THE WRITE STUFF: ASSISTIVE TECHNOLOGY AND ITS IMPACT ON EARLY WRITERS

by

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Abstract

This mixed methods study examined assistive technology and its role in the world early writers. It investigated the function of word predictive and speech synthesis software in the early primary, mainstream classroom. A technology based writing intervention with 27 first grade students was carried out to assess how the use of Co:writer software affected the content of student writing. It looked at how the length of the writing sample, word use and sentence complexity was affected by this writing intervention. It also investigated how students interacted with the software and how they felt about its effect on their writing. The hypothesis was that the use of assistive technology while writing would aid students in creating more sophisticated, content rich writing samples and give students a positive feeling about their writing. Using a pre-post design, participant writing samples were analyzed for length, word use and sentence complexity. Targeted interviews and field notes revealed how students interacted with the software and how they felt about its effect on their writing. The data shows that within this study participants improved the length, and sentence complexity in their written samples. Qualitatively participants reported that the software helped to improve their vocabulary, length of writing sample, spelling, reading and editing. This study lays groundwork for more research into the use of assistive writing technology in early mainstream participants.
Acknowledgements

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(March, 2011)
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Chapter 1. Introduction

Early in the year, a grade one student in my classroom once said, “I guess in grade one you are allowed to sharpen your own pencils because you have to do SO MUCH writing.” Mastery of writing is critical to a child’s success at school. Writing can be used as a tool for communication, persuasion, self exploration and to express knowledge (Graham, Harris & MacArthur, 2004). Students in elementary school generally become used to writing with a pencil, but it can be difficult for them to put their various ideas onto paper. In an intensive study of students writing from kindergarten to grade five, Donovan (2001) found that there was a “very distinct change at second grade” (p. 21). Students in kindergarten and grade one focused on writing with labels and statements, yet in grade two they were writing with a great deal more complexity. In this study, many first grade students struggled with the physical and cognitive burden of writing, leaving little energy left for the content of their writing. Vanderberg and Swanson (2007) also agreed that “writing is a difficult skill to master because many cognitive abilities are utilized during the writing process” (p. 721). Research has shown that hand writing and spelling often predicted how well and how fluently students write (Graham, Harris & Fink, 2000; McCutchen, 2000). With the rapid development of digital technologies, writing in the home, school and work place has changed drastically (Juzwik, Curcic, Wolbers, Moxley, Dimling, & Shankland, 2006). Assistive digital technologies have been show to improve the quality and quantity of the writing of upper elementary and high school students (Russell & Cook, 2003).
John R. Hayes (2004) explained that, “writing depends on an appropriate combination of cognitive, affective, social and physical conditions if it is to happen at all” (p. 1402). Early writers have little experience with the various conditions needed to produce written text. These writers have many obstacles to overcome on their journey toward text creation. Word prediction and speech synthesis software could ease the burden of some cognitive, affective and physical conditions, making the process of writing more accessible to early writers. This software gives students an alternative way to create text and think about writing. There is little empirical research that focuses on early writers and the use of word predictive and speech synthesis software (MacArthur, 1999; Mirenda, Turoldo & McAvoy, 2006). I decided to examine if young writers can benefit from using assistive technology in a mainstream classroom setting. Studying its use with early writers adds much needed empirical evidence to the body of research surrounding assistive technology. Based on the theoretical foundations and previous empirical research, the purpose of this research was to compare and describe how assistive technology affects the writing of grade one students. The specific questions that informed my research were:

1) How was the quality (length, word use, sentence complexity) of students’ writing affected by the use of assistive technology?

2) How did students interact with the assistive technology, how did they feel about its effect on their writing?
The second chapter reviews the literature on the description of early writing, the research related to writing and cognition, the physical demands of writing, and assistive technology and its use in writing. In Chapter Three, I discuss the rationale for using mixed methods to carry out this study. I describe the Instruments, Participants, Quantitative Methodology (sampling procedure, data collection, coding and analysis) and Qualitative Methodology (data collection, coding and analysis). The fourth chapter reports the findings of the analysis of the quantitative data. I describe the process of analyzing the data, the results that were found and a brief description of the data that was found. In the fifth chapter, I report on the qualitative results. I describe the categories that emerged from the data, and the themes that were formed from these categories. Chapter Six provides a side by side comparison of the quantitative and qualitative data. Finally, I discuss the limitations of this study and the lengths I took to counteract these limitations.
Chapter 2. Literature Review

Rationale and Review of Relevant Literature

A focused review of empirical evidence and theory has informed this study. There are wide ranging definitions of writing. Writing can be defined as a social construction of text, the physical act of putting ideas onto paper, or the cognitive process as defined in Flower and Hayes’ influential paper, “A Cognitive Process Theory of Writing” (1981). In their paper, Flower and Hayes defined writing, “as a set of distinctive thinking processes which writers orchestrate or organize during the act of composing” (p. 366). In this research, I accepted the definition of writing as proposed by Bereiter and Scardamalia (1987) which combined the cognitive process approach and physical approach to writing. They defined writing as a translating process. This process of translation involves taking mental ideas (plan for writing, goals, thought process about the topic) and putting those thoughts into words. This process of translation can be difficult for many early writers.

The process of writing is influenced by many different factors. These factors include the role of memory, both working and long term, the effect handwriting and spelling has on the content and executive function that manages the process. The process is further constrained by the developmental abilities of young writers. Existing research on the function of assistive technology and student’s text production was reviewed to provide an empirical and theoretical basis for this thesis.
Description of grade one writing.

Writing acquisition is not a generic or standard process (Rowe, 2008). Students do not grow evenly from one stage to another in their writing as discussed in the Guide to Effective Instruction in Writing (Ontario Ministry of Education, 2005). However, it is important to provide an accurate view of the developmental continuum along which grade one writers can be placed. The discourse surrounding writing acquisition does not consistently categorize writing stages in the same terms. The first emergent stage of writing uses pictures, symbols and some conventional letters to imitate adult writing (Ontario Ministry of Education, 2005). In the literature, the next stage is referred to as early or beginning writers with these terms being used almost interchangeably.

![Developmental Stages of Writing](image.png)

Figure 1. Developmental Stages of Writing. Adapted from the *Guide to Effective Instruction, Kindergarten to Grade 3*, by Ontario Ministry of Education, 2005, p. 1.5.
To clarify the terminology for this study, beginner or early writer refers to student writing that demonstrates a basic understanding of writing, understands some reasons for writing, uses simple forms of writing including short sentences, and often invents spelling and early uses of punctuation. In grade one, students will often display behaviours that fall between the emergent and early stages of writing (Ontario Ministry of Education, 2005). For many beginning writers, their oral retelling shows much more complexity than their written text (Rowe, 2008). Early writers develop an understanding of concepts of print and illustrate greater knowledge of writing purposes. Their ideas can be expressed using invented spelling based on phonetic awareness in short, simple sentences (Ontario Ministry of Education, 2005). Grade one students choose their writing topics hastily with the goal of writing their thoughts down quickly. Such beginning writers compose in the moment without preplanning or revising (Rowe, 2008). In a supportive environment, beginning writers can exceed traditional expectations and begin to write in more and more sophisticated ways (Rowe, 2008). In Ontario, by the end of grade one, students are expected to:

Communicate ideas (thoughts, feelings, experiences) for specific purposes; organize information so that the writing conveys a clear message; produce short pieces of writing using simple forms; begin to revise their written work, with the assistance of their teachers; use and spell correctly the vocabulary appropriate for this grade; use correctly the conventions specified for this grade. (Ministry of Education, 1999, p. 2)

**Writing and cognition**

Long term memory is used extensively in writing. The long term memory stores the important pieces of information and is accessed by the working memory while
writing. All writers must rely on their long term knowledge of text structures, for example what expository text should look like, as well as task schemas, that is, knowledge of a task based on previous experience (MacArthur, 2000; Olive et al., 2009). Hayes (2004) in his model highlights the effect of extensive practice. With practice, students acquire more effective writing strategies and gain strategies for evaluating writing and more experience with specific genres. In their research on early writers and the effect of working memory, Hoskyn and Tzoneva (2008) also explain the importance of retrieval from long term memory, and state that emergent writers rely on specific orthographic representations of letters for name writing. The information in long term memory opens the gateway to effective writing for an early writer.

Baddeley’s (2000) model (see Figure 2. Baddeley’s Model of Working Memory. Adapted from The episodic buffer: A new component of working memory? by Baddeley, 2000, p. 461 describes working memory as a limited resource that one draws on for maintaining and storing information in the short term and in controlling cognitive processes. This model of working memory has influenced the view of how early writers organize and prioritize in their text composition. Baddeley’s (2000) model divides working memory into four parts. In his model, working memory includes a phonological loop, visuospatial sketchpad and episodic buffer which all work in connection with the central executive. The phonological loop stores verbal information on a short term basis and assists in refreshing the material to be stored. The visuospatial sketchpad is used for visual information. The episodic buffer links information across the other areas and is thought
to have a link to long term memory. The central executive manages the other parts of working memory as well as directs attention or inhibition of external distractions.

Figure 2. Baddeley’s Model of Working Memory. Adapted from *The episodic buffer: A new component of working memory?* by Baddeley, 2000, p. 461.

In 1981, Flower and Hayes built a model outlining and describing the components and organization of the writing process (see Figure 3). In the model, they discussed three major influences in writing. The first is the task environment which includes all the things outside of the writer including the reason for writing, audience, writing goals and the actual text that is written. The second is the writer’s long-term memory which involves retrieving the right piece of knowledge in the long term memory and reorganizing the information for the purpose of writing. The third is the writing process itself. Writing processes outlined in the model are planning, translating and reviewing. Planning involves the retrieval of information stored in long term memory, and then
organizing it for writing. Translating is the actual task of taking the mental ideas and putting them into words; this is where younger writers may experience difficulty due to handwriting, spelling and other stressors on working memory. Finally, the reviewing process includes the evaluation and revision of text. Reviewing may be a conscious effort or may happen unconsciously during the writing process. Flower and Hayes` model was a very influential beginning model for the writing process.

Figure 3. Model of Components and Organization of Writing. Adapted from “A cognitive process theory of writing” (Flower and Hayes, 1981, p. 370).

Hayes later revised this early model in 1996. He re-conceptualized the model, adding working memory as a central function which is used by all of the writing processes. Hayes added more elaborate discussions about motivation, affect and memory.
which were largely untouched by the 1981 model. Under the cognitive processes, reflection was changed to include planning, decision making and inferencing. Translation was renamed as text production. The revised model was updated to include additional knowledge about the cognitive processes involved in writing. This theoretical framework focuses on adult or expert writers.

Bereiter and Scardamalia (1987) were two of the few early writing researchers who focused specifically on the child or novice writer as a different type of writer, not just an inadequate adult writer. One of the most important features of their work was the idea that writing could be conceptualized in two different ways, as either knowledge telling or as knowledge transforming. Knowledge telling describes the way a novice writer will write about a familiar topic or assignment. Knowledge telling does not require the need for a plan or specific goal, the writer simply goes through a think-and-say process. They think about what is needed to complete the task and draw on prior knowledge about a subject or genre to meet the expectations of the activity. On the other hand, knowledge transforming is a problem solving process. The writer encounters two different problems – problem of content (what to say about the topic and the steps to solving this problem) and the problem of rhetoric (how to say it in a clear, interesting way). Expert writers who use a knowledge transforming approach to writing reflect on text, alter it and modify their own ideas about the topic or writing.

Early writers view writing as knowledge telling (Bereiter & Scardamalia, 1987). In this type of writing, the child only has to retrieve what he or she already knows about a
topic. They are not creating any new knowledge through this knowledge telling process as this is often too complex a task. One example of early writing as knowledge telling would be a student who writes about cars; in this case, retrieval from long term memory would be verbalized or written as, “something I know about cars is...”. Following this prompt, the already stored information is triggered by activating this schema of knowledge. The other influential constraint on writing that Bereiter and Scardamalia (1987) discuss is that of writing as conversational. They explain that without another member in the conversation students are forced to write without any support from a listener; this causes students to stray off task and struggle with the content of their writing. In addition, they also found that writers may lack sufficient working memory to coordinate the revision processes. During revision, students are reading for text meaning but also for the detection of problems. This incorporates a variety of processes such as reading, evaluating meaning and detecting problems; these put stress on working memory, causing revision to break down.

McCutcheon (1996, 2000) proposed that the more efficient one becomes at writing, the less stress is placed on working memory. From this hypothesis, she created a capacity theory of writing. Her theory postulates that practice leads to more automatic processes. The resources that were once used by that now automatic process can be freed and used by other processes. An example of this is as students gain more automatic spelling patterns, working memory can devote less of its resources to spelling and more to other aspects of writing. In her 2000 study, McCutcheon said that “Trade-offs exist
between working memory’s storage and processing functions because of resource limitations within the system. When more resources are devoted to processing, fewer resources are available for storage. Conversely, when storage is privileged, processing can suffer” (p. 14). Graham, Harris, and Chorzempa (2002) demonstrated that this is indeed the case by providing spelling instruction to a group of second graders and giving a control group math instruction. The spelling intervention led to improvements in writing. As spelling improved, it required fewer resources from working memory, allowing the children to devote more resources to other writing processes. The capacity theory is specifically relevant to the writing development of early writers.

**Physical demands of writing.**

Handwriting is also a strain on student working memory in the primary grades. When handwriting or printing is not automatic it takes up capacity in the executive function; this leads to less developed content, planning and revision (McCutchen 1996, 2000; Olive, Favart & Beauvais, 2009). Bereiter and Scardamalia (1987) hypothesized that the difference between students’ written and oral text could be due to the slow rate of writing or the heavy processing load. The researchers studied children’s texts when written and spoken at the slow pace of writing, and found that the written texts were the shortest. Olive et al.’s (2009) study of grade five and nine students investigated the link between handwriting and the cognitive effort involved in writing. They concluded that less cognitive effort being expended on handwriting could be translated into more complex texts. The researchers found that an increase in the number and diversity of
connectives used in the writing of the grade nine students reflected higher achievement in planning processes.

**Assistive technology.**

If spelling and handwriting are major stressors on a child’s working memory, one could hypothesize that an assistive technology that removes some of the stress on the limited resources would improve writing. The definition of assistive technology is generally accepted as any technology, item or piece of equipment that is used to facilitate (increase, maintain or improve) the capabilities of students (Ontario Ministry of Education, 2005) with disabilities (Edyburn, 2000; Wepner & Bowes, 2004). The use of assistive technology in education was broadened in 1997 when the U.S. Congress reauthorized the Individuals with Disabilities in Education Act (IDEA Amendments of 1997). This act required students with disabilities to be considered for assistive technology. In 2005, the Ontario Ministry of Education produced an expert panel report, Education for All, which does not require the use of assistive technology but advises that technology is to be used whenever necessary to facilitate students’ learning. It states that the “applications and adaptations can help open doors to previously inaccessible learning opportunities for many children with special needs” (Ontario Ministry of Education, 2005, p. 127). However, the document reminds educators that assistive technology is a tool to support learning and does not replace teaching and learning processes. Legislation and expert reports such as these have brought the use of assistive technology into the forefront of education. This growing awareness has opened up the field, creating a
variety of programs aimed at helping student’s writing. However, while this legislation has influenced research which primarily focuses on assistive technology use in the special education arena, it has not led to research on assistive technology in the mainstream classroom or with young students.

Early research on writing technology was focused on word processing. A 1993 meta-analysis found that there was a small improvement in student writing due to word processing, and that improvement was transferrable from word processed writing to handwritten samples (Bangert-Drowns). Two more recent meta-analyses looked at technology based writing research and reported higher effect sizes and significant improvement for struggling writers (Goldberg, Russell & Cook, 2003; Graham & Perin, 2007). Writing programs, such as word predictive software, have been shown to have some positive effects on writers. Word prediction was originally designed to reduce the keystrokes needed for students with physical disabilities (MacArthur, 1999, 2009; Montgomery & Marks, 2006). Word prediction creates a list of words based on a student’s typing (MacArthur, 1999) and enables poor spellers to choose the appropriate word based on the first few letters (Mirenda, Tuoldo & McAvoy, 2006). Mirenda cautions that the word prediction software interface should match the level of the student writer and that the instructional design should support the specific needs of the user (Boone & Higgins, 2007). Much like the interface, it is important that the vocabulary of the user be matched in the dictionary provided by the software (MacArthur, 2009; Montgomery et al., 2006). MacArthur (2009) found that design features of the software
affected student success. Another product that is available to aid writing is speech synthesis. With this product, a simulated voice reads the text that is written in the software; it can be read as written or read after being selected (Mirenda et al., 2006). Speech synthesis can be helpful for students, and as they hear their own writing it can encourage revision. Revision is also affected when the burden of reading is removed by the speech synthesis (Montgomery et al., 2006). It has also been found to improve word identification skills (Montgomery et al., 2006). However, speech synthesis is best used in combination with other types of software (MacArthur, 1999). Unfortunately, there is a void of recent and empirical research in the area of speech synthesis (MacArthur, 2006; Mirenda et al., 2006). Moreover, the evidence in this area is limited; studies either focus on one specific piece of the software or have small sample sizes (Cullen, Richards & Lawless-Frank, 2008). Allowing students to have access to word predictive software and speech synthesis may diminish the importance of spelling and reading and thereby improve student writing.

While the research focused on assistive technology is limited, it is almost fully dedicated to its use with students having a disability or with those categorized under the special education umbrella. The focus on assistive technology in the special education population is most likely due to the importance placed on technology by the Individuals with Disabilities Education Act (IDEA, 1997) legislation which specifically supports students who are identified as having a disability. Assistive writing technology (word predictive, speech synthesis or both) has been studied using physically disabled subjects
(Mirenda et al., 2006; Tumlin & Heller, 2004), the learning disabled (Chernek & Wollak, 2009; Gilette, 2006; Williams, 2002; Zhang, 2000), those who are severely spelling disabled (MacArthur, 1998, 1999), adult learners with low literacy (Mueller, Wood, Hunt & Specht, 2009) and even students with emotional and behavioural disorders (Parette, Crowley & Wojcik, 2007). The results of these studies were varied, as they were influenced by the interface and uses of the technology and its suitability to certain populations as stated above. Overall, there was a generally positive effect on student writing samples, motivation and engagement with the technology. When analyzing studies that reported using Co:writer as part of their study (Chernek et al., 2009; Mirenda et al., 2006; Mueller et al., 2009; Tumlin & Heller, 2004), only Tumlin (2004) found a neutral effect when two of his four subjects improved and the remaining two students showed no effect or showed decreased performance. In Chernek’s (2009) two case studies, she found that students and teachers reported an expanded vocabulary and increased enjoyment in writing. Mueller’s 2009 study exposed adult learners to a variety of assistive technology programs; however, Co:writer was one of the most frequently used programs over the time of the study. Mirenda’s 2006 research found that Co:writer helped the students to improve their spelling, vary their word use, produce more complete sentences, write more quickly, write with less frustration, and write more without tiring. Co:writer has shown some positive outcomes in students with disabilities. While the study of assistive technology in the special education population is important for
identifying strong pieces of technology it does not address the effect of writing
technology for all learners.

It is often said that making accommodation or differentiating instruction is ‘good

teaching’ however, this has not been applied to the research of assistive technology.

MacArthur (2009) states that:

Research on assistive technology for writing is limited, sufficient research exists
to establish that applications like word prediction and speech recognition can be
beneficial at least for some students. What we do not know enough about is who
can benefit in what contexts. Is word prediction only helpful for students with
severe spelling problems or could it also be helpful for reluctant writers or those
who have trouble learning to type, or could it help all students use more varied
vocabulary? (p. 101)

This line of questioning led to the investigation of empirical evidence of assistive
technology use in mainstream classrooms or with young children. In the expert panel’s
(Ontario Ministry of Education, 2005) review of assistive technology, they advocated that
assistive technology features can be advantageous for a broad range of individuals. Many
position papers and teacher journals have supported the use of assistive technology to
facilitate learning for all those who need extra assistance with learning (Wepner &
Bowes, 2004). FoulksBoyd (2006) explains that the Montessori curriculum can be
greatly enhanced using assistive technology with all children in the classroom, clarifying
that is not just for those with special needs. The Montessori curriculum is not an
exception; it is possible that all students could benefit from assistive technology.
However, there is very little empirical evidence to support this position. Mueller’s
(2009) study of adult learners was the one limited view of students who have not been
identified as having an exceptionality or special education designation. These adult students, however, suffered from low literacy rates. Within this inclusive mainstream adult education classroom, subjects felt that the assistive technology was a tool to help individualize their learning. Mueller et al. found that writing software had made the computer into a writing tool that can accommodate a variety of adult learners with and without learning disabilities. This tool can balance weaknesses and build on each student’s strengths. Unfortunately, this limited research only points out the need for further study into the use of writing technology in the mainstream classroom. Assistive technology has been touted as especially appropriate for early childhood education, early childhood special education, and special education (Council for Exceptional Children/Division of Early Childhood, 2001). While this report should have been a catalyst for research into young learners’ use of assistive technology, it resulted in a limited study. The research has focused on students at the upper elementary level (Gilette, 2006; MacArthur, 1998; Mirenda et al., 2006; 1999; Williams, 2002; Zhang, 2000), high school level (Chernek et al., 2009; Tumlin & Heller, 2004). While this is generally the age at which students are identified as having a special education designation, it should not limit research on using assistive technology with younger writers.

Criteria for software selection.

Hayes (2004) claims that writing processes are influenced by the writing medium itself; essentially how a person writes is influenced by what they are using for their writing. For example, a writer may revise more on a computer than paper and pencil
writing because the computer allows the writer to receive easy reminders of mistakes (indicators for misspelled words and grammatically incorrect phrases, for example).

Based on this influence and the caution by Mirenda (2006) regarding the matching of interface with student skill level, it was important to critically assess the various assistive writing programs and choose one that was appropriate for this study. The assistive writing technology was chosen based on specific criteria. The program needed to be widely accessible to schools, so software that was free to acquire or was licensed by the Ontario Ministry of Education for use in Ontario schools was sought. Each program fitting the first condition was assessed using a criteria based on Sturm, Rankin, Beukelman and Schutz-Muehling’s 1997 article, “How to select appropriate software for computer-assisted writing”. Table 1 shows the criteria used to evaluate different types of software. Table 2 shows the comparison rubric created to objectively compare the software and decide on the most suitable program.

**Table 1**

**Software Selection**

<table>
<thead>
<tr>
<th>Criteria</th>
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<tbody>
<tr>
<td><strong>EASE OF USE</strong></td>
<td>Is the program developmentally appropriate for early primary use?</td>
</tr>
<tr>
<td></td>
<td>Is the program intuitive/ easy to learn?</td>
</tr>
<tr>
<td><strong>MECHANICS</strong></td>
<td>Does program assist with appropriate spacing between words?</td>
</tr>
<tr>
<td></td>
<td>Does program assist with appropriate margins?</td>
</tr>
<tr>
<td></td>
<td>Does program assist with appropriate punctuation and capitalization?</td>
</tr>
<tr>
<td><strong>SPELLING</strong></td>
<td>Does program recognize first-letter spellings?</td>
</tr>
<tr>
<td></td>
<td>Can program recognize a word spelled incorrectly?</td>
</tr>
<tr>
<td></td>
<td>Does automatically correct spelling errors?</td>
</tr>
</tbody>
</table>
| **FORM** | Does program assist with word order in sentences?  
| Does program assist with grammatical features? Within or across sentences? |
| **VOCABULARY** | Does program assist with appropriate word to express meaning?  
| Does program consider every day, favoured words and/or specialty, sophisticated words? |
| **CONTENT** | Does the program assist with writing ideas? |
| **ORGANIZATION** | Does program allow student to plan before writing?  
| Can the program assist writing product with shape, sequence, or direction?  
| Does program have pre-existing organizational structures that are appropriate to the task? |
| **EDITING** | Can program assist with editing process?  
| Does the program allow for a text to be read aloud to detect writing errors? |
| **FEATURES** | **KEYBOARDING ASSISTANCE**  
Access, Speed, Accuracy  
**TALKING WORD PROCESSORS**  
Level of speech output (Individual letters, Sentences, Paragraph, Selected (highlighted) text, Entire documents, Highlights units spoken)  
Speaking rate adjustment  
Loudness adjustment  
Headphone/external speaker option  
**TYPES OF SPELLING AND VOCABULARY SUPPORT**  
Spell checking (At conclusion of document, Simultaneously)  
Error detection (with suggestions)  
Automatic spacing and capitalization  
**FORMS OF ORGANIZATIONAL ASSISTANCE**  
Topic suggestions  
Writing style guides  
**GRAMMAR ASSISTANCE**  
Error detection, Grammar correction, Grammar tutoring  
**ILLUSTRATION ASSISTANCE**  
Pictures/art work  
Drawing tools/coloration |

After extensive consideration, Co:writer 4000 was chosen for this study. It includes both word prediction and speech synthesis in one program. It works with any application, and therefore can be used in many different areas, for example, with both word processors and in online environments (blogs, email, etc.) Co:writer interprets spelling and grammar, offering word suggestions in a variety of ways such as word completion, bigram/trigram prediction (two or three word patterns), linguistic word prediction (grammatical intelligence), flex spell (phonetic spelling e.g., Elef still brings up the word elephant) and an extensive dictionary. Co:writer’s word prediction can also be matched to the ability level of the user, offering words at the beginning, intermediate and advanced level. Co:writer’s speech synthesis is a simulated voice that reads the student’s written text. It can be read as written or read after being selected (Mirenda et al., 2006). Word prediction and speech synthesis can encourage revision as students hear their own writing and correct their errors.
<table>
<thead>
<tr>
<th>Developmentally Appropriate</th>
<th>Ease of Use</th>
<th>Co:writer 4000</th>
<th>Write:OutLoud</th>
<th>Word Q</th>
<th>UltraKey 4.0</th>
<th>EasyBook Deluxe</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Writing Features</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>o Mechanics</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>o Spelling</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>o Form</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>o Syntax</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
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<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>o Content</td>
<td>X</td>
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<td>X</td>
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<td></td>
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<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
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<td><strong>Types of Assistance</strong></td>
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<td></td>
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</tr>
<tr>
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<td></td>
<td>X</td>
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<tr>
<td>o Talking Word Processor</td>
<td>X</td>
<td></td>
<td>X</td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>o Spelling and Vocabulary</td>
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<td></td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>o Organizational</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>o Illustration</td>
<td></td>
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<td></td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td><strong>Accessibility</strong></td>
<td></td>
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<td></td>
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<tr>
<td>o Ministry Licensed Software</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>

Chapter 3. Methodology

In this mixed methodology study, both quantitative data and qualitative data were collected to gain a comprehensive view of the affect assistive technology has on grade one writers. Figure 4 gives an overview of the study.

![Figure 4. Structure of the Study](image)

**Use of Writing Prompts as Instruments**

Research indicates that authentic learning prompts can be more effective than story starters when students are allowed to discuss and interact with stimulus (Hudson, Lane & Mercer, 2005). It also has been argued that students write with more sophisticated skill if they are writing in an authentic situation (Cameron, Hunt & Linton, 1996; Graves, 1983; Slavin, 2004). Therefore, in the study, each week students were given a real life authentic prompt for their expository writing. These real life prompts
included making a recipe, completing an art activity, folding origami, creating a craft, conducting a science experiment and playing active games. Students wrote about the experiential learning tasks that they participated in as a group. These common experiential learning activities were used to lessen the potential effect of different amounts of background knowledge affecting the writing samples. The activities for each weekly session were organized with the developmental abilities of the participants in mind. Frequent changes in the tasks and time for a nutrition break were included in the intervention. The layout of each session (one and two) is slightly different – session one focused more on the learning of Co:writer and experiential prompts, and session two was geared toward the actual writing time.

**Participants**

Students from four grade 1 classes in one school were invited to join the writing intervention groups (the writing club). The intervention took place after school for one hour every other day. A sample size of 27 students ages 6-7 were chosen from a potential 80 students on a first come, first serve basis.

**Structure of the Study**

These 27 students were placed in two mixed ability groups (Monday and Wednesday) or (Tuesday and Thursday). Parents chose which group the child would attend based on convenience for the parent. Each group met for one hour twice a week for a total of 16 hours (16 sessions). The specific timeline of each session is illustrated in Table 3. The groups both participated in the activities and data collection, and there was
no control group based on timing of the intervention and the request of the school administration. The study ran for eight weeks, from April 19th, 2010 to June 17th, 2010. To avoid bias, students were given numbers and student writing samples were only identified by these numbers.

**Table 3**

<table>
<thead>
<tr>
<th>Weekly Sessions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Session</td>
</tr>
<tr>
<td>--------</td>
</tr>
<tr>
<td>1</td>
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<td>1</td>
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<tr>
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<td>2</td>
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<tr>
<td>2</td>
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<tr>
<td>2</td>
</tr>
<tr>
<td>2</td>
</tr>
</tbody>
</table>

Each week, participants were taught by the investigator about a specific component of the Co:writer software. Students wrote expository text with the aid of the assistive software. Expository writing was chosen as it is less familiar to younger elementary students (Donovan, 2001). When participants write on expository topics that are preceded by common experiential learning activities, the potential for different amounts of background knowledge affecting the writing samples is lower. During the sessions each week, students practiced using the various aspects of Co:writer that were taught, while writing expository text on the common experiential learning task. The
prompt activities for writing are described in Table 4. See Appendix A for a detailed description of a topic over two sessions.

Table 4

**Prompt/Tutorial**

<table>
<thead>
<tr>
<th>Week</th>
<th>Prompt Activity</th>
<th>Co:writer Tutorial</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Tag game (animal tag)</td>
<td>Pre data collection</td>
</tr>
<tr>
<td>2</td>
<td>Make Crazy Putty</td>
<td>How to use word prediction extended – typing words, choosing words, sending</td>
</tr>
<tr>
<td></td>
<td></td>
<td>sentences to page, waking up Co:writer</td>
</tr>
<tr>
<td>3</td>
<td>Play a game</td>
<td>Word prediction continued- how to choose the best word for your story, how to</td>
</tr>
<tr>
<td></td>
<td></td>
<td>delete the wrong word, why do we think about the best word?</td>
</tr>
<tr>
<td>4</td>
<td>Make Salt dough</td>
<td>How to use speech synthesis – highlighting and listening – words, sentences, all</td>
</tr>
<tr>
<td></td>
<td></td>
<td>writing</td>
</tr>
<tr>
<td>5</td>
<td>Secret messages</td>
<td>How to use speech synthesis to improve writing – asking does this make sense?</td>
</tr>
<tr>
<td></td>
<td></td>
<td>What can I do if it doesn’t make sense?</td>
</tr>
<tr>
<td>6</td>
<td>Make a recipe</td>
<td>Putting it all together – making Co:writer the best for you, how to change</td>
</tr>
<tr>
<td></td>
<td></td>
<td>options so the program works best for the student –</td>
</tr>
<tr>
<td>7</td>
<td>Origami frogs</td>
<td>How to used a topic dictionary – why do we use a topic dictionary? How to add</td>
</tr>
<tr>
<td></td>
<td></td>
<td>word to a dictionary (based on activity) Create a topic dictionary about our</td>
</tr>
<tr>
<td></td>
<td></td>
<td>activity (brainstorm together)</td>
</tr>
<tr>
<td>8</td>
<td>Tag game (hot dog tag)</td>
<td>Post data collection</td>
</tr>
</tbody>
</table>
Quantitative Methodology

Student samples were formally collected six times throughout the intervention. Three beginning pieces of writing were taken before the intervention and three final writing samples were taken at the end. Both pre and post samples included a hand written piece of writing and a piece of writing created with a word processor, and the final sample was completed with students using the assistive technology.

Coding and analysis.

Student samples were formally collected six times throughout the intervention. The three beginning pieces of writing were taken before the intervention (hand written, word processor and first use of Co:writer) and three final writing samples were taken at the end (using Co:writer, using a word processor and hand written). At the end of the intervention, all pre and post samples were coded for length, word phrasal use and word use frequency.

Length.

As writers gain experience with the language, phrases and sentences increase in length (Hayes, 2004). Length was determined by the word count function within the word processing software. A one way, repeated measures ANOVA was used to determine the mean differences within the pre samples (pre handwritten, pre word processed, pre assistive technology) and post samples (post handwritten, post word processed writing and post assistive technology). A paired samples t-test was used to analyze the difference in means from pre to post data.
**Word use.**

Word use was determined by comparing the word use of participants and ranking it on the Word Zones™ corpus (Hiebert, 2005). Hiebert based her zones on the The Educator’s Word Frequency Guide (Zeno, 1995), the most recent frequency count. Hiebert included 5,586 words in zones one through four. Basing them on the most frequently used words, zone one includes the first 300, zone two adds 500 more words, the next 1,200 make up zone three, and zone four includes the final 2,000 words. The percentage of words used in each zone (calculated at http://cehs07.unl.edu/reading/zone/custom.php?cvalue=5) in the piece of writing was analyzed. A one way, repeated measures ANOVA was used to determine the mean differences within the pre samples (pre handwritten, pre word processed, pre assistive technology) and post samples (post handwritten, post word processed writing and post assistive technology). A paired samples t-test was used to analyze the difference in means from pre to post data.

**Sentence complexity.**
### Table 5

**Scott’s Summary of Developmental Indicators of Syntactic Complexity**

<table>
<thead>
<tr>
<th></th>
<th>Emerging complexity (1)</th>
<th>Continuing complexity (2)</th>
<th>Long-term complexity (3)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Coordination</strong></td>
<td><em>and</em> as a clausal and sentential coordinator</td>
<td><em>and</em> continues as the dominant coordinator of the sentences</td>
<td><em>and</em> continues at high frequency rates other explicit connectives are used</td>
</tr>
<tr>
<td><strong>Clause-adding subordination nominal</strong></td>
<td>Infinitive-as-object is highest frequency</td>
<td>nominal with a greater variety of main clause verbs</td>
<td>nonfinite nominals and nominals as subjects</td>
</tr>
<tr>
<td><strong>Adverbials</strong></td>
<td><em>because</em> and <em>when</em> account for majority of adverbials</td>
<td><em>if</em>, <em>to</em>, and <em>so</em> increase in narrative and conversational texts</td>
<td>expanded meanings for common clause types increasing use of logical relations and specific subordinators. Non finite forms in written language</td>
</tr>
<tr>
<td><strong>Relatives</strong></td>
<td>Pronouns <em>that</em> and <em>what</em> used in narrative discourse</td>
<td>Additional pronoun and grammatical functions of pronouns</td>
<td></td>
</tr>
<tr>
<td><strong>Non clausal complexity</strong></td>
<td>a small set of adverbial conjuncts emerge in spoken language, very few in written language</td>
<td>Adverbial conjuncts as sentential connectors continue to develop, appearing more frequently in written language. Word order alterations in writing</td>
<td></td>
</tr>
</tbody>
</table>

*Note. Adapted from “Producing complex sentences”. *Topics in Language Disorders.* (Scott, 1988, p. 44).*
Student writing samples were coded for sentence complexity using Scott’s (1988) summary of developmental indicators of syntactic complexity (Table 5). This summary examined student writing in the areas of coordination, adverbials, relatives and non-clausal complexity. Using the scale student writing was rated (1-3): emerging complexity (1), continuing complexity (2) and long-term complexity (3). A one way, repeated measures ANOVA was used to determine the mean differences within the pre samples (pre handwritten, pre word processed, pre assistive technology) and post samples (post handwritten, post word processed writing, post assistive technology). A paired samples t-test was used to analyze the difference in means from pre to post data.

**Handwriting**

Using the information from the ANOVAs used to analyze the previous pieces of data, it was possible to see if there was any transference from the potential benefits of Co:writer to the post handwritten samples of writing.

**Qualitative Methodology**

In order to explore the effect of the assistive technology, it was not only necessary to look at the quantitative writing data, but also to investigate how students felt about the software function and its effect on their writing. To assess the effect on students, qualitative data was collected in two ways: field notes and targeted questioning. The field notes of observations of how students interacted with the technology were used to examine specifically how students choose words, input text, react to program choices and their own writing. Targeted questions assessed how students themselves felt about using
the Co:writer program and how they felt it affects their writing. When interviewing children it was important to give voice to the student’s interpretation of the program rather than relying on adult understandings (Elder & Fingerson, 2001).

**Interviews with targeted questioning.**

Three times throughout the intervention, participants were asked a question that discussed a specific function of Co:writer. The questioning took place during snack time. Students were asked individually. Participant responses were recorded by the researcher. The first question was asked after the students learned the word prediction function. At that time, I asked each student “What is it like writing now that you can use word prediction?” This targeted question allowed students to reflect on the function of Co:writer and how it affected their writing. When it was required I also asked student to “explain” their answer. The second question was asked after the students learned the speech synthesis function. At that time, I asked the students “What is it like writing now that you can use speech synthesis?” This targeted question allowed students to reflect on the speech synthesis function of Co:writer and how it affected their writing. If it was required I also asked students to “explain” their answer. The third question was asked at the end of the intervention during the post data collection. At that time, I asked each student to compare handwriting, word processing and assistive technology, asking which one the participant preferred. In order to have students describe their thinking in detail I asked a follow up question to gather information about why they preferred their chosen form of writing.
Interviews took a standardized open ended format where participants were all asked the same question. To avoid dichotomous-responses, questions that prompted the students to answer in a yes/no format, or leading questions, which can lead students toward a preferred implied response, or presupposition questions that imply an answer within the question (Schumacher & McMillian, 2009) were not asked. Eder and Fingerson (2001) found that it is important to avoid playing the ‘teacher role’ when interviewing students, as this makes students feel that there is a ‘right answer’. At the onset of each interview, I explained to students that I wanted to know how they felt and what they thought, and that there were no wrong answers. In my interviews I also strove to take a conversational tone that allowed students to discuss the technology as they would with a peer. This also allowed me to use the discourse of the students being interviewed, using simplified language that would allow students to answer the question in their own communicative style (Eder & Fingerson, 2001). The interview questions were constructed in an open-ended, non-biased way that encouraged students to share an experience without leading them toward the answer. “What is it like writing now that you can use word prediction?” did not lead the student to give a yes/no, or like/dislike answer; it also did not lead or presuppose that the student will be fond of the word prediction. Word prediction was not in the discourse of the students prior to the intervention. However, this is the language that was used when teaching Co:writer and students were familiar with it when this interview was conducted.
In accordance with the guidelines set out in Schumacher and McMillian, the five contingencies that are believed to influence an interview session were strategically planned. (1) duration – the length of the interview question was purposely short to allow for young children’s attention span and the limited time of the intervention; (2) number – the interview was separated into three sections of questions to collect data at sensitive times (after learning each specific piece of Co:writer) and to allow for young children’s attention span; (3) setting- the interview questions took place in the natural setting of the writing study, students were participating in the study for four, six and eight weeks and would have become comfortable in this setting; (4) identity of the individual – all participants in the study were questioned to receive a comprehensive view of students in the study, and were asked questions while surrounded by peers, however they were asked to respond to the question individually; (5) informant styles – information was conducted after a piece of Co:writer had been learned (word prediction, speech synthesis, altogether).

**Salient field observation.**

Observation is a useful qualitative tool that allows researchers to observe what is happening without altering the environment (Patton, 2002). I conducted salient field observations that were important to the predetermined issues in the study. It was important to describe how the students interacted with the software. Observing how students chose words, inputted text, and reacted to program choices and their own writing allowed me to see what affected the students’ use of the assistive technology. Field notes
were anecdotally recorded throughout the writing portions of the intervention.

**Analysis**

I used inductive analysis to determine patterns in the participant answers and field notes (McMillan & Schumacher, 2006). This inductive analysis sought to identify concepts that emerged from the data. The purpose was to develop an understanding of (a) how students described their experiences with word prediction, and how this specifically affected their writing, (b) how students described their experiences with speech synthesis, and how this specifically affected their writing, (c) what types of writing students preferred and the rationale behind the participants’ choices.

Data Analysis took place in phases – coding, categorizing and interpreting. The first phase looked for an overall sense of the student responses and field notes. After a general sense was obtained, I looked for overarching themes and ideas in the data. The themes and ideas were tentatively coded after looking for similarities, differences and anomalies in the qualitative data. From the themes and ideas, patterns began to emerge. The patterns were then categorized. The categories were interpreted into overall representations of the data.
Chapter 4. Quantitative Results

Overview of Quantitative Results

In this section, I report the findings from the quantitative analysis of pre-and-post-test writing samples. The categories of analysis were length of writing sample, sentence complexity and word use. The data were analyzed to look at the difference within the pre-or-post-test writing as well as the difference between the pre-and-post-test data. A repeated measures analysis of variance (ANOVA) was chosen to look at the difference within the data (pre-or-post-test). A paired-samples t-test was chosen to analyze the difference between the pre-and-post-test data as I was comparing data from the same group at different times, and the samples are dependent. All results were analyzed at the 95% confidence level.

Comparison of Pre-Test Modalities

In this section data is analyzed to reveal differences within the pre-test data in each of the modalities (handwriting, word processor and Co:writer). Data will be broken into the differences in length, sentence complexity and word use across modalities at pre-test. Figure 5 gives an overview of the findings in the pre-test modalities.
Figure 5. Within Modalities Pre Results

**Length of writing at pre-test.**

A one-way repeated measures ANOVA was conducted to compare the mean length of pre handwritten, pre word processor and pre Co:writer writing samples. The means and standard deviations are presented in Table 6. There was an interaction found between the length in pre written samples = F(2,26) = 6.996, p=.004. A pairwise test was used to make post hoc comparisons between samples. Pairwise comparison indicated that there was a significant difference in the scores for pre handwritten samples.
(M=24.3, SD=18.8) and pre Co:writer samples (M=11.1, SD=10.1). These results suggest that in the initial samples students struggled to write longer pieces of text when using the assistive technology for the first time.

**Table 6**

**Within Measures Analysis of Variance - Pre Samples**

<table>
<thead>
<tr>
<th></th>
<th>Handwritten</th>
<th></th>
<th>Word Processor</th>
<th></th>
<th>Co:writer</th>
<th></th>
<th>F (2, 26)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
<td>M</td>
<td>SD</td>
<td>M</td>
<td>SD</td>
<td></td>
</tr>
<tr>
<td>Length</td>
<td>24.3</td>
<td>18.8</td>
<td>18.9</td>
<td>22.4</td>
<td>11.1</td>
<td>10.1</td>
<td>.004</td>
</tr>
<tr>
<td>Sentence Complexity</td>
<td>.874</td>
<td>.404</td>
<td>.837</td>
<td>.333</td>
<td>.689</td>
<td>.315</td>
<td>.127</td>
</tr>
<tr>
<td>Word Use</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zone 1</td>
<td>57.7</td>
<td>26.1</td>
<td>50.7</td>
<td>27.2</td>
<td>51.9</td>
<td>24.5</td>
<td>.308</td>
</tr>
<tr>
<td>Zone 2</td>
<td>6.69</td>
<td>6.71</td>
<td>6.97</td>
<td>7.26</td>
<td>6.06</td>
<td>10.61</td>
<td>.946</td>
</tr>
<tr>
<td>Zone 3</td>
<td>5.65</td>
<td>4.37</td>
<td>8.07</td>
<td>11.16</td>
<td>11.29</td>
<td>13.44</td>
<td>.112</td>
</tr>
<tr>
<td>Zone 4</td>
<td>.983</td>
<td>1.81</td>
<td>1.65</td>
<td>3.78</td>
<td>7.87</td>
<td>9.32</td>
<td>.003</td>
</tr>
</tbody>
</table>

**Sentence complexity in writing at pre-test.**

A one-way repeated measures ANOVA was conducted to compare the mean sentence complexity score of pre handwritten, pre word processor and pre Co:writer writing samples. The means and standard deviations are presented in Table 6. There were no interactions found in pre written samples =F (2, 26) =2.24, p= .127. These results suggest that in the initial samples students wrote samples with similar complexity in the writing samples across modalities.
Word use in writing at pre-test.

A one-way repeated measures ANOVA was conducted to compare the word use in each zone (one to four) of pre handwritten, pre word processor and pre Co:writer writing samples. The means and standard deviations are presented in Table 6. There were no interactions found in zone one \( F(2,26) = 1.235, p = .308 \), zone two \( F(2,26) = 0.056, p = .946 \) or zone three \( F(2,26) = 2.391, p = .112 \). There was an interaction found in the word use in zone four in pre written samples \( F(2,26) = 7.243, p = .003 \). A pairwise test was used to make post hoc comparisons between samples. Pairwise comparison indicated that there was a significant difference in the zone four scores for pre handwritten samples (\( M = 0.985, SD = 1.81 \)) and pre Co:writer samples (\( M = 7.87, SD = 9.32 \)). These results suggest that in the initial samples students wrote words in the highest word zone much more regularly when using Co:writer than when writing by hand or on a word processor.

Comparison of Pre-Test and Post-Test Data

Paired sample t-tests were used to compare the data between pre test and post test. Samples were analyzed for length, sentence complexity and word use in handwritten, word processed and Co:writer modalities. In this section changes between pre-and-post-test data will be reported. Figure 6 gives an overview of the findings in the pre to post-test findings.
Length of writing samples.

Comparison of length in pre-and-post-test data will be discussed below.

Results of all samples analyzed for length are displayed in Table 7.

Table 7

<table>
<thead>
<tr>
<th></th>
<th>Pre</th>
<th></th>
<th>Post</th>
<th></th>
<th>df</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
<td>M</td>
<td>SD</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Handwritten</td>
<td>24.3</td>
<td>18.9</td>
<td>24.8</td>
<td>18.8</td>
<td>26</td>
<td>.834</td>
</tr>
<tr>
<td>Word Processor</td>
<td>18.9</td>
<td>22.4</td>
<td>10.4</td>
<td>11.6</td>
<td>26</td>
<td>.049</td>
</tr>
<tr>
<td>Co:writer</td>
<td>11.1</td>
<td>9.98</td>
<td>22.2</td>
<td>13.5</td>
<td>26</td>
<td>&lt;.001</td>
</tr>
</tbody>
</table>
**Length of handwritten samples.**

A paired-samples t-test was conducted to compare the length in pre-test handwritten samples and post-test handwritten samples. There was not a significant difference in the scores for pre-test handwritten sample length \((M=24.3, \ SD=18.9)\) and post-test handwritten sample length \((M=24.8, \ SD=18.8)\); \(t(26)=-.212, \ p=.834\). These results suggest that in the conditions of this research length of handwritten writing samples was not affected by using assistive technology for writing.

**Length of word processed samples.**

A paired-samples t-test was conducted to compare the length in pre-test word processor written samples and post-test word processor written samples. There was a significant difference in the scores for pre-test word processor length \((M=18.9, \ SD=22.4)\) and post-test word processor length \((M=10.4, \ SD=11.6)\); \(t(26)=2.06, \ p=.049\). These results suggest that in the conditions of this research the length of word processor writing samples was negatively affected by using assistive technology for writing. Specifically, the results suggest that when students became used to writing with assistive technology, as in this intervention, they had difficulty word processing without it.

**Length of Co:writer samples.**

A paired-samples t-test was conducted to compare the length in pre-test Co:writer written samples and post-test Co:writer written samples. There was a
significant difference in the scores for pre-test Co:writer length ($M=11.1, SD=9.98$) and post-test Co:writer length ($M=22.2, SD=13.5$); $t(26)=-4.19, p < .001$. These results suggest that in the conditions of this research the length of Co:writer written samples was affected by the assistive technology writing intervention. Specifically, the results suggest that when students became used to writing with assistive technology, as in this intervention, they were able to compose longer pieces of writing.

**Sentence complexity of writing samples.**

Comparison of pre-and-post-test sentence complexity data will be discussed below. Results of all samples analyzed for sentence complexity are displayed in Table 8.

<table>
<thead>
<tr>
<th></th>
<th>Pre</th>
<th></th>
<th>Post</th>
<th></th>
<th>df</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
<td>M</td>
<td>SD</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Handwritten</td>
<td>.874</td>
<td>.404</td>
<td>.933</td>
<td>.451</td>
<td>26</td>
<td>.393</td>
</tr>
<tr>
<td>Word Processor</td>
<td>.843</td>
<td>.328</td>
<td>.800</td>
<td>.442</td>
<td>26</td>
<td>.577</td>
</tr>
<tr>
<td>Co:writer</td>
<td>.693</td>
<td>.310</td>
<td>1.057</td>
<td>.210</td>
<td>26</td>
<td>&lt;.001</td>
</tr>
</tbody>
</table>

**Sentence complexity of handwritten samples.**

A paired-samples t-test was conducted to compare the sentence complexity in pre-test handwritten samples and post-test handwritten samples. There was a not a significant difference in the scores for pre-test handwritten sentence complexity ($M=.874, SD=.404$) and post-test handwritten sentence complexity ($M=.933,$
These results suggest that in the conditions of this research, sentence complexity in handwritten writing samples was not affected by the assistive technology writing intervention.

**Sentence complexity of word processed samples.**

A paired-samples t-test was conducted to compare the sentence complexity in pre-test word processor written samples and post-test word processor written samples. There was not a significant difference in the scores for pre-test word processor sentence complexity ($M=.843$, $SD=.328$) and post-test word processed sentence complexity ($M=.800$, $SD=.442$); $t(26)= .565$, $p = .577$. These results suggest that in the conditions of this research sentence complexity in both word processed samples were not affected after our assistive technology writing intervention.

**Sentence complexity of samples written with Co:writer.**

A paired-samples t-test was conducted to compare the sentence complexity in pre-test samples written with Co:writer and post-test samples written with Co:writer. There was a significant difference between the pre-test scores for Co:writer sentence complexity ($M=.693$, $SD=.310$) and post-test scores for Co:writer sentence complexity ($M= 1.057$, $SD=.210$); $t(26)= -.567$, $p = .001$. These results suggest that in the conditions of this research sentence complexity in Co:writer written samples was affected by the assistive technology writing intervention. Specifically, the results suggest that when students became used to writing with assistive
technology, as in this intervention, they were able to compose more complex sentences.

**Word use in writing samples.**

Comparison of pre-and-post-test word use data will be discussed below.

Results of all samples analyzed for word use are displayed in Table 9.

**Table 9**

<table>
<thead>
<tr>
<th>Word Use of Participant Samples</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Zone One</td>
<td>Pre</td>
<td>Post</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zone One</td>
<td>M</td>
<td>SD</td>
<td>M</td>
<td>SD</td>
</tr>
<tr>
<td>Handwritten</td>
<td>57.7</td>
<td>26.1</td>
<td>56.1</td>
<td>21.9</td>
</tr>
<tr>
<td>Zone Two</td>
<td>6.69</td>
<td>6.71</td>
<td>7.57</td>
<td>7.14</td>
</tr>
<tr>
<td>Zone Three</td>
<td>5.56</td>
<td>4.37</td>
<td>10.18</td>
<td>5.11</td>
</tr>
<tr>
<td>Zone Four</td>
<td>.983</td>
<td>1.81</td>
<td>7.22</td>
<td>7.16</td>
</tr>
<tr>
<td>Word Processor</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zone One</td>
<td>50.7</td>
<td>26.7</td>
<td>41.7</td>
<td>26.7</td>
</tr>
<tr>
<td>Zone Two</td>
<td>6.72</td>
<td>7.25</td>
<td>7.57</td>
<td>8.81</td>
</tr>
<tr>
<td>Zone Three</td>
<td>8.67</td>
<td>11.41</td>
<td>5.43</td>
<td>9.95</td>
</tr>
<tr>
<td>Zone Four</td>
<td>1.59</td>
<td>3.73</td>
<td>5.42</td>
<td>7.29</td>
</tr>
<tr>
<td>Co:writer</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zone One</td>
<td>52.2</td>
<td>24.1</td>
<td>59.3</td>
<td>7.9</td>
</tr>
<tr>
<td>Zone Two</td>
<td>6.20</td>
<td>10.44</td>
<td>9.21</td>
<td>6.69</td>
</tr>
<tr>
<td>Zone Three</td>
<td>10.88</td>
<td>13.36</td>
<td>10.17</td>
<td>5.01</td>
</tr>
<tr>
<td>Zone Four</td>
<td>7.95</td>
<td>9.15</td>
<td>4.93</td>
<td>5.30</td>
</tr>
</tbody>
</table>

**Word use in handwritten samples.**

A paired-samples t-test was conducted to compare the word use of all the zones in handwritten pre-test samples and handwritten post-test samples. There was
not a significant difference between the pre-test scores for word use of zone one words in handwritten samples ($M=57.7$, $SD=26.1$) and post-test scores for word use of zone one words in handwritten samples ($M=56.1$, $SD=21.9$); $t(26) = .359$, $p = .722$ or in zone two words for pre-test handwritten samples ($M=6.69$, $SD=6.71$) and post-test handwritten samples ($M=7.57$, $SD=7.14$); $t(26) = -.452$, $p = .655$. These results suggest that in the conditions of this research word use of the zone one and zone two words did not change. However, when a paired samples t-test was conducted to compare the word use of zone three words in pre-test handwritten samples and post-test handwritten samples there was a significant difference between the pre-test scores for word use of zone three words in handwritten samples ($M=5.65$, $SD=4.37$) and post-test scores of zone three words in handwritten samples ($M=10.18$, $SD=5.11$); $t(26) = -4.039$, $p < .001$. There also was a significant difference for zone four words, between the pre-test scores of handwritten samples ($M=.9833$, $SD=1.81$) and post-test scores of handwritten samples ($M=7.22$, $SD=7.16$); $t(26) = -4.480$, $p < .001$. These results suggest that in the conditions of this research students were able to use more complex words in their handwritten writing after the assistive technology writing intervention.

*Word use in word processed samples.*

A paired-samples t-test was conducted to compare the word use in word processed pre-test samples and handwritten post-test samples. There was not a significant difference in the pre-test scores for word use of zone one words of pre-
test word processor samples ($M=50.7$, $SD=26.7$) and post-test samples ($M=41.7$, $SD=26.7$); $t(26)= 1.33$, $p = .195$ or zone two for pre-test word processed samples ($M=6.72$, $SD=7.25$) or post-test samples ($M=7.57$, $SD=8.81$); $t(26)= -.417$, $p = .680$. The data were also not significantly different for zone three word use in pre-test word processing samples ($M=8.67$, $SD=11.41$) or in post-test word processed samples ($M=5.43$, $SD=9.95$); $t(26)= 1.01$, $p = .322$. These results suggest that in the conditions of this research word use in zones one to three in word processed samples were not affected by the assistive technology writing intervention. However, a significant difference was found in the pre-test scores for word use of zone four words of word processed samples ($M=1.59$, $SD=3.73$) and in post-test scores of word processed samples ($M=5.42$, $SD=7.29$); $t(26)= -2.39$, $p = .024$. These results for zone four word usage suggest that in the conditions of this research students were able to use more complex words after the assistive technology writing intervention in their word processed writing.

Word use in samples written with Co:writer.

A paired-samples t-test was conducted to compare the word use in pre-test samples written with Co:writer and post-test samples written with Co:writer. There was not a significant difference between the pretest and post-test scores for use of words in any of the word use zones; in zone one of the samples using Co:writer pre-test ($M=52.2$, $SD=24.1$) and post-test ($M=59.3$, $SD=7.9$); $t(26)= -1.49$, $p = .148$, in zone two of the samples using Co:writer pre-test ($M=6.20$, $SD=10.44$) and post-test
\[ M = 9.21, SD = 6.69; \] \[ t(26) = -1.20, p = .239, \]
in zone three of the samples using Co:writer pre-test \( M = 10.88, SD = 13.36 \) and post-test \( M = 10.17, SD = 5.01 \); \[ t(26) = .302, p = .765. \] Finally, in zone four of the samples using Co:writer pre-test samples \( M = 7.95, SD = 9.15 \) and post-test samples \( M = 4.93, SD = 5.30 \); \[ t(26) = 1.42, p = .167. \] These results suggest that in the conditions of this research word use in all Co:writer samples was not affected by the assistive technology writing intervention.

**Comparison of Post-Test Modalities**

In this section, data is analyzed to reveal differences within the post-test data in each of the modalities (handwriting, word processor and Co:writer). Data will be broken into the differences in length, sentence complexity and word use across modalities at post-test. Figure 7 gives an overview of the findings in the post-test modalities.
Figure 7. Within Modalities Post Results

**Length of writing at post test.**

A one-way repeated measures ANOVA was conducted to compare the mean length of post handwritten, post word processor and post Co:writer writing samples. The means and standard deviations are presented in Table 10. There was an interaction found between the length in post written samples = F (2,26) = 26.11, p < .001. A pairwise test was used to make post hoc comparisons between samples. Pairwise comparison indicated that there was a significant difference in the scores
for post handwritten samples (M=25, SD=18.5) and post word processed samples (M=10.4, SD=11.5). Pairwise comparisons further showed there was another significant difference between post word processed samples (M=10.4, SD=11.5) and post Co:writer sample length (M=22.2, SD=13.5). These results suggest that after the intervention students were able to produce texts with similar lengths when writing by hand and with Co:writer; however, students wrote significantly less when using a word processor without any assistive technology.

**Sentence complexity in writing at post test.**

A one-way repeated measures ANOVA was conducted to compare the mean sentence complexity scores of post handwritten, post word processor and post Co:writer writing samples. The means and standard deviations are presented in Table 10. There was an interaction found between the sentence complexity scores in post written samples= F (2, 26) =4.44, p= .022. A pairwise test was used to make post hoc comparisons between samples. Pairwise comparison indicated that there was a significant difference in the scores for post word processed samples (M=.8, SD=.42) and post Co:writer samples (M=1.06, SD=.209). These results suggest that after the intervention students were able to produce more complex sentences when writing by hand and with Co:writer; however, the students wrote significantly fewer complex sentences when producing text with only a word processor.
Table 10

Within Measure Analysis of Variance – Post Samples

<table>
<thead>
<tr>
<th></th>
<th>Handwritten</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
<td>M</td>
<td>SD</td>
<td>M</td>
<td>SD</td>
</tr>
<tr>
<td>Length</td>
<td>25.0</td>
<td>18.5</td>
<td>10.4</td>
<td>11.5</td>
<td>22.2</td>
<td>13.5</td>
</tr>
<tr>
<td>Sentence Complexity</td>
<td>.943</td>
<td>.445</td>
<td>.800</td>
<td>.442</td>
<td>1.06</td>
<td>.209</td>
</tr>
<tr>
<td>Word Use</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zone 1</td>
<td>56.2</td>
<td>21.5</td>
<td>41.7</td>
<td>30.1</td>
<td>59.3</td>
<td>7.95</td>
</tr>
<tr>
<td>Zone 2</td>
<td>7.64</td>
<td>7.02</td>
<td>7.57</td>
<td>8.81</td>
<td>9.21</td>
<td>6.96</td>
</tr>
<tr>
<td>Zone 3</td>
<td>6.91</td>
<td>6.34</td>
<td>5.43</td>
<td>9.95</td>
<td>10.2</td>
<td>5.01</td>
</tr>
<tr>
<td>Zone 4</td>
<td>7.18</td>
<td>7.03</td>
<td>5.42</td>
<td>7.29</td>
<td>4.93</td>
<td>5.30</td>
</tr>
</tbody>
</table>

**Word use in writing at post test.**

A one-way repeated measures ANOVA was conducted to compare the word use in each zone (one to four) of post handwritten, post word processor and post Co:writer writing samples. The means and standard deviations are presented in Table 10. There were no interactions found in zone two = F(2,26) = .412, p=.667 or zone four =F(2,26) = 1.26 p=.300. There was an interaction found in the word use in zone one in post written samples = F (2,26)= 4.77, p=.017. A pairwise test was used to make post hoc comparisons between samples. Pairwise comparison indicated that there was a significant difference in the scores for zone one post word processor samples (M=41.7, SD=30.1) and zone one post Co:writer samples (M=59.3, SD=7.95). Pairwise comparison showed there was another significant difference
between zone three post word processed samples (M=5.43, SD=9.95) and zone three post Co:writer sample (M=10.2, SD=5.01). These results suggest that after the intervention students wrote with more varied words using Co:writer than they did using a word processor.
Chapter 5. Qualitative Results

Overview of Qualitative Results

In this section, I report the findings from the analysis of the intervention based field observations and the participants’ interview data. The data will be presented in the categories that best describe the overall representations of the data. These categories are supported by observations, interviews and relevant literature.

Interaction with Software

Keyboarding.

In both field observations as well as interview data the overarching issue of keyboarding skills was evident. There were many observation notes about the difficulty that participants had communicating with the keyboard. This resulted in lost writing time and frustration. “Hunt and peck” typing was observed on the part of all participants. Hunt and peck keyboarding habits result in a low typing speed (Perkins, 1992) and are the most basic and earliest form of typing. This was due to participants having no knowledge of where the letters were located on the keyboard. Participants’ pace of typing was also slowed by the interaction between keyboard and screen. Observations showed that on numerous occasions during a writing period participants would struggle to find the correct letter to match their initial letter sound; when this letter was found, the participant then spent even more time matching that letter to its representation on the screen. This interaction was often noted and brought up in participant interviews. Participant 1005 explained, “I don’t
like the computer for writing, I don’t like to use the keyboard and look at the screen.” That sentiment was echoed by the majority of the participants in the intervention sessions and collections of interview data. Participants also struggled with the universal or QWERTY set up of the keyboard. Interviews revealed that participants 1008 and 1013 felt, “the letters are hard to find” and said, “the letters they are all jumbled.” Most notably, the lack of keyboarding skill created a barrier to the transcription of ideas; as participant 1009 explained, “sometimes you can’t find the letter you are looking for and it’s tricky and you might forget what you were thinking.” Struggling to find the letters affected participants’ typing and enjoyment of the program and in some cases led to issues with text transcription.

**Trouble shooting.**

Problems with software and hardware in the intervention had a negative effect on the participants’ experience. Some problems were addressed in the week three, the word prediction continued session. Participants were specifically taught how to problem solve issues such as Co:writer going into sleep mode, and how to choose the word prediction style they preferred (paragraph, sentence or word box). In week four, the speech synthesis session participants were taught how to turn on speech synthesis, and how to check the sound on the computer, in Co:writer and in the headphones. However, the field notes are rife with descriptions of technical issues. These issues were generally found in two areas – software (the use of Co:writer and its components) and hardware (audio, sound and connection issues). When
participants used the software they generally found a type of word prediction at
either the word level, sentence level or paragraph level that worked for their writing
needs. However, some participants wished to go back and forth between types of
prediction. This was not available within the program, and numerous participants
were frustrated when Co:writer used their previous settings and would not allow
them to access a different type of word prediction. The software also became
problematic during pauses in participant writing. As participants temporarily halted
their writing, Co:writer would “go to sleep”. In both of these cases participants had
difficulty in trying to solve their software issues. The majority of the questions
asked in the lab area of the intervention sessions were regarding how to solve a
problem in the hardware or software. Participants would often stop when they
reached a problem and not continue writing until their issue was remedied. Similar
problems existed in regard to the hardware of the computer. In order for participants
to access the speech synthesis aspect of Co:writer it is important that the hardware be
working. Field notes indicated that participants who could not access their sound did
one of two things. They would continue without the benefit of speech synthesis or
they would stop writing and appeal for help from the researcher. In the majority of
cases participants made no attempt to solve the problem, although problem solving
was often as simple as pressing a button on screen to turn the speech synthesis on or
turning the dial on their headphones so they could access the sound.
This was an issue that was strictly recorded in the field observation notes; no interview data discusses that trouble shooting was a problem. It was noted that participant discussions during writing time touched on the fact that when Co:writer disappears it is “tricky” to write. The researcher noted that the participants did not glean full exposure to the program if they struggled with audio issues that were never resolved.

**Transfer.**

There was a transfer of knowledge from the intervention to other aspects of participants’ lives. Classroom teachers, the Special Education Resource Teacher (SERT) and parents commented on the transfer of use. One of the members of the intervention had asked the teacher if they could use Co:writer during a classroom based computer lab activity. When the teacher saw how the participant used the program she asked the researcher if she could show the entire class Co:writer. There were also other participants who used the program outside of the intervention. Another teacher commented that it was being used during their computer lab time as well. The SERT teacher also discussed how participants were using Co:writer in an academic resource time. The transfer of knowledge also went beyond the school, and participants were requesting that their parents buy Co:writer for home use. When the participants were picked up at the end of the day, one parent asked where they could purchase the software, and one parent who was a teacher at the high school level mentioned that she had requested the program be put on the computers.
of her high school. The transfer of use from intervention to their outside life was noted in both adult comments and participant use.

**Negative Attitudes and Feelings Toward Software**

**Less practice.**

The data presented some negative attitudes or feelings toward the software. Field notes and interviews revealed that the minimal exposure that these grade one participants had to computers in their early years perhaps contributed to some negative experiences. At the beginning of the intervention, participants had difficulty logging on to the school computers. This cost participants writing time and was very frustrating for them. As the intervention continued, participants generally were able to acquire the skill of logging in and this difficulty was mentioned less in the field notes. One skill that did not seem to improve with time was locating the path to find Co:writer and the word processing tool that was used with it. Notes continually mention participant frustration levels rising when they were not able to “find” Co:writer in the right folder.

Participants echoed their minimal exposure to computers in the third question of the interview. Often participants who reported that they would prefer to write with pencil and paper elaborated on their answer by explaining, “that’s what we use at school” (participant 1007) and “we don’t use computers in our class.” (participant 1029). It is clear that lack of exposure and practice with computers limited the enjoyment and use of Co:writer.
Voice of speech synthesis.

Participants had difficulty relating to the computerized voice used by the speech synthesis. Observations showed that many participants laughed and giggled after being introduced to the speech synthesis. For a few of these participants the amusement with the synthesized voice never dwindled. There are notes throughout indicating that the voice caused laughter or conversations. In some cases the laughter was replaced with confusion. Numerous times participants would explain that they could not understand what the voice was saying or that Co:writer had not predicted the word correctly. The synthesized voice was a barrier to writing for certain participants as they had difficulty becoming accustomed to it.

Participants articulated this issue in their interviews. Participants 1003, 1015, 1020 and 1023, made comments about the “funny voice.” A generalized concern over the computerized voice was the most common response; however, participants also mentioned that, “it says the words wrong” and “sometimes I don’t really understand the words the woman says.” The computerized voice caused some drawbacks when it came to student comprehension of the speech synthesis.

Positive Attitudes and Feelings Toward Software

Vocabulary.

Qualitatively, participants felt that Co:writer increased their written vocabulary. Observations indicated that this was also happening while participants were choosing words on screen. Participants would often say the word aloud while
typing it, but based on Co:writer’s suggestions change to another word. This was repeated by participants when they reflected on their writing in the interview period. Participants felt that Co:writer increased their written vocabulary. Participants often responded that Co:writer “helped me learn new words” (Participants 1004, 1006, 1011, 1015, 1016, 1025). Many participants described this occurrence in more detail, which allowed a glimpse into their written word acquisition. Student 1029 explained that, “I know a lot of words but I don’t know words like awesome and exciting so I can use those ones.” Participant 1016 explained that if a computer, “doesn’t have Co-writer and its hard words I won’t write it cause I don’t know the words.” These participants were explaining what Hiebert (2005) describes about written language acquisition and how written word use is often behind oral word use.

**Keystrokes.**

Assistive technology was originally designed in order for physically disabled persons to reduce the number of keystrokes needed to type (MacArthur, 1999, 2009; Montgomery & Marks, 2006). Observations and interview data show that this reduction of keystrokes had a dramatic effect on the majority of the participants in the intervention. Field notes often refer to participants commenting on how quickly Co:writer predicted their word. In the notes there are numerous exclamations of participants saying “Co:writer knew my word after (given number) of letters.” This reduction of keystrokes allowed the participants to feel as if they were able to write more quickly and with less effort.
Since each word required less effort participants felt as if they could write more. In the interviews participants repeatedly claimed, “I can write more” or “I don’t have to write as much”. Participant 1020 explained that, “sometimes I don’t even have to type” while participant 1012 said, “it’s pretty cool, it can spell excellent with only three letters.” Participants enjoyed the fact that the word prediction assisted their writing by reducing the amount of letters that were to be typed.

**Cognitive Load**

There are numerous factors that lead to increased cognitive load in writing. Field notes and interviews showed that the following factors were affected when using assistive writing software.

**Spelling.**

Spelling was an aspect of writing that put stress on participants’ working memory. This was obvious in the field notes and interview data. Observations recorded participants’ worry about correctly spelling words in both the pre and post handwriting samples. The researcher repeatedly reminded participants to sound out their words and focus on getting their ideas on the paper. This same concern about spelling was noted in computer lab observations as well. Participants often would not continue their writing if a word had a red line underneath it to indicate it was misspelled. This stress on spelling was also noted by the teacher whose student was using Co:writer in class. The participants’ reason for using Co:writer was that it
helped with spelling. The observations indicated that spelling was a major concern for participants while writing both with and without technology.

The participants themselves felt that while spelling was a concern for them, the assistive technology alleviated this anxiety. Participants generally commented at some point in their interview that “it helped them spell better.” Some participants went into detail about their spelling process and how the assistive technology aided in that process. Participant 1004 explained that, “it would help me know the words because if you’re stuck on a big word you would have to sound it out, without it [Co:writer] you might get it wrong.” In this quotation you can see the emphasis on “getting it right” which puts stress on working memory and limits the writing of young participants. Participants felt that Co:writer was helpful because it was able to use phonetic spelling as well. Participant 1024 summed it up this way, “it tells you what the word could be and how they spell it even if you spell the words wrong it gives you the right word.” The assistive technology alleviated some of the stress of spelling correctly during text production.

**Reading.**

Reading and writing are linked in text production (Bereiter & Scardamalia, 1987) as the writer reads what she or he has already written before composing another sentence. Co:writer’s speech synthesis alleviated some of this by allowing the writers to rely on the assistive technology to do the reading for them. This theme appeared in the field notes with various participants who could not choose a word
without earphones or the sound on to hear it. These participants were halted in their writing until the problem was fixed. Field notes also indicated that participants would listen to all of the word choices even if one was their obvious choice. One participant commented to the researcher “this way I learn to read all the words.” Since reading is linked to text production, the assistive technologies speech synthesis seemed to lessen the reliance on reading.

Interview data also indicated that participants felt they benefitted from the speech synthesis and the lower dependence on reading. One participant whose teacher identified them as a “non-reader” explained that speech synthesis will, “sound out the words I write, it’s good for my reading” (participant 1011). This student clearly valued the assistance that Co:writer offered. Other participants explained that they didn’t have to read the words back now or that they didn’t need to read what they wrote. Participants appreciated the speech synthesis and how it lessened their reliance on reading.

**Editing.**

Bereiter and Scardamalia describe editing as one of the most taxing aspects of writing for working memory (1987). In the intervention, field observations and interviews participants demonstrated the positive effect the assistive technology had on their writing. During the speech synthesis tutorial (session four) participants enjoyed writing sentences that did not make sense. As this activity wrapped up, participants were observed discussing whether their sentence made sense or not with
each other. Observations focused on some participants that used the Co:writer tool bar to ‘go back’ and fix a sentence if it did not make sense. This ‘go back’ button was not something that was taught in tutorial sessions. The use of the go back button showed participants revised their writing after they had heard it being read.

Participants also noted the assistance of speech synthesis in editing. Generally many participants responded that they enjoyed speech synthesis because they didn’t have to “read it over.” Re-reading is an expectation that is taught in revision, but re-reading written text for meaning can be a daunting task for participants who lack reading skills (Bereiter & Scardamalia, 1987). Participants felt that the speech synthesis was helpful in reading for meaning. Participant 1024 described that, “It’s good because then you can know if it [writing] makes sense or not.” The stress on reading for editing was noted in this comment by participant 1013, “I like it so I don’t have to read it over to see if it makes sense.” The cognitive load on working memory is evident in participant 1029’s response, “I feel happy because Co:writer says the words I wrote and it helps me remember what I writed.” Allowing participants to listen for errors in their writing, instead of putting the emphasis on reading for errors assisted participants with their editing skills.
Chapter 6. Discussion of Quantitative and Qualitative Data

In this chapter, I discuss the qualitative and quantitative data together. I provide a side by side comparison for merged data analysis (Plano, Clark, and Creswell, 2011). I present the quantitative data and the qualitative findings together so that their information may be easily compared and discussed. The quantitative data was examined first and the qualitative follows in a discussion of how the data either confirmed or differed from the quantitative results. I do this by addressing the research questions at the beginning of the research process and how the findings relate to the literature that exists. I then discuss how my research contributes to this area of the literature. I address the limitations of my study and how I attempted to counteract these limitations. Finally, I discuss the implications that my study has for future practice.

Research Questions

I address each of the research questions that I identified as the guidance for my research in terms of how each was answered by the results and findings of this study. I will begin with the two questions research questions:

1) How is the quality (length, sentence complexity, word use) of participants’ writing affected by the use of assistive technology?

2) How do participants interact with the assistive technology, how do they feel about its effect on their writing?
**Length.**

The quantitative data showed that in pre to post-test comparisons the mean length of participants’ writing did not increase in handwritten samples or word processed samples. Data did show that there was a significant difference when participants became used to writing at post-test with Co:writer assistive technology they were able to compose longer pieces of writing.

Quantitative analysis of the difference within the lengths of the writing samples at the pre test showed that participants had initially written less when writing with word processor or Co:writer. Within post test samples word processor samples were significantly shorter than handwritten and Co:writer samples.

Qualitative data from the participants supports this quantitative analysis. As discussed in the qualitative analysis, participants felt that Co:writer increased their ability to write longer pieces. The positive effect of Co:writer on length was often coupled with the idea that participants felt they could write more with fewer keystrokes. These findings are consistent with the literature that assistive technology was created to assist persons with physical disabilities in composing longer pieces of writing with fewer keystrokes (MacArthur, 1999, 2009; Montgomery & Marks, 2006).

The field notes and participant interviews also provided qualitative support for the decrease in length of writing when using a word processor without the assistive technology. There were no participants who wanted to use a word
processor without assistive technology when given the choice in the third interview question. This reinforces the quantitative data that indicates a negative effect on length of the writing sample at post-test when participants’ returned to the use of a word processor after becoming accustomed to the support of word prediction and speech synthesis while writing.

The technological issue of minimal practice that participants discussed qualitatively confirms the data that were found in the analysis within the pre-test analysis. Participants initially wrote much longer pieces when composing handwritten text. This could be due to a lack of practice participants had experienced writing in a computer-based setting. In Bangert-Downs 1993 metanalysis of writing technologies, they found that longer studies were found to have higher effect sizes. This finding lends itself to the idea that the longer participants use a piece of technology the better they become at using it. MacArthur (2009) discusses the fact that participants will struggle without regular writing practice in a computer based setting. Students felt that they wrote longer pieces with Co:writer and this was echoed by the findings that they did write longer text when using Co:writer.

**Sentence complexity.**

The quantitative data showed that in pre to post comparison, the mean percentage of syntactic complexity in participants’ writing did not increase in handwritten or word processed samples. Data did show that when participants
became used to writing with Co:writer assistive technology they were able to generate more complex sentences.

Quantitative analysis at the pre-test for sentence complexity within the writing modalities showed that there were no significant differences. However, the within analysis of writing modalities at post-test found a significant difference in sentence complexity when using Co:writer.

Qualitative data from the students does not discuss the sentence complexity of their writing, this is not surprising with grade one students as this is not part of grade one instruction. However, participants commented on Co:writer’s positive effect on their spelling, reading and editing. This may be due to the decreased cognitive load that may have allowed participants to create more complex sentences. McCutcheon’s (1996, 2000) capacity theory postulates that practice leads to more automatic processes. She explains that the resources that were once used by the now automatic process can be freed and used by other processes. This effect may have allowed them to devote more resources to the content of their sentences. MacArthur (1999), Mirenda (2006), and Montgomery (2006) all found that word prediction reduced spelling errors and increased production of more complete sentences. When participants write they must focus on reading, evaluating meaning and detecting problems; these put stress on working memory causing the content of writing to break down (Bereiter & Scardamalia, 1987; MacArthur, 2009). Taking the burden away from reading and editing could have also helped to improve the content of participants’ sentence writing.
Co:writer may have lessened the burden of editing as discussed above but it is not a magical cure for editing. It allows students to access some of the resources needed for editing, but Co:writer alone does not create students who always edit their work or edit their work effectively. It is also possible that the above results may have been due to the instructional design of the intervention. As the instruction included prompts for writing and the researcher encouraged the participants to record their work to see if it made sense, these may have contributed to the results. Thus, it is not known if Co:writer in and of itself contributed to the editing of the writing or if it was also influenced by the design as the two were not studied separately.

**Word use.**

The quantitative data showed that in the pre to post test comparison of the mean percentage of words used in the four different zones there was only a significant difference in the words used in zone three and four during handwritten samples and zone four during word processed samples. There were not significant differences found between the percentages of word use in each zone when analyzing Co:writer samples.

Quantitative analysis of the difference within word use at the pre-level showed that there was a positive difference in the words used in zone four of Co:writer samples. Within the post analysis there was a significant difference found between the zone one word use with Co:writer samples versus word processed samples. There was also a significant difference between Co:writer and word
processed samples in zone three word use, showing that students using Co:writer used more varied words than in a word processor sample.

One possible explanation for this difference in word use was an unforeseen difference in the lexicon that surrounded the differing tag games played as a prompt for writing pre and post samples. While the games were similar in rules, norms and both were familiar to the students’, they had differences which led to unanticipated changes in the words used in students written samples. The initial tag game that students played as a prompt for pre-test writing was animal tag, this game was an individual game in which students were to freeze their choice of animal. Students wrote about the one animal they chose and discussed the rules, norms and any other exciting ideas. Conversely, the final tag game was a game that included students working in teams to create a hot dog and two buns to become unfrozen. The teamwork and interaction with other participants prompted expressions and wording. These differences could have created the variation in word use amongst the samples.

Another justification for the varied results in the word use findings could have been the order in which the students wrote their samples. After each of the prompts the students wrote first by hand, then used keyboarding on the word processor, and finally wrote samples with Co:writer. Students were asked to write about the same prompt activity; this could have led students to write with less enthusiasm and detail in the second and third writing tasks (word processor and Co:writer). This could explain the higher means for word use found in the handwriting samples.
The minimal negative difference in the pre to post co:writer samples may be explained using data found in two other analyses. Initially in the within modalities analysis, there was a significant difference found when students wrote with Co:writer; they used more words in zone four than any of the other samples. This jump could be explained by the novelty factor. Students were initially excited to use Co:writer to write ‘big words’ that were predicted by the software. However, the pre to post sentence complexity analysis showed that there was a significant difference when students used Co:writer; at post-test they were able to create more complex sentences. This suggests that while students were excited by using more difficult words initially they may not have been using them to construct as coherent sentences at the pre-test. When students became familiar with the uses of Co:writer the novelty may have worn off. Students could have then used the assistive technology to construct more complex sentences with more effective word choices. While these choices were not always in the highest word zones, the word use was more cohesive within the complex sentences they were producing.

With no control group the change in word use is most likely a result of development, as it is not possible to look at a separate group of equal students. Research indicates that the lack of a dramatic increase in written vocabulary could be attributed to the development of the participants. Hayes (1998) described that oral language and writing have different time constraints. This is echoed by Biemiller and Boote (2006), who explained that “vocabulary is affected by age but not by
school experience in the primary years. Thus, the average vocabulary of relatively “old” kindergarten children and “young” Grade 1 children is similar. (They differ in school experience by a year, but in age by 1 or 2 months.) Similarly, the average vocabulary of old Grade 1 children and young Grade 2 children is also about the same” (p.45). The development of the participants may have had as much to do with their written vocabulary as the intervention.

However, while there was minimal change in the word use students felt that there was a positive effect on their word use when writing with Co:writer. Participants had the impression that Co:writer had an effect on their vocabulary. They spoke positively about the ‘new words’ they were learning and writing. While the data does not support a direct improvement from pre to post test with the use of Co:writer, students benefitted from the positive impression of their word use.

**Qualitative Data**

Above, I addressed questions one and two as the questions that guided my research. The majority of the qualitative findings were discussed above in the side by side comparison of merged data analysis (Plano, Clark & Creswell, 2011). There were some qualitative findings that stand independently and could not be discussed in connection with the quantitative data. This qualitative results section will be broken into three sections: the interaction with software, participants’ feelings about its effect on their writing and design for instruction.
Interaction with the software.

Participants’ interaction with the software revealed dualistic views about the assistive technology. On the one hand, participants struggled with the use of the software, yet on the other hand there seemed to be a transfer of use to other areas beyond the intervention. Keyboarding and troubleshooting seemed to pose the most difficulties in the study. Difficulties with keyboarding were noted in the field notes and discussed in the participant interviews. Recent studies also found keyboarding to be a major struggle for participants beginning to use assistive technology. Specifically, studies have found that poor typing skills are a barrier to participant writing (MacArthur, 1999, 2009; Mirenda, 2006). When the keystrokes are reduced this frustration with the keyboard becomes diminished for participants. MacArthur makes the recommendation that participants be giving typing instruction to diminish the effect of poor keyboarding skills on writing interventions. Participants had difficulty interacting with the assistive technology in large part due to their lack of keyboarding skills.

The usability of the software was also found to be an unhelpful aspect of the interaction with the software. Boone (2007) warns about the usability of software programs. Participants struggled with this issue as described in field notes and discussed in interview questions. Participants found that some aspects of Co:writer were not always user friendly, such as the log on procedure, duration before it went to sleep, and the transcription of sentences in the sentence window. This led to issues
with trouble shooting and often to lack of use of the software. Montgomery (2006) echoes this sentiment regarding frustration over software usability stating that, “when selecting software, educators should choose user-friendly programs that have the features necessary to enhance the skills of their participants” (p. 36). At their young age these participants initially had difficulties interacting with the interface of the program. As the intervention went on participants began to learn how to trouble shoot; however, the interface was still an issue for many. Participants’ interaction with the software was hindered by the unfriendly interface and participants’ unfamiliarity with keyboarding.

Positively, the interaction with assistive technology went further than the intervention. There were many reported incidences of participants who used the software in other settings. This transfer of use from the intervention to other areas of their lives showed that the interaction was not always negative and participants were enjoying the use of Co:writer.

**Feelings toward assistive technology.**

Participants displayed both negative and positive feelings toward the assistive technology and the effect it had on their writing. Participants were frustrated by the voice of speech synthesis. This was an issue that was voiced in the qualitative interviews and field observations. It has been found previously that the synthesized voice can be difficult for children to become accustomed to (MacArthur, 1999; Montgomery, 2006). Boone (2007) warns that sometimes, “educators are so
impressed by the text-to-speech capabilities of screen-reader software that they just accept the fact that the speech is difficult to understand” (p. 137). The voice of speech synthesis is a significant issue with speech synthesis software. Finding a more realistic voice would create a more positive experience, especially for younger participants.

Participants found that there were numerous positive effects on their writing. When given the choice of writing with paper and pencil, word processor or Co:writer, 15 of the 27 participants chose to write with Co:writer. The majority of the participants who chose to write with a pencil and paper cited that they had more experience using it in their classroom as a reason for choosing it. Among the positive reactions voiced, participants cited an improvement in their written vocabulary, assistance with spelling, less keystrokes to produce longer texts, less reliance on reading and assistance with editing texts.

Participants felt that Co:writer had an effect on their vocabulary. They spoke positively about the ‘new words’ they were learning and writing because of the word prediction and the speech synthesis. Hiebert (2005) explains that oral and written vocabularies often differ in childhood. In this study, participants found that they were finally able to write the words they already knew how to say. Montgomery (2006) also found that “word-prediction programs provide correctly spelled word choices, decreasing the spelling demand placed on participants during the writing phase and allowing participants to compose at a level commensurate with their oral
expressive language ability” (pg. 34). Participants found the word predictive software was encouraging for their written vocabulary and also helped with their spelling as mentioned above. Mirenda (2006), MacArthur (1999) and Montgomery (2006) found that the Co:writer also had a positive effect on participant spelling and vocabulary acquisition.

Participants also expressed enthusiasm toward the word prediction as it lessened the amount of typing they needed to do to produce words. Mirenda (2006) found that Co:writer resulted in significantly longer lengths of consecutive correct word sequences. My participants found that they were able to write more while typing fewer letters. This served as great motivation for participants and was evident in both field observations and interviews.

As reported above, participants particularly felt that Co:writer affected their reading for comprehension and editing. This was a specific attribute of the speech synthesis feature. Participants explained how they did not have to re-read texts and how that assisted them in reviewing their writing. As discussed above, reading for comprehension and errors makes the editing process difficult. Participants enjoyed the assistance provided by the speech synthesis.

Overall, participants found there to be many positive benefits from the software, and they felt it had a positive effect on their writing. They found both word prediction and speech synthesis equally helpful in their writing.
Design for instruction.

While in much of the thesis I discuss the effects of assistive technology on students’ writing and in their qualitative responses, it is important to note that there was a design to this intervention that also included instructional techniques and activities. The prompts for writing and instruction were embedded in a meaningful way in the design for instruction. The prompt activities, feedback from researcher, and instructional tips and techniques may have contributed to the findings of the study. It is possible that some of the findings could be from the elements that were embedded in the design of the instruction and not from Co:writer itself. This on-going instruction was not an addition to the study; rather, instruction was scaffolded through meaningful tasks to inspire a purpose for writing, active engagement, and rich teaching and discussion.

Also embedded in the design was a purpose for writing. Students were given an authentic activity to create a purpose for writing. This purpose could have become a motivational factor and increased students’ desire to write. The purpose of the researcher could have also been a factor in the students’ writing outcomes. The researcher continually discussed the process of developing as a writer. The purpose of the researcher to assist students in learning the assistive technology and to grow as writers may have encouraged students to think of their purpose for writing in a new way.

Limitations

One of the limitations of this study is the lack of a control group. While I initially attempted to include a control group, this design was not approved by the
principal, in order to do the study I could not include a control group that did not get
the intervention. A design with delayed treatment was not possible as data collection
was within the last three months of school. Due to this limitation it is difficult to
determine whether my findings could have been influenced by the maturation of the
participants over the eight weeks without a control group to provide a developmental
control. Therefore, the findings of the study cannot be generalized beyond this
specific context. However, based on the findings, the fact that this area of research
is largely unstudied, in addition to the positive effects I found, show that further
research will be very important in determining the impact of assistive technology on
young, mainstream writers.

There are limitations in what I have found due to the design of the study. While I cannot be sure about the causal effects of the study, the fact that there were
some effects found in such a short timeframe is an indication that there is a benefit to
using assistive writing technology with young mainstream populations. While the
study was conducted for eight weeks (a total of 16 hours) actual time spent in
instruction and writing practice was only approximately ten hours. With four hours
lost to data collection, and time spent providing snack and prompts for writing,
students were still able to glean a benefit from the intervention in the short ten hour
time period. Although it is not surprising that minimal effects were found based on
this time frame, the fact that there was any kind of difference is positive.
Another limitation to my study is the small sample size of 27 participants from one area which is mostly comprised of high socio-economic families. To make the most valid selection from this group, participants were chosen from various Grade 1 classes, and a random selection of those participants were chosen to participate in the sample.

One of the most noticeable limitations is the effect of keyboarding as a confounding variable. Embedded within the design of the study, keyboarding in a word processing environment was not given the same profile as the Co:writer. While handwriting continued to be used daily in school activities, keyboarding on a word processor was not required by either setting (the intervention or school). With this design, it is not surprising that there were minimal effects found with participants’ word processing quantitatively or qualitatively. A word processing condition may have given more insight into the actual effects of Co:writer. However, inherent in both of these technology based writing tools is the confounding issue of keyboarding skills. It is possible that the results of the study were a consequence when the students didn’t have any instruction in keyboarding. Diminishing the keyboarding impact by providing students with keyboarding instruction may have resulted in different findings. Nevertheless, in both word processing and Co:writer, typing remained an unmeasured variable. As discussed above, keyboarding skill was diminished with the use of Co:writer; however, it was not negated. Assistive technology does lessen the impact of keyboarding skills, however it is imperative to
provide keyboarding instruction whether using a word processor or assistive writing technology. Assistive technology can initially lessen the burden of heavy reliance on keyboarding skill as an interim instructional strategy for writing. In this study, it was seen that regardless of typing skill the assistive technology did create a willingness to write and a confidence that cannot be discounted. This technology could also become a gateway to writing while students master keyboarding skills.

Finally, as a graduate participant, I am an inexperienced researcher, which is also a limitation to this study. However, I was guided by my workplace knowledge as a teacher of grade one participants as well as by my committee members. My committee members have extensive research and technology experience, and they provided me with feedback about my research throughout the process.

Contributions

This study builds on the existing literature that surrounds the use of assistive technology to aid writing. Much like the studies of MacArthur (2009), Mirenda, et.al. (2006), Tumlin and Heller (2004), Williams (2002), Zhang (2000), Chernek and Wollak (2009), Gilette (2006), and Parette, Crowley and Wojcik (2007), I have aimed to look at how assistive technology affects the content of participants’ writing. This study is unique amongst the literature as it researched the use of assistive technology within a mainstream population of early writers. Both the mainstream and early writing aspects of the research are largely unstudied and quite novel. Within the constraints of this study I have shown that assistive technology can be
used with a younger population to improve the content of their writing. The data
shows that within this study participants improved the length and sentence
complexity of their written samples. Moreover, qualitatively, participants felt that
the software helped to improve their vocabulary, length, spelling, reading and
editing.

**Implications for Future Practice**

This research has implications for two different levels of practice - the
classroom or school setting and a research setting.

In the classroom and school setting, this research provides evidence that
there is a positive effect gained from exposing young writers to assistive technology.
The data shows that in the context of this research participants had improvements in
the content of their writing and found it to have had a positive effect on their writing.
This gave participants motivation to write in a new and different way. Based on the
findings of this study I feel that in classroom practice there are many implications.
As seen in the qualitative data, early exposure to technology and computers is
important. In the study students were not able to glean all of the benefits because of
the minimal ability logging onto and maneuvering around the computer interface.
Teaching students basic troubleshooting techniques will allow them to experience
less frustration with the computers.

As mentioned above, keyboarding experience was a confounding factor that
limited students writing results and posed a high level of frustration. Allowing
students to learn how to keyboard will lessen the effect and allow students to create pieces of text more freely.

While assistive technology is positive for students, teachers hold the key to accessing this software. Teachers must be made aware of the assistive technology that is available to students. Providing teachers with the proper information and training about how assistive technology can support students in their writing could create a more encouraging environment for writing. When teachers have the information they may begin to train their students on the software. Teaching teachers about the benefits of using assistive technology in the mainstream classroom may empower all learners, instead of singling out students who ‘need’ it, by providing universal access. When teachers learn about the assistive technology that is available they can then provide training to their students. Teachers should be allowing students to use this as a tool to assist with their writing. Providing instruction on the varied assistive technologies available will allow students to see assistive technology as a choice that they can make to help themselves grow as writers. This can be incorporated in a classroom as easily as scribing, or providing a primary versus traditional pencil to students. When students begin to see that assistive technology is a choice for all writers and not just a specialized few, assistive technology will become a mainstream option. It is my hope that this study will provide an opportunity for mainstream students to be able to use assistive
technology. This may diminish the stigma that can often become associated with the use of assistive technology in the classroom today.

This study has also shown that there are some positive effects to assistive technology being taught in an engaging way. The instruction built into this study may have had a positive benefit on the writing of the students. Teaching students how to use assistive technology with meaningful prompts and activities allows the students to have a positive purpose for writing. When assistive technology is taught in an exciting way it allows students to glean more positive effects than if it is taught on a computer with no reason or motivation to write.

Regardless of statistical significance, students indeed perceived that there was a positive effect on their writing. This went beyond the level of the technical aspects of writing and offered students motivation to write and a platform that allowed them to write with more confidence. The tool itself may have a feedback effect in motivation to write; it can be used to lessen the burden of writing, scaffolding the students’ writing experiences and providing support for more complex word use and sentence structure. There is a compounding effect with the use of assistive technology; if students are more successful it provides a boost to engagement and a positive reason to write.

For a research-based setting, this study lays some groundwork for more research into how young mainstream participants use assistive technology in their writing. Aspects identified for classroom practice are all avenues that could be
studied. Research that includes keyboarding instruction as part of the research design would clarify its role in the use assistive technology with young writers. Teachers’ instructional role in using assistive writing technology with young mainstream writers needs to be carried out. As well, the possible positive effect of assistive technology for motivation and self-efficacy beliefs of young writers could be examined.

For this study, I researched just one type of assistive technology. However, there are many products that could also have an effect on students’ writing. Looking at the combination of assistive technologies that are available and the differing uses of the technologies would be an exciting study. Assessing how different technologies support students in different ways and if some are better than others would allow researchers to point students toward the software that might be most helpful for them. This type of research would provide valuable feedback to developers of assistive technology who could begin to tailor their products to the needs of students and teachers.

As described in the study, student’s affective response to assistive technology was a major effect. While the assistive technology was intertwined with the instruction in this design, teasing out the two would provide for influential research into what role assistive technology plays, and the effect of instructional strategies. How does the instruction affect student engagement and motivation versus the
assistive technology? It is crucial to separate the two and determine the impact of each.

The positive effect that was found both quantitatively and qualitatively shows that there is much promise in the research of young writers and their use of assistive technology in a mainstream setting.
Appendix A

Description of a How a Topic Was Covered Over Two Sessions

<table>
<thead>
<tr>
<th>Session</th>
<th>Minutes</th>
<th>Activities</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>30 min</td>
<td>Teach Co:writer - topic dictionary function. Students add origami to the topic dictionary and practice to see if the word comes up while writing it.</td>
</tr>
<tr>
<td>1</td>
<td>10 min</td>
<td>Nutrition Break – students eat snack provided by their caregivers</td>
</tr>
<tr>
<td>1</td>
<td>20 min</td>
<td>Activity/Prompt – while led by researcher students learn how to fold an origami frog together. They fold two frogs one that is big to practice the folding technique without stressing fine motor skills. The small frog they try to fold in partners with less instruction from the researcher. Students write names on their frogs for next session. For instructions to fold a frog use this website - <a href="http://www.frogsonice.com/froggy/origami/">http://www.frogsonice.com/froggy/origami/</a></td>
</tr>
<tr>
<td>2</td>
<td>10 min</td>
<td>Revisiting Prompt and Co:writer – Researcher hands back frogs to students for them to play with. Together they create one last huge frog and discuss other words they might add to the topic dictionary that are linked to their prompt.</td>
</tr>
<tr>
<td>2</td>
<td>20 min</td>
<td>Write About Prompt – Students write about prompt using new skills practiced in previous session.</td>
</tr>
<tr>
<td>2</td>
<td>15 min</td>
<td>Snack and Talk – Researcher discusses with students how their writing is going.</td>
</tr>
<tr>
<td>2</td>
<td>15 min</td>
<td>Return to Writing – Students complete writing about their frogs on their computer.</td>
</tr>
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</table>
References


