading the story with the Pen and comprehended less of the story when using the Pen than they did without the Pen.

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Table 1 Match pair t-test for dependent variable

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper			
Pair 1	MISCUE1 - MISCUE2	.8333	5.56477	2.27181	-5.0065	6.6732	.367	5	.729
Pair 2	TIME1 - TIME2	-122.1667	51.59619	21.06406	-176.3135	-68.0198	-5.800	5	**.002**
Pair 3	WPM1 - WPM2	17.8333	19.05168	7.77782	-2.1602	37.8268	2.293	5	.070
Pair 4	COMP1 - COMP2	.1217	.09806	.04003	.0188	.2246	3.039	5	**.029**

Miscue: total miscues without Pen (Miscue 1) and with Pen (Miscue 2) for each story; Time: time it took to complete stories converted into seconds(time 1 = w/Pen; time 2 = w/o Pen); Comprehension: percentage of comprehension questions correct (Comp 1 = w/Pen; Comp 2 = w/o Pen; WPM: words per minute to read each of the stories (WPM 1 = w/Pen; WPM2 = w/o Pen

Table 2 outlines how students were rated on the Boder Test of Reading and Spelling to see how children within this reading level faired vis-à-vis the dependent variables. This table confirms that students who were diagnosed as needing more challenging text by the Boder (7 was considered an upper middle level) and had slightly more miscues with the Pen than without the Pen. In addition, students reading the 7th grade text had the lowest comprehension averages with and without the (36% without the pen and 23% with the Pen). Students were able to decode more than 50% of the words in the Boder Reading and Spelling test, but their comprehension and understanding of the text (as demonstrated by their comprehensions score) suggests that students were frustrated by the text. Also, student reading rate slowed as text increased in difficulty. On average, students' word reading accuracy also decreased.

Table 2 Comparison of means of dependent variables by Boder Reading Level

BODER		MISCUE1	MISCUE2	TIME1	TIME2	COMP1	COMP2	WPM1	WPM2
4.00	Mean	27.0000	16.0000	233.0000	274.0000	.6300	.5000	68.0000	57.0000
	N	1	1	1	1	1	1	1	1
	Std. Deviation	.	.	.	.	.	.	.	.
5.00	Mean	14.5000	14.0000	184.0000	339.5000	.8000	.7000	97.5000	60.0000
	N	2	2	2	2	2	2	2	2
	Std. Deviation	2.12132	.00000	25.45584	71.41778	.00000	.00000	13.43503	7.07107
7.00	Mean	24.0000	26.3333	293.3333	420.3333	.3667	.2333	73.6667	66.6667
	N	3	3	3	3	3	3	3	3
	Std. Deviation	5.56776	8.32666	25.65801	23.71357	.15275	.05774	8.14453	11.59023
Total	Mean	21.3333	20.5000	246.8333	369.0000	.5550	.4333	80.6667	62.8333
	N	6	6	6	6	6	6	6	6
	Std. Deviation	6.53197	8.31264	57.51319	70.56345	.23611	.23381	15.40995	9.08662

Table 2a confirms what was reported in the QRI-III categorization of Oral Reading Levels that are based on the numbers of words per minute. For example, student reading in a Boder 4th grade reading level read 68 words per minute in the first story and 57 words per minute in the second story using the Pen. This was converted to Oral Words Per Minute (Leslie & Caldwell Pg. 68) to get the grade level range (ranges are based on normal readers). For example, the student reading at the Boder 4th grade level read out loud at the second grade level. In addition, the instructional level was determined based on the number of correct responses in their comprehension score. As you can see from Table 3a many of the students were at the “frustration level” and were at least two grades or more below their

Boder diagnosed reading level. The data suggest that many of these students (except for those students reading at the 5th grade level who were at the instructional level) were frustrated reading the text whether they used the Reading Pen or not. According Oral Reading Level, all children reading level declined somewhat when they used the Reading Pen (ORL 2). This was due to extra time students took to scan the words and the milliseconds the Reading Pen took to convert the scanned words in sound and text.

Table 2a Case Summaries for students' Oral Reading Level and Informal Reading Level[a]

				ORL1	ORL2	IRL1	IRL2
BODER	4.00	1		2.00	2.00	frust	frust
		Total	N	1	1	1	1
	5.00	1		4.00	2.00	instruc.	instruc.
		2		4.00	2.00	instuc.	instruc.
		Total	N	2	2	2	2
	7.00	1		2.00	2.00	frust.	frust.
		2		2.00	2.00	frust	frust
		3		2.00	1.00	frust	frust
		Total	N	3	3	3	3
	Total	N		6	6	6	6

a. Limited to first 100 cases

The most interesting and promising feature of the assistive technology was students' ability to recall the words they scanned. Students scanned the words and the investigator jotted each of the words down. After the subject completed the second comprehension test, the investigator pointed to each of the words the student scanned and was asked to repeat the word. All of the students were able to recall many of the words they weren't able to pronounce before the experiment (words like *anthropologist*, *mutiny*, *straits*, *skirmish*, *circumnavigated*). Students' retention of how to pronounce words was impressive particularly given those students who were reading at upper grade levels who were “frustrated” with the text. The recall of the words pronounced for many of the students was instantaneous. Table 3 reports the percentages of words that were recalled by each student.

Table 3 Number of words scanned by students with Reading Pen and Percentages of words recalled (i.e. pronounced correctly) after trial

Students	Number of Words Scanned	% of words recalled/re-pronounced
A	4	75%
B	6	100%
C	10	80%
D	3	100%
E*	1	100%
F	3	66%

*Student E only scanned one word during the reading. However, when prompted student was also able to recall several difficult words on the Reading Pen Practice manual.

It should be noted that students used a number of methods for scanning, but there was no one systematic approach. Some students first tried to decode words, had difficulty decoding, then scanned the words. Other students immediately scanned words they did not recognize, and yet other students pronounced the words, but they weren't certain of the pronunciation, and scanned the word for good measure. Some students, particularly students with graphomotor problems, had difficulty scanning altogether (the investigator assisted this student scan a number of words).

After each session students were asked how they felt about using the Reading Pen (did they like it and did they think it was useful?). Students were very excited about the pen. All of the children said it was "cool," one student thought it was "awesome." In fact, one student called the investigator at home to ask more questions about the device, how it worked, how much it cost etc. This student said it built his "confidence" in reading and was glad to have been made aware of the Pen.

5.0 Discussion

5.1 *Summary of findings*

The study was conducted to see whether children could increase their comprehension skills text better using a Reading Pen. My hypothesis was that by having students use a Reading Pen students' would make fewer vocabulary errors and students' comprehension

skills would increase as demonstrated on an informal reading assessment. When students used the Reading Pen they took more time reading passages and they did not perform as well on comprehension measures (compared to when they did not use the Pen). One very encouraging result from this study was the fact that subjects were able to recall many of the words they could not previously pronounce without the help for the Reading Pen. Students could recall the pronunciation of almost all of the words they scanned. Answer to questions posed in the introduction:

- Does this assistive technology help students increase their comprehension and fluency? No, in fact students take more time with the technology; it slows down their reading and comprehension decreases. This may be caused by the fact that students were excited/distracted by the act of scanning and perhaps not concentrating on the task at hand. Or it could be that students, particularly students with reading disability, are already working very hard to read the passage. Additionally, the novelty of the Reading Pen could have distracted the students. It is possible that with practice the time it took to read passages would shorten
- At what point do students use the Reading Pen and on what kinds of words? Students use the Reading Pen at different times: after they tried to decode a word unsuccessfully; immediately upon not recognizing a word; reading a word, but not being certain of its pronunciation, and scanning it to make certain of the word's pronunciation.
- Can subjects recognized and recall how to pronounce words that hey previously scanned? This was most impressive finding of the study. Students were able to recall a high percentage of words they previously scanned.

5.2 *Alternative explanations*

With the exception of two subjects most of the students found the text "frustrating" as measured by the QRI-III. Because many of the students had been well trained in decoding complex text many of the students were able to attack the words in the Boder Test of Reading - Spelling Patterns. Several students (3) were able to read words up to the 7th grade level and hence were given passages that were not too hard but not too easy. When students struggled

(or miscued) on 40-50% of the words it was determined that this was the appropriate text. (The justification for picking 40%-50% was so that the texts read would include unfamiliar words needing decoding assistance for application of the Pen). This suggests that many of the students have internalized many of the reading strategies taught to them at their school (chunking text, blends, using multi-sensory strategies) and have figured out how to read the multisyllabic words even though they may not know the meaning of the words by themselves.

5.3 *How findings bear on issues identified in the introduction*

As noted in the introduction, technology infrastructure is in place in the majority of schools but schools still struggle to identify low cost, more ubiquitous technology to improve reading achievement. The Reading Pen could be an interesting solution for schools. It is apparent, however, that the Reading Pen is best suited for students in older grades from fifth grade and above. Students also need good manual dexterity when using the Pen. The Pen could be frustrating for those students have difficulty with hand and eye coordination. One of the subjects was severely disabled and had problems gripping the Pen and finding the right target to begin scanning the words.

The policies that have been established for reading in our country are for Kindergarten through third grades. Few policies exist for students beyond the third grade. Given the need to "close achievement gaps" and to develop students' comprehension skills, assistive technology tools hold some promise, but more research is needed to investigate the potential impact of the Reading Pen on student learning. For example, if students used the Pen for a longer period of time (for example, over several months) some of the immediate mechanical difficulties students were having could easily be overcome with practice using the Pen.

5.4 *Results of compared to previous studies reviewed*

The present study is consistent with the 1986 Olson et al. study. Olson found that disabled readers word recognition level increased after using a speech recognition system to aid in subjects' comprehension. Similarly, the present study confirmed what Olson found: after hearing the text through the Reading Pen students were able to identify anywhere from 66% to 100% of the words they previously were not able to pronounce. The Freese study

found that students adjusted their reading rate with more difficult text, reading fewer words per minute (the participants in the Freese study read passages to themselves). The present study found that students generally read at a grade level or two below their assigned reading level. Having the students read out loud might have been much more difficult for some of the subjects. Students read slowly without the pen and even slower with the pen. Future studies may want to ensure that there is a group of subjects that read to themselves.

5.5 *Discuss implication of data for instruction and classroom practice, student learning*

Students enjoyed using the Pen immensely, however, this study clearly demonstrates that students may need more practice to use the Pen effectively. After reviewing the data, it might be useful to students to use the pen naturalistically in their classroom. Students may need to use the Reading Pen for several hours before becoming comfortable using with different texts. It may also be more useful for students if they used text that was not too cumbersome and the student was comfortable reading a leveled text and scanning the occasional unfamiliar word. Scanning every other word is frustrating for proficient as well as disabled readers. In addition, it may also be useful for teachers to use this as a resource in the classroom when reading grade level text, but may be slightly more challenging; like a science text book for example. Given that students were able to recall high percentage of their words, if used over a long period of time the Reading Pen could potentially have substantial increase in students' vocabulary and, hence, comprehension skills.

5.6 *Discuss strengths of study, design features which make the results especially convincing useful generalizble.*

There were a number strengths to the study: the students' ages were right for the study. Students were excited by the tool and were also a good group because of their foundational knowledge with words and the strategies they used to comprehend. This is the stage where students begin to get challenged by text. A tool like a Reading Pen could become another part of repertoire for understanding and comprehending text. The pre-post test was a good design feature, but students should have had more practice with the Pen.

5.7 *Discuss the limitations of the study, how far generalizations can be drawn (different age level, to group instruction, to different materials). Discuss weaknesses in design, how study might be redesigned to eliminate weakness.*

One of the limitations of the design was might have been the reliance on the Boder test. Even though the test was developed as a diagnostic and screening tool for developmental dyslexia, the investigator either implemented the diagnostic improperly or the cut-off used (40-50%)percentage of used was too high. Since students were able to decode many of the words it might have given a "false" impression of students' ability. Three students were given 7th grade reading materials which was frustrating to the students. Other measures could be used to prescreen disabled students. For example, teacher interviews to find out the level students are reading at (and asking at what level they may find students will struggle). Perhaps a combination of the Boder diagnostic with others would be more useful. For example, a Border combined with a read aloud. Another possibility, for a future study perhaps, is to have a control group with students who are "garden variety poor readers" who have not had as much explicit phonics instruction.

Another limitation of the study was the training. While the training was necessary, subjects could have had more exposure to the Reading Pen before using it in a test case. A more naturalistic setting (for example children using the Pen for several weeks) might have allowed students to use the Pen with more proficiency. It might also have been useful to control for the training through statistical measures for this particular study.

A greater range of students might have been interesting. There were 5 ten year olds and one 11 year old. A greater range might have yielded different results.

Lastly, it is not clear whether an informal assessment such as the QRI-III (which is not norm referenced) is a particularly good assessment to use with disabled readers. Questions of transfer of learning from one reading disabled population to the other may be possible, but it would be difficult to generalize to the general population of students.

5.9 *Identify directions for future research suggested by results, specific additional studies needed to answer unresolved questions, indicating how such studies might be designed.*

Given that many of the students had just learned how to use the technology this might have been a factor in effects. A future study could investigate using the Reading Pen in a natural environment that would give students longer exposure to the Pen—perhaps several

weeks or an entire semester. This would allow students to use the Pen at home and at school and get used to the way the Pen functions. Given how well students performed on their word recall, if students can use the Pen for a longer period, vocabulary could improve which should have direct impact on students' comprehension. A pre-post design separated by many months (as opposed to several minutes) may be more revealing. Unresolved questions remain: can the Reading Pen also improve student motivation to read more text if the Pen gives them the confidence they need? This is possible and it would be interesting to explore ways to gauge whether a tool like this can increase the range of material students read. Future research could reveal how these handheld ubiquitous technologies can help struggling readers overcome their fear of reading.

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