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TUTORING BILINGUAL STUDENTS WITH AN AUTOMATED READING TUTOR THAT LISTENS*

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ABSTRACT

Children from non-English-speaking homes are doubly disadvantaged when learning English in school. They enter school with less prior knowledge of English sounds, word meanings, and sentence structure, and they get little or no reinforcement of their learning outside of the classroom. This article compares the classroom standard practice of sustained silent reading with the Project LISTEN Reading Tutor which uses automated speech recognition to "listen" to children read aloud, providing both spoken and graphical feedback. Previous research with the Reading Tutor has focused primarily on native speaking populations. In this study 34 Hispanic students spent one month in the classroom and one month using the Reading Tutor for 25 minutes per day. The Reading Tutor condition produced significant learning gains in several measures of fluency. Effect sizes ranged from 0.55 to 1.27. These dramatic results from a one-month treatment indicate this technology may have much to offer English language learners.

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INTRODUCTION AND MOTIVATION

Of the many challenges facing public schools today, one clear area of concern is how to meet the growing demand to educate our country's rising population of students from non-English-speaking households. Slavin and Cheung (2003) identify reading instruction for English language learners[1] (ELLs) as "one of the most important issues in all of educational policy and practice." A surprising 20% of all U.S. students come from homes where English is not the primary language spoken (Van Hook & Fix, 2000). This population continues to grow at an overwhelming pace. From 1991-92 through 2001-02 ELL enrollments rose 95% compared to a 12% growth in total K–12 enrollment. This signifies an ELL growth rate of nearly eight times that of the general student body (Padolsky, 2002). While this population represents a wide range of language groups, roughly ¾ of all English language learners come from Spanish speaking homes (Moss & Puma, 1995; Ruiz de Velasco & Fix, 2000; Zehler et al., 2003).

Not only is this population growing, but also their achievement levels continue to lag far behind their native English-speaking peers. Third grade ELL students rank in the 30th percentile for reading, with 16% of this group receiving a grade of unsatisfactory in reading compared to only 7% of native English speakers (Moss & Puma, 1995). School district coordinators report that 76% of third grade English language learners were either below or well below grade level in reading (Zehler et al., 2003). The National Center for Education Statistics find that a mere 7% of LEP fourth graders were at or above the Proficient level and only 28% reached the Basic level for reading achievement within nine major urban school districts sampled (NCES, 2003).

Research overwhelmingly indicates that current educational practices are not meeting the needs of this population. Guerrero and Sloan (2001) cite a large body of research indicating lower achievement levels for minority-language children (predominantly Spanish speaking) and conclude that this group has an increased risk of poor literacy in both their native and second languages (see, Arias, 1986; Congressional Budget Office, 1987; De La Rosa & Maw, 1990; Durgunoglu, 1998; Haycock & Navarro, 1988; Kao & Tienda, 1995; Orfield, 1986; Verhoeven & Aarts, 1998).

Under the present political environment, this issue is becoming even more critical. The No Child Left Behind Act of 2001 (NCLB) has placed demands on school districts to meet Adequate Yearly Progress goals for all subgroups including English language learners. In fact, Title III of this legislation (Language Instruction for Limited English Proficient and Immigrant Students) is devoted specifically to the need to raise the achievement levels of our nation's English

[1] In the literature, the terms, "Limited English Proficient" and "English Language Learner" are used somewhat interchangeably. Following the convention of August and Hakuta (1997) we adopt the term English Language Learner or ELL whenever possible as it carries a more positive tone.

language learners. Those schools that fail to meet goals for this or any other subgroup over three consecutive years will face sanctions (NCLB, 2001). Clearly, a top educational priority must be to reduce the gap between English language learners and their native English speaking peers. While NCLB places strong demands on performance and accountability, it does not legislate the methods that schools must use.

In the area of reading pedagogy, a great deal of research has centered on the language of instruction. This research can be divided into two broad categories; one supporting the use of native language instruction initially and then transitioning students to English and the other supporting instruction based in English-only immersion. Although there are extensive findings on both sides of this paradigm (see August & Hakuta, 1997; Chu-Chang, 1981; Seder, 1998; Slavin & Cheung, 2003, 2004; Thomas & Collier, 2001), one conclusion that seems common among research reviewers is that instructional practices may in fact have greater bearing on achievement than the language of instruction (August & Hakuta, 1997; Slavin & Cheung, 2003). Unfortunately, there is little agreement on which instructional practices are most effective for this population. August (2003) specifically identifies "a desperate need for more theoretically-driven research that employs quasi-experimental designs and high quality assessments to examine the effectiveness of instructional practices designed to bolster the literacy of English language learners."

Technologically based reading interventions are specifically cited as an area where future research is needed. August (2003) identifies the use of technology to support ELL literacy education as one of two areas particularly worthy of research efforts, noting its ability to both teach and assess component literacy skills. The National Reading Panel identifies the use of speech recognition technology in reading instruction as an area in need of further research (NRP, 2000). The use of technology and electronic texts has been observed as an important component in K–8 grade ESL classrooms (Meskill, Mossop, & Bates, 1999). Finally, ESL teachers report that their students are both highly motivated by the use of computers and that they perceive higher social status with the mastery of computer skills (Meskill & Mossop, 2000).

In response to this driving need for research to identify better tools and methods to help English language learners, this research seeks to provide some initial findings on the efficacy of one particular computer-based tool for reading instruction, the Project LISTEN Reading Tutor.

BACKGROUND

The Project LISTEN Reading Tutor has been an ongoing area of research at Carnegie Mellon University since 1992. Its development has been research based and has centered on modeling expert teachers (Mostow & Aist, 2001; Mostow et al., 2003a). Since its inception, the Project LISTEN team has compiled an

extensive body of research indicating the technology to be an effective tool for literacy instruction within various populations of native English speaking children (Aist, 2002; Aist et al., 2001; Aist & Mostow, 1997; Mostow et al., 2003a; Mostow & Aist, 2001; Mostow & Beck, 2003).

The Project LISTEN name is based on the acronym "Literacy Innovation that Speech Technology ENables." Central to the pedagogy of this tutor is its implementation of the Sphinx II speech recognition engine. This technology enables the Reading Tutor to analyze children's oral reading, track their place within the context of a story, and provide feedback to children both preemptively and in response to difficulties they encounter during the oral reading task (Mostow & Aist, 2001). The software is implemented on standard Windows computers and utilizes inexpensive headphones with a noise-canceling microphone. Although a complete description of the research basis and findings of Project LISTEN is beyond the scope of this article, we include below a brief summary. Details can be found at: http://www-2.cs.cmu.edu/~listen/research.html.

- A 1996-97 pilot study of six third-grade children who pre-tested at approximately 3 years below grade level identified an average two-year gain in reading level pre- to post-test while using the Reading Tutor during the eight-month study as measured by school administered reading inventories (Aist & Mostow, 1997).
- A 1998 within classroom controlled study of 72 second, fourth, and fifth graders compared the Reading Tutor to regular instruction and commercial reading software over a four-month study. The Reading Tutor group significantly out-gained the regular instruction control group in Passage Comprehension as measured by the Woodcock Reading Mastery Test (WRMT). No significant differences were recorded between groups for Word Attack, Word Identification or oral reading fluency (Mostow et al., 2003b).
- A 1999-2000 between classrooms controlled study of 131 second and third graders from 12 classrooms compared daily usage of the Reading Tutor to daily human tutoring by a certified teacher and to a regular instruction control group within each classroom. Results from the year-long study indicated that children assigned to the Reading Tutor condition as well as those children assigned to the human-tutor condition significantly out-gained control in word comprehension and suggestively in passage comprehension. The human tutored group significantly out-gained the Reading Tutor group in Word Attack only. No significant differences in gains for Fluency and Word Identification were recorded (Mostow et al., 2003a).
- A 2000-2001 study of 178 children from grades 1 through 4 at two schools compared 20-minute daily treatments of the Reading Tutor to the standard practice of 20 minutes sustained silent reading over a seven-month study. The Reading Tutor group significantly out-gained a statistically matched SSR group in word identification, word comprehension, passage

comprehension, fluency, phonemic awareness, rapid letter naming, and spelling measures. Most of the significant gains were observed in grade 1 (Mostow et al., 2002).

- A 2002 pilot study of 35 Canadian English language learners ranging from first to sixth grade investigated the usability of the Reading Tutor for ELL's. Participants represented three different native languages: Tamil, Mandarin, and Cantonese. Results indicated that roughly 86% of participants were able to effectively interact with the Reading Tutor. However, questions were raised as to whether the ELLs would be able to benefit from the Reading Tutor in its current form (Li, 2002).

The primary goal of this research was to build on to the results presented by Li (2002) and determine if English language learners would demonstrate measurable gains in reading skills as a result of reading instruction that includes regular use of the Project LISTEN Reading Tutor.

Reading Activities

All Reading Tutor sessions begin with the student logging in to the system by selecting their name and birth month from talking menus. When students log in for the first time, they are presented with an initial reading activity that also serves as a basic tutorial. Students are walked through the simple controls for the tutor via a story featuring a mouse named Kyle, who in the context of the story is also learning to use the Reading Tutor. This tutorial focuses on learning navigation controls, understanding when the student is expected to read aloud, and how to get help from the tutor on difficult words. Two other "tutorial stories" are presented to the students at later times, one on how to use the keyboard and the other on how to write and narrate a story within the Reading Tutor environment.

After completing the initial tutorial, students begin taking turns with the Reading Tutor to select the next story to read. This alternating choice approach was first implemented in the 1999 version of the Reading Tutor in order to address a pattern where students were repeatedly selecting the same easy stories (Aist, 2000; Aist & Mostow, 2000; Mostow et al., 2003a). When it is the student's turn to pick a story, the tutor suggests an appropriate level and the student is free to choose any story at that level or select a story from any other level. The number of times a student has read a particular story is displayed alongside each story title in the menu. When it is the tutor's turn, a previously unread story is selected at the student's current recommended reading level. The recommended reading level is continuously assessed and adjusted by the tutor based on the student's oral reading rate (Aist 2000; Jia, Beck, & Mostow, 2002; Mostow & Aist, 2001; Mostow et al., 2003a).

Figure 1 shows a typical screen during the assisted oral reading task. Sentences (or phrases) are displayed one at a time for the student to read. Words that have been accepted by the tutor are highlighted as the student reads them. The Reading

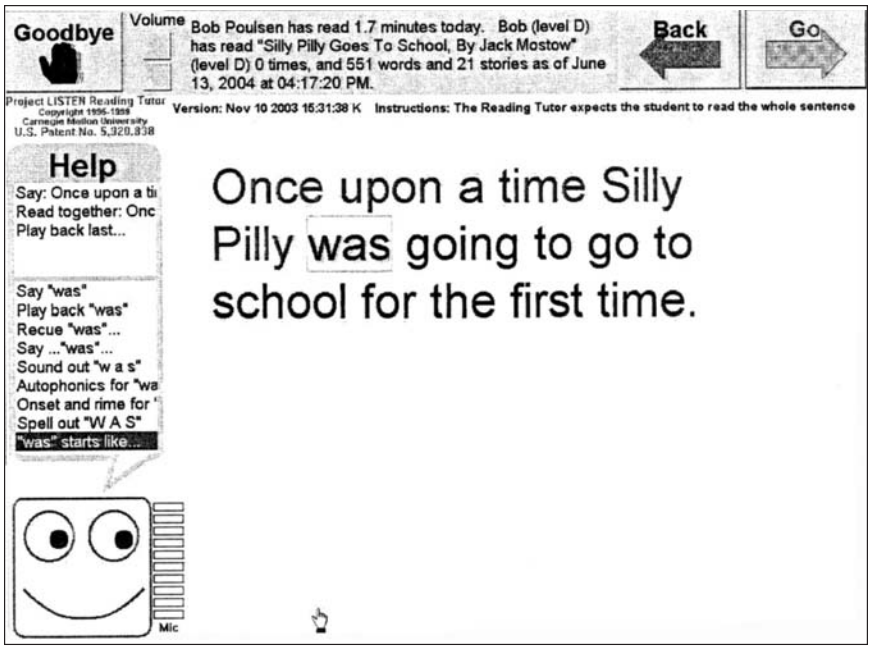

Figure 1. Screen capture from the Project LISTEN Reading Tutor.

Tutor provides assistance whenever it detects a long pause, a skipped word, a seriously misread word or preemptively for difficult words (Mostow & Aist, 2001; Mostow et al., 2003a).

Students can also request help from the tutor by simply clicking on a word. The Reading Tutor provides assistance in one of the following forms:

- speaks the whole word aloud
- re-cues the word by rereading the sentence leading up to (but not including) the word
- decomposes the word into syllables, onset and rhyme, or phonemes (speaking each component while highlighting it)
- displays and reads a different word with the same onset or rhyme (e.g., for "lump" it might display "jump" while saying "rhymes with jump")
- display a picture (e.g., display an apple for the word apple)
- play a sound effect (e.g., a roar for the word lion)

The last two interventions are only available for a small set of words and are therefore rarely used. When more then one of these interventions is appropriate, the tutor chooses randomly between them (Aist, 2002; Mostow et al., 2003a).

To support comprehension, the Reading Tutor also provides whole-sentence help in one of two forms. It either reads the sentence fluently or it reads the sentence one, word, at, a, time while asking the student to read along. Words in the sentence are highlighted as the tutor reads them. This type of support is provided whenever the student requests it (by clicking on the screen below the sentence), when the student has difficulties on multiple content words, when the tutor detects long pauses between words or preemptively for sentences containing difficult words (Aist, 2002; Mostow et al., 2003a). For most words and sentences, the Reading Tutor "speaks" using recorded human voices as opposed to computer-synthesized speech.

HYPOTHESES

The fundamental hypothesis of this study is that use of the Reading Tutor will improve reading ability within a population of English language learners. Current reading research concludes that, due to limitations on human memory, attention, and cognitive processing, students must automatize word decoding before they can concentrate on the structure and meaning of sentences. The Reading Tutor acts primarily at the level of word decoding. Therefore, our hypothesis was that using the Reading Tutor would lead to learning gains primarily on the sight word and fluency measures. Comprehension gains would depend on the extent to which gains in fluency liberate cognitive resources for the higher level tasks.

EXPERIMENTAL DESIGN

The participants in the study were recruited from a Chicago area suburban school where the first author volunteered as a reading tutor for children attending both traditional and bilingual classes. The school enrollment of almost 600 students is made up of approximately 51% Hispanic, 35% Caucasian, 4% African American, and 10% Asian/Pacific Islander. Thirty-six percent of the students are enrolled in the school district's bilingual education program, and 36% of the student body is designated as low-income (ISBE, 2003). All students enrolled in the bilingual program in grades two, three, and four at the school were invited to participate via a consent agreement sent home with the children. The consent form was distributed in Spanish as many of the children's parents have a very limited capacity to read in English.

The consent agreement indicated that all students who wished to participate would need to stay after school for one hour Monday through Thursday. This was because the school district had initially agreed only to allow the study outside of regular classroom hours. This requirement may have reduced the number of children who volunteered to participate, although no measure of this was collected. After the completion of pre-testing and assignment to groups, a transportation issue caused the after school aspect of the treatment to be cancelled and

the study treatments were rescheduled to occur Monday through Friday during the classroom's daily scheduled silent reading time.

Subjects

All students who replied to the consent letter were admitted into the study except for nine students who were concurrently enrolled in a peer-tutoring program. Because of scheduling conflicts between the two programs, it was decided that those children enrolled in peer tutoring would not be eligible for this study. We also intended to screen out those children whose English language skills were felt to be too limited to operate the Reading Tutor. However, based on the results of Li (2002) determining that very low English proficient students are able to operate the Reading Tutor and discussions with the teachers, it was decided that all of the remaining 34 applicants met this liberal standard for inclusion. It should be noted that students whose self-assessed English reading proficiency was extremely low may have "screened themselves out" by simply not volunteering. Participants came from four classrooms: one second grade, one third grade, one third/fourth multi-age classroom, and one fourth/fifth multi-age classroom. Table 1 shows the distribution of participants by grade level and gender.

Treatment Model and Group Assignments

A crossover model was used in which students were randomly assigned to two groups, stratified by reading fluency pretest score (total words read) and by grade level. During the first month of the study, group one was assigned to the Reading Tutor intervention while group 2 was assigned to the control condition. During the second month, group treatments were reversed. This design allowed us to control for reading gains unrelated to Reading Tutor use. An additional motivation for this design was to allow all volunteers the opportunity to participate in the reading tutor treatment condition for some amount of time. This was considered important because the majority of the respondents who enrolled in the study did so specifically because of a desire to use the computer-based reading tutor.

Table 1. Participant Distribution by Grade Level and Gender

N	2nd Grade	3rd Grade	4th Grade	Total
Male	3	6	8	17
Female	8	4	5	17
Total	11	10	13	34

Interventions

Reading Tutor interventions took place in a small pull-out lab staffed by the first author and equipped with 10 PCs, each running the 2004 version of the Project LISTEN Reading Tutor. Students spent 25 minutes in the lab each school day over the four-week treatment. During each session, students independently worked on oral reading tasks with the computer-based tutor as described in the background section of this article. All reading tutor interventions were provided in English language only.

While students in the experimental condition were in the reading lab, students in the control condition remained in the regular classroom with non-participating students. During this time they participated in what the school defines as D.E.A.R. time (Drop Everything And Read). This time is somewhat unstructured, but is primarily designated as a time students spend engaged in Sustained Silent Reading (SSR) of self-selected materials. All four teachers reported 100% of this time was spent in some form of reading instruction and confirmed that SSR was the primary activity. Additional group interventions reported by teachers included some "read alouds" (teachers reading a story to the class) and partner reading (two students taking turns reading to each other). Two teachers also reported that some writing activities took place in the form of time spent writing in their daily journals.

The second and third grade teachers reported working individually with approximately one to three students per day in guided reading activities during this time. The second grade teacher indicated this individual instruction included word recognition, phonics, and decoding skills, "mainly in Spanish, but some English." The third grade teacher indicated this time was spent individually reading with each student. She further indicated that this instruction took place in both Spanish and English depending on the individual needs of the student. No quantitative data about the exposure and specific nature of this individual attention provided to control subjects was available.

All teachers reported that both Spanish and English reading instruction was included during D.E.A.R. time. Students were free to pick materials in either language as part of their silent reading activity. The second grade teacher reported students were more likely to select Spanish material than English, the third grade teacher reported that the children were equally likely to read in Spanish or English, and the fourth grade teachers reported that English materials were more commonly chosen.

Other Reading Instruction

The school's principal reports that between 120 and 150 minutes per day is devoted to direct reading instruction in the classroom. This figure was confirmed by feedback obtained from teachers and was consistent across all classrooms involved in the study. The language used for reading instruction is much more difficult to characterize. In general terms, the ratio of Spanish instruction to

English instruction was higher for the younger grades. Second grade instruction was reported to be primarily in Spanish with some English, third grade instruction was reported to be 50/50, and fourth grade instruction was reported to be primarily English. However, this was reported to be a broad characterization and all teachers reported that the language of instruction was primarily determined by the needs of the individual students.

Measures

Assessments used were selected reading components from the school district's Curriculum-Based Measures (CBMs). The particular measures selected constitute an informal reading inventory used throughout the school district and included measures for fluency, sight word recognition, and comprehension. All reading passages selected were adapted from the basal reading curriculum used in the school. All assessments for a given grade level used the same reading passages and word lists.

The comprehension measure was made up of a single, group-administered cloze test where students were asked to identify 10 missing words from a reading passage at their current grade level. Second grade passages provided three multiple-choice options for each word. Third and fourth grade passages required students to fill in the blank.

The fluency measure included two subcomponents: a measure of total words read in one minute (referred to as "fluency: total words") (see Figure 2), and a measure of words read correctly in one minute (referred to as "fluency: read correct") (see Figure 3). Reading passages were selected at one year below grade level. This selection is supported by Mirkin and Deno (1979) who find that passage difficulties at the independent or instructional level are more sensitive to growth than passages at the frustration level.

The sight word recognition measure also included two subcomponents, one a measure of the number of words identified automatically (words identified within a 2 second time limit) and the other a measure of total words decoded (words identified with no time limit). These measures are referred to throughout this article as sight words timed and sight words untimed respectively. All students were tested on three levels of sight words ranging from two levels below grade level through their current grade level. Each level was made up of a set of 20 words (60 words in total) adapted from the Houghton Mifflin Informal Reading Inventory.

The CBMs were selected for several reasons. First, research has consistently supported the validity and reliability of these measures (Baker & Good, 1995; Deno, 2003; Fuchs & Deno, 1991). The characteristics of these measures make them particularly well suited to monitoring short-term progress compared to published norm-referenced tests that are geared toward measuring growth over long periods of time (Baker & Good, 1995). A primary use of the CBM identified

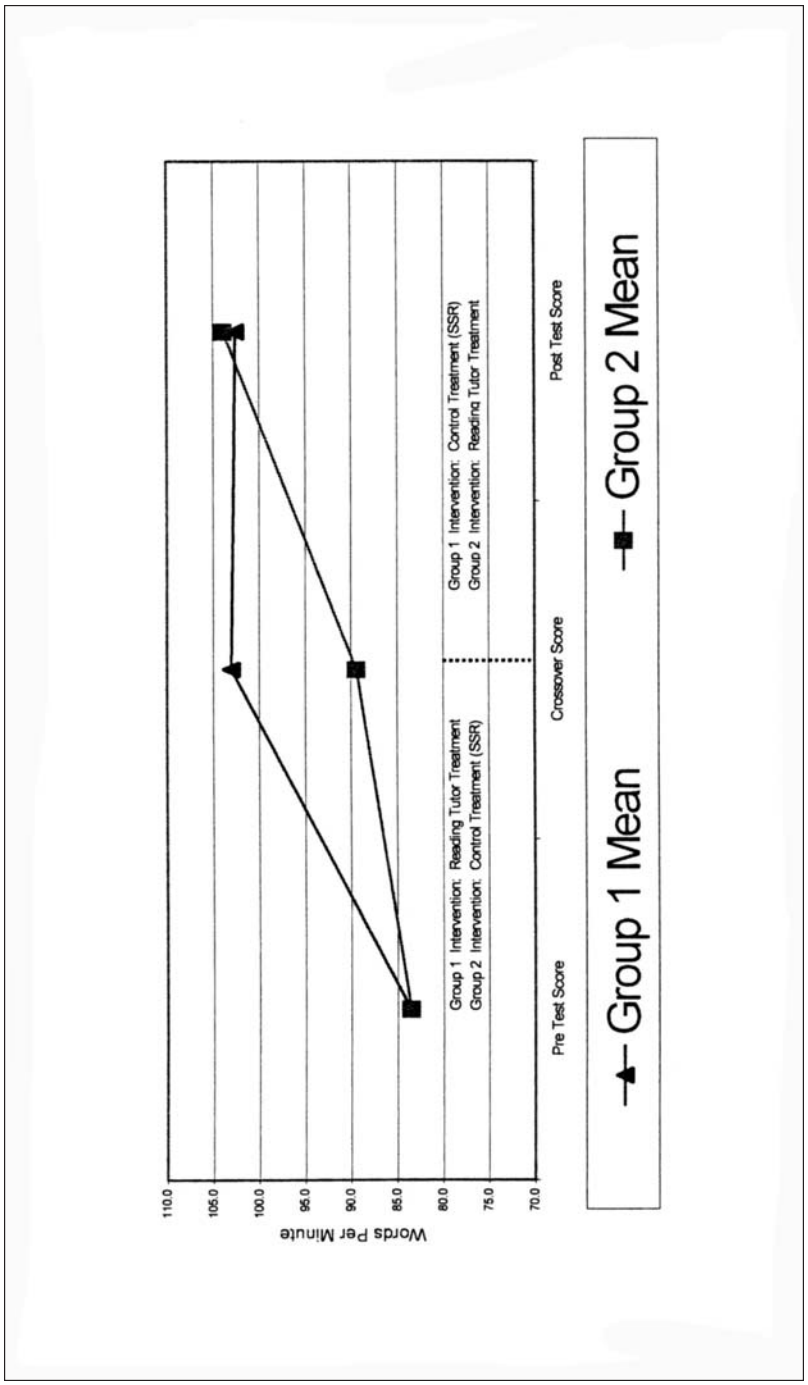

Figure 2. Fluency results for total words read in one minute.

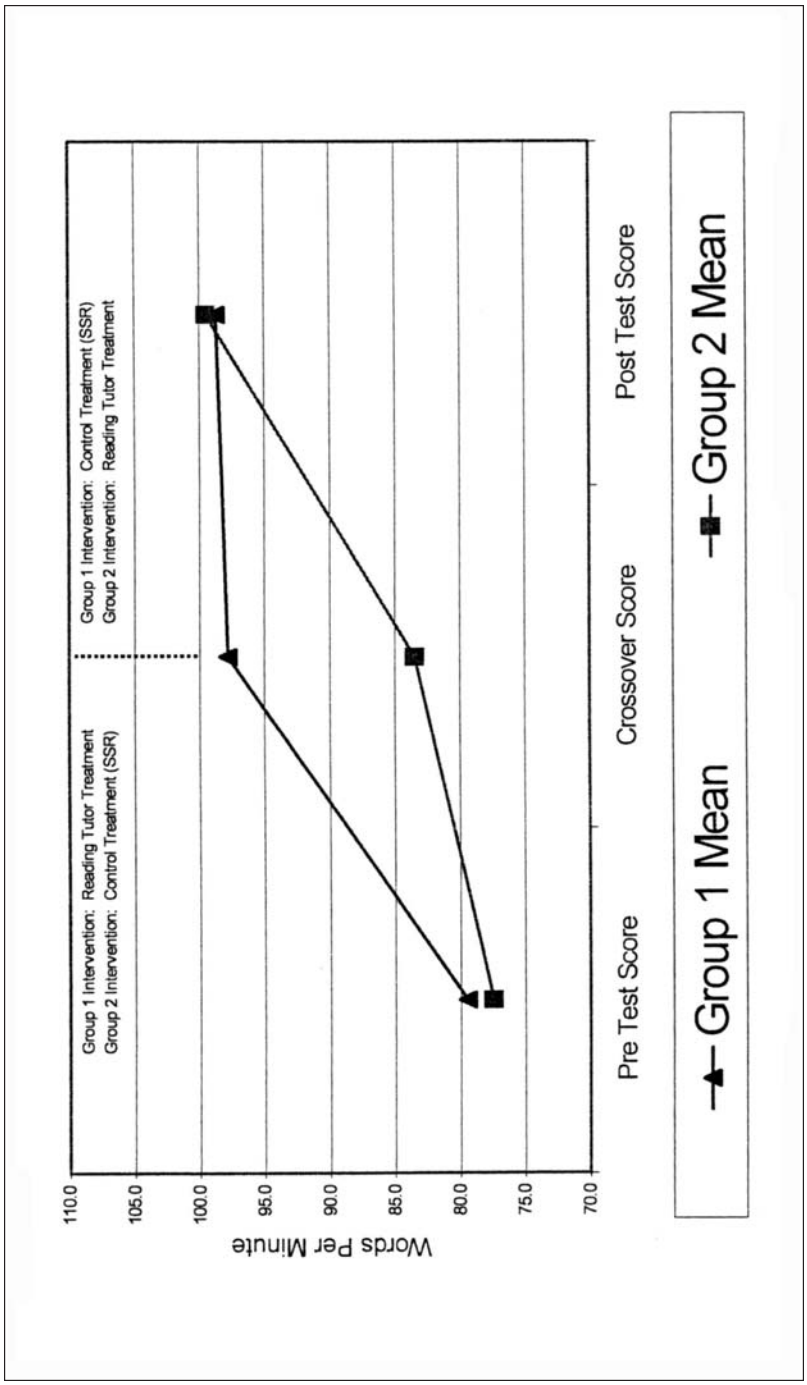

Figure 3. Fluency results for words read correctly in one minute.

by Deno (2003) is the formative evaluation model where regular fine-grained assessments are used to make judgments on the effectiveness of particular interventions. Finally, research has identified the reliability, validity, and sensitivity of CBM assessments within populations of English language learners (Baker & Good, 1995; Deno, 2003). These characteristics combined with the nature of this short duration study made the established district CBM reading inventories a robust assessment choice.

Materials

Reading materials available to students during regular classroom instruction include both Spanish and English language materials. The teachers characterized this material as very general in scope, including both fiction and non-fiction books of various levels and lengths. Teachers indicated that materials were separated by level and that students were individually directed toward material appropriate for their recommended reading level. Students were also allowed to use materials checked out from the school's library. The third grade teacher further indicated that materials were rotated and the selection would normally include books related to a general theme being discussed in class, for example, "Ocean books."

The Reading Tutor contains hundreds of grade level ranked stories for students to choose from representing a wide range of interests and styles. Stories are drawn from a variety of sources including *Weekly Reader*, public domain Web sources like www.gutenberg.net and stories written specifically for the Reading Tutor. Mostow et al. (2003a) presents a detailed description of the specific types of materials included in each level.

RESULTS

Of the 34 students included in the experiment, four failed to complete either the pre-test, the cross-over test administered between the two treatment conditions, or the final post-test, and their data were excluded from the analyses. An additional five students completed the tests for all but the comprehension measure, and their data was excluded only from the comprehension analysis. The mean pre-test, crossover test, and post-test scores for each of the five measures are presented in Table 2. Note that because reading treatment was manipulated within-subjects, the means in Table 2 reflect only the overall learning gains averaged across both treatments and do not compare the Reading Tutor condition to the SSR control condition.

Reading Treatment Effects

To test the hypothesis that the Reading Tutor improved reading performance compared to the SSR control, we computed gain scores for the two conditions for each student. The mean gain scores by treatment condition are presented in

Table 2. Mean Pretest, Crossover Test, and Posttest Scores, Collapsing Across Condition

	Pre-test		Crossover test		Post-test	
Dependent measure[a]	Mean	St. Dev.	Mean	St. Dev.	Mean	St. Dev.
Fluency: total read (n = 30)	82.1	32.6	94.4	35.3	103.3	31.1
Fluency: read correct (n = 30)	76.8	33.0	88.7	36.4	99.1	32.1
Sight word: timed (n = 30)	49.6	7.0	52.3	6.6	54.1	6.3
Sight word: untimed (n = 30)	53.1	5.5	55.0	5.7	56.1	5.0
Comprehension (n = 25)	5.9	2.0	6.7	2.1	6.6	1.9

[a]Data based only on subjects who took all three tests for a given dependent measure (four students missed post-testing, five additional students missed crossover comprehension tests).

Table 3, along with effect sizes calculated using the National Reading Panel (NRP, 2000, p. 15) standardized mean difference formula (treatmentMean – controlMean) / (0.5 * (treatmentStdDev + controlStdDev)). Effect sizes were robust for both fluency measures (1.16 for fluency: total read and 1.29 for fluency: read correct). Effect sizes for the sight word measures were also substantial at 0.58 for sight words timed and 0.49 for sight words untimed (see Figure 4). For each measure, the gain scores were entered into a repeated-measures ANOVA with reading treatment (Tutor vs. SSR) as the within-subjects factor. Three between-subjects factors were also included in the model: order (Tutor the first month vs. SSR first), grade (second, third, or fourth), and gender. All effects reported below were statistically significant at an alpha level of .05 except as noted, and non-significant main effects and interactions (other than the main effect of treatment) are omitted.

Because the Reading Tutor focuses primarily on decoding skills, we predicted that gain scores would be greater in the Tutor condition than in the SSR condition for the fluency and sight word measures. We did not expect to find significant comprehension gains in this study because during the students' relatively brief exposure to the Reading Tutor, most of their cognitive resources would be focused on word decoding. With longer exposure to the Reading Tutor, however, we would expect that comprehension would be facilitated by the increasing automaticity of word decoding. The analyses mostly confirmed our predictions, with the Tutor producing significantly greater gains in fluency: total words [$F(1, 18) = 8.83$], fluency: read correct [$F(1, 18) = 9.87$], and sight words timed [$F(1, 18) = 5.78$]. Although the gain scores for sight words untimed were in the predicted direction, the difference was not statistically significant [$F(1, 18) = 2.21$, $p = .155$]. The sight word measures were, however, subject to a ceiling effect with

Table 3. Reading Gains with Reading Tutor and with SSR

Dependent Measure[a] Treatment	Mean gain	*SD*	*p*[b]	Effect[c]
Fluency: total read (n = 30)				
Reading Tutor	17.1	11.1	0.008	1.16
SSR[d]	4.1	11.3		
Fluency: read correct (n = 30)			0.006	1.29
Reading Tutor	17.7	9.8		
SSR[d]	4.6	10.5		
Sight word: timed (n =30)			0.027	0.58
Reading Tutor	3.0	1.4		
SSR[d]	1.4	2.8		
Sight word: untimed (n = 30)			0.155	0.49
Reading Tutor	2.0	2.1		
SSR[d]	1.0	2.1		
Comprehension (n = 25)			0.2	0.22
Reading Tutor	0.6	2.0		
SSR[d]	0.1	2.0		

[a]Data based only on subjects who took all three tests for a given dependent measure (four students missed post-testing, five additional students missed crossover comprehension tests).
[b]Based on repeated measures ANOVA.
[c]Effect size based on NRP (2000) Standardized Mean Difference formula.
[d]Sustained silent reading.

three students identifying all 60 sight words on the timed measure and seven students able to decode all 60 words for the untimed measure. These ceiling effects would tend to decrease observed effect sizes and statistical power, and could be responsible for the lack of statistical significance in the untimed sight word analysis. The gain scores for the comprehension measure did not differ significantly between treatments [$F(1, 13) = 1.82$, $p = .20$], although the exclusion of five additional subjects in this analysis limited power, and the trend favored the Tutor condition.

Between-Subject Effects

The main effect of treatment having confirmed our primary prediction of greater reading gains from the LISTEN Reading Tutor than SSR, we turn now to

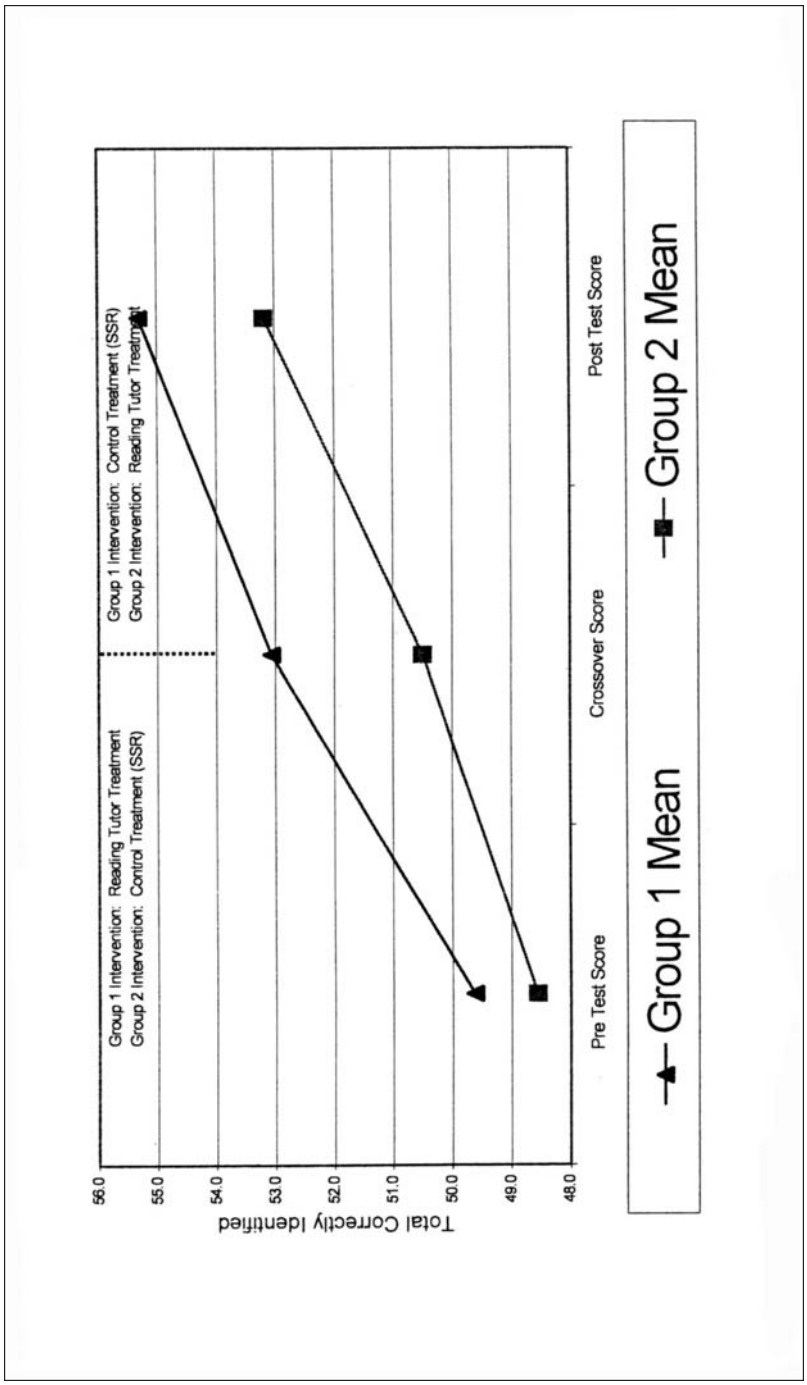

Figure 4. Timed sight word results.

the other three factors in our design, the subject variables of gender and grade level, plus the between-subjects grouping factor of treatment order (Tutor first or SSR first). None of the three had a significant main effect on gain scores for any of the five measures. For the fluency (total words and read correct) measures, there were also no significant interactions. There were, however, several significant interactions in the analyses of gain scores for the comprehension measure and the two sight word measures.

Although we did not predict (or find) a main effect of treatment on comprehension gain scores, we thought we might find a treatment by order interaction. If the Reading Tutor improved the automaticity of students' word decoding skills, then comprehension gains might be expected to appear some time after students had used the Reading Tutor. Thus comprehension gains should be more likely for students who used the Tutor in the first treatment period (order = 1) than in the second (order = 2), because only when the tutor was used first would there be time to see subsequent effects manifested in comprehension scores. This predicted interaction was significant [$F(1, 13) = 4.79$], but was in the opposite direction to that which we expected. Students who used the Reading Tutor first had significantly greater comprehension gains in the Tutor treatment than in the SSR treatment [means: 1.4 Tutor vs. –0.7 SSR, simple main effect $F(1, 18) = 5.61$], while comprehension gains for students who used the Tutor second did not differ significantly between treatments [means: 0.2 Tutor vs. 0.7 SSR, not significant]. The three-way interaction of treatment, order, and grade level was significant [$F(2, 18) = 11.59$], with simple effects analyses indicating that the predicted treatment by order interaction was primarily evident in the scores of the second graders rather than the third or fourth graders.

For the sight words measures the two subject variables, grade level and gender, both interacted with the effect of treatment. A treatment by grade interaction in the sight word: timed analysis [$F(2, 18) = 5.51$] reflected a significantly higher gain score in the Tutor condition than in the SSR condition for second graders [means: 3.6 vs. –0.1, $F(1, 18) = 14.54$]; but no significant differences between Tutor and SSR conditions for third or fourth graders (means: 2.4 vs. 3.0 and 2.9 vs. 1.7 respectively, not significant). The same interaction was also evident in the analysis of the sight word: untimed gain scores [$F(2, 18) = 4.26$], again with a significant difference between Tutor and SSR gain scores for second graders [means: 2.6 vs. –0.2, $F(1, 18) = 9.10$] but not for third or fourth graders (means: 1.6 vs. 2.0 and 1.8 vs. 1.4 respectively, not significant). Because the same pattern was evident for both sight word measures, one is tempted to conclude that the Reading Tutor's benefits were greater for younger students. This interaction could, however, have been a statistical artifact resulting from the ceiling effects in the sight word measures noted previously; third and fourth graders had relatively high sight word scores at pre-test, and therefore little room on the scale to display improvement.

Gender also interacted with treatment for the sight words: timed [$F(1, 18) = 11.57$], but not for the sight words: untimed. This interaction reflected a greater advantage for the Tutor over the SSR condition for boys [means: 3.9 Tutor vs. 1.2 SSR, $F(1, 18) = 15.98$] than for girls [means: 2.3 vs. 1.6, not significant]. Given that the pattern of treatment effects was qualitatively similar for both genders (greater gains for the Tutor than for the SSR treatment), and that no gender by treatment interaction was significant in the sight word: untimed measure (nor the comprehension or fluency measures), this interaction should be interpreted with caution.

The three-way interaction of treatment, order, and grade level was significant for both the timed [$F(2, 18) = 3.83$] and untimed sight words [$F(2, 18) = 3.72$], and the pattern of the interaction was similar for both measures. Second graders had higher gain scores in the Tutor than in the SSR condition, regardless of which treatment came first: Mean gain scores for second graders when the Reading Tutor was first (order = 1) were 4.6 vs. –0.4 [$F(1, 18) = 9.18$] for Tutor and SSR treatments respectively for timed words, 3.2 vs. –0.4 [$F(1, 18) = 4.13$] for untimed words. When SSR was the first treatment (order = 2), second graders' mean gains were 2.8 Tutor vs. 0.2 SSR [$F(1, 18) = 5.36$] for timed, and 2.2 vs. 0.0 [$F(1, 18) = 3.67$, $p = .07$] for untimed words. No simple main effects of treatment were significant in either treatment order group for third graders. For fourth graders, the simple main effect of treatment was significant only when the Tutor was administered first [mean gains: 4.3 vs. 0.3, $F(1, 18) = 8.26$ for timed; 2.8 vs. –0.5, $F(1, 18) = 4.50$ for untimed], and there was no advantage at all for the Tutor condition when it was the second treatment (fourth graders' mean gains: 2.0 Tutor vs. 2.7 SSR for timed; 1.2 Tutor vs. 2.7 SSR for untimed, not significant). Given the small N (four to six students per cell for the three-way interaction analysis) and the previously noted ceiling effects in the sight word measures, no meaningful interpretation of this interaction is evident.

In the sight word: timed analysis two additional interactions that did not involve the effect of treatment were significant. Grade level interacted with gender [$F(2, 18) = 5.45$] such that gain scores for second grade girls were higher than for boys [marginal means: 2.3 vs. 0.1, $F(1, 18) = 4.39$, $p = .051$], while fourth grade girls' gain scores were lower than boys' [marginal means: 1.5 vs. 4.2, $F(1, 18) = 5.60$], and for third graders there was no significant gender difference [marginal means: 2.1 vs. 3.3, not significant]. The three-way interaction of gender, grade level, and order was also significant [$F(2, 18) = 3.63$] with more evidence for a gender by grade level interaction in the first treatment period than in the second, but no interpretation for this pattern was readily apparent.

Usage Measures

Usage data recorded by the Reading Tutor indicates that participants spent 323 minutes on average engaged in Reading Tutor activities over the course of a

four-week intervention. This exposure was relatively consistent with a standard deviation of only 45.86 minutes or 15%. It is also interesting to note that the lab was only available for 450 minutes during each treatment period (18 actual school days * 25 minutes per day available to each class), indicating a very high overall utilization of better than 70%.

DISCUSSION

The purpose of this study was to investigate the efficacy of the *Project LISTEN* Reading Tutor within a population of English language learners. Mostow and Beck (2003) define efficacy as the gain achieved based on a specified amount of usage and further define effectiveness as the increase in gains produced by a particular intervention when compared to what the intervention replaces. The simple formula they present to relate these terms is *effectiveness = efficacy * usage*. Based on these definitions, we now discuss the results of this study in terms of the observed usage and effectiveness, noting that the consistency of the observed usage would make any attempt to separate efficacy from effectiveness a tenuous prospect at best. We then conclude the discussion by examining the limitations of this study and potential directions of future research.

Usage

The high usage levels recorded for the Tutor are impressive when considering the context of this study during the last two months of the school year. This is a very chaotic period and there were many end-of-year assemblies, field trips, and other distractions. The usage data supports the observation that students were highly motivated to work on the Reading Tutor. Teachers reported that students regularly reminded them when it was time to use the lab and looked forward to their scheduled time throughout the duration of the study. Teachers also reported a belief that the Reading Tutor was beneficial to their students. This level of acceptance is critical. Mostow and Beck (2003) showed that teacher attitude is the largest predictor of Reading Tutor usage.

As a second usage note, we also briefly consider the usability of the Reading Tutor for ELLs. The results of this study confirm the findings of Li (2002) that children with very low English proficiency are able to interact effectively with the tutor. All participants in this study were able to operate the Reading Tutor with very minimal support. During their first day of attendance, participants were assisted by the lab supervisor in creating a login account and then completed the initial tutorial reading activity independently. During all subsequent sessions, students logged in and interacted with the Reading Tutor independently. Observations of these sessions by the first author suggested that the children were empowered by their ability to work independently within the Reading Tutor environment and this may well have been a factor in the positive outcomes. The

only area where additional direction was consistently requested was in writing tasks, and even this was infrequent and more commonly related to writing skills than operating the tutor.

Effectiveness

Clearly, the results indicate the Reading Tutor was effective, primarily in terms of raising fluency. Ultimately, however, the object of the exercise in literacy education is comprehension. Many studies indicate a direct link between fluency and comprehension based on the ability of the fluent reader to redirect attention and cognitive resources from decoding to comprehension (De la Colina, Parker, Hasbrouck, & Lara-Alecio, 2001; Denton, Anthony, Parker, & Hasbrouck, 2004; NRP, 2000; Snow, Burns, & Griffin, 1998). Fuchs and Deno (1991) have specifically demonstrated a strong correlation between oral fluency measures and reading comprehension measures from the Woodcock Reading Mastery Test.

Fluency has also been identified as a critical component of comprehension in research specific to English language learners (August, 2003; De la Colina et al., 2001). While the results of this study do not show a significant overall difference in comprehension scores between treatment and control conditions, there was a non-significant trend of higher gain scores in the treatment condition. Furthermore, the magnitudes of the gains observed in fluency measures give a good basis to believe the tutor can effectively support the ELL's future comprehension growth.

In order to more fully examine the effectiveness of the Reading Tutor, we now address two critical questions: what needs of English language learners did the Reading Tutor effectively meet and what can be done to make the Reading Tutor more effective for these students.

What Does the Reading Tutor Have to Offer English Language Learners?

Foorman and Torgesen (2001) conclude that children who are most at risk for reading failure should be supported by the same instructional components as their higher performing peers, but that these components need to be emphasized in ways that make them more comprehensive, intensive and explicit, and further that these characteristics be supported by a base of small-group and one-on-one instruction. Research has shown that intensive reading interventions designed for native English speakers are also effective in bilingual settings when those interventions are carried out with fidelity and high levels of student engagement (De la Colina et al., 2001). The Reading Tutor fulfills all of these general criteria.

Clearly, it can provide one-on-one assisted oral reading opportunities for at-risk bilingual students. Additionally, the interventions used by the tutor support phonological awareness and provide explicit models of decoding strategies, both of which are critical to teaching English reading to ELLs (Denton et al., 2004).

Further, Mostow and Beck (2003) cite the Reading Tutor's ability as an automated tutor to ensure treatment fidelity to an extent not possible by human interventions. The qualitative assessments discussed previously in the context of usage also indicate the tutor is very effective in engaging and motivating students.

Slavin and Cheung (2003, 2004) in reviewing the body of research on language of instruction conclude that there is strong evidence supporting paired bilingual strategies where students are taught reading in both English and their native language concurrently. In this context, the results of this study combined with the body of research detailed in Mostow et al. (2003a) indicate that the Reading Tutor may be a very effective tool in supporting English literacy for English language learners.

What Can the Reading Tutor Do Better to Support English Language Learners Unique Needs?

We have paid a great deal of attention to the reasons why interventions designed for native English speakers are relevant for English language learners. We now address some of the unique characteristics of this population in an attempt to determine areas for future improvements to the Reading Tutor that will bolster its effectiveness for ELLs.

Li (2002) in her pilot investigation of the usability and benefits of the Reading Tutor for English language learners identifies two major areas where the reading tutor could be modified specifically to better support the needs of these students. They are the need to better support the limited oral vocabulary and background knowledge of ELLs and the need to provide more culturally sensitive and content appropriate reading material targeted toward this population.

The Reading Tutor relies primarily on a background of word knowledge to build up vocabulary and consequently comprehension. The limited oral vocabulary of English language learners may account in part for the limited gains observed in comprehension measures during this study. Li (2002) specifically identifies the need for illustrations in the tutor to provide ELLs an alternative source from which to draw meaning. The version of the Reading Tutor used in this study contained few illustrations, and these were primarily used in level K material. The addition of this content would not only benefit ELLs, but would provide additional context to all readers. Further, this type of modification would improve the look and feel of the tutor, intensifying the motivational component of the tutor.

The Reading Tutor may also be more effective for ELLs if its reading material were to include more culturally sensitive content. As cited earlier, educational statistics demonstrate that roughly 76% of this nation's English language learners come from Hispanic cultures (Moss & Puma, 1995; Ruiz de Velasco & Fix, 2000; Zehler et al., 2003) and therefore it may be possible to address a large majority of the ELL population with a limited but focused amount of additional

material. Quintana (2001) presents a unique methodology to inventory the reading preferences of Mexican immigrant students. Her research focuses on the reading preferences of sixth through ninth grade students, but can equally be applied to younger children. By using methods like these, new reading material in the tutor will benefit ELLs by providing them with content that supports their comprehension based on a better alignment with their particular background knowledge and interests.

Limitations and Directions for Future Research

A summary of this study following the National Reading Panel Coding Scheme is shown in the Appendix. Clearly the most significant limitation of this study is its size. Although our results show significant learning gains for this ELL population, they are based on a sample of only 34 students observed over a span of two months with only one month of experimental treatment. It is possible that once the initial excitement of using the new technology wears off, the students would not be as motivated to use it, and the learning gains would fall off. Alternatively the fundamental learning gains could be consolidated, and larger gains in comprehension may then be demonstrated. As such, a pressing direction for future research should be to evaluate the Reading Tutor on larger ELL populations using commercially norm-referenced measures over much longer treatment periods. Future research should also address the following possible limitations in the data presented here.

First, as this sample population was drawn from students who volunteered to stay after school to participate in a computer based reading tutor program, the potential of a sample bias must be considered. It seems reasonable that our population may have included a disproportionate number of students who were very eager and motivated to become more fluent English readers. Thus, even with our counterbalanced design, it is possible that the students were more committed to learn than the average student, and therefore made a special effort to learn in the experimental condition. Teachers indicated their belief that the students enrolled in the study were representative of the general attitudes and abilities of their students, but this is anecdotal. Future research should extend these findings to a larger sample to determine whether the Reading Tutor's effectiveness generalizes to less highly motivated student populations.

Another issue that should be addressed in future research is the variable nature of language of instruction. In this study, the SSR condition did not control for (or even record) language of instruction. It is therefore not clear how much of the observed gains may have been attributable to English only instruction in the treatment condition versus a mix of Spanish and English instruction during control treatment. This mix of language of instruction is common in bilingual education programs and may therefore be difficult to control for, but future research should put measures in place to record the balance of the language of instruction during

control and treatment, and account for it in the analysis of the results. Additionally, cleaner studies may be done in schools that employ English-only immersion methods, though it is not clear how those results could be applied to the more commonly used bilingual model.

CONCLUSIONS

The technology employed by the Reading Tutor clearly has the power to provide inexpensive one-on-one assisted oral reading opportunities within ESL classrooms. This research gives an initial indication that this practice may be significantly more effective in helping English language learners develop English literacy skills than the common practice of sustained silent reading. The technology seems to be both highly motivating and effective in engaging ELLs in reading activities. All study participants were able to independently interact with the tutor indicating that the Reading Tutor is accessible to students with very limited English proficiency.

Future research needs to be done to validate and extend these findings, and should include controls for language of instruction. Additional research is also needed to determine areas where the Reading Tutor can be improved to specifically meet the needs of bilingual students. This should include research into how to best provide support for comprehension in a population with a limited English oral vocabulary.

APPENDIX: NRP Style Research Summary

States or countries represented in sample	Illinois: Suburban Chicago community
Number of different schools represented in sample	1: (Eugene Field Elementary School)
Number of different classrooms represented in sample	34
Number of participants	4 total (1 second grade, 1 third grade, 1 multiage 3-4, 1 multiage 4-5)
Age	7–11
Grade	Second through fourth
Reading levels of participants	Below grade level through grade level as measured by school districts informal reading inventories
Whether participants were drawn from urban, suburban, or rural settings	Suburban
Pre-tests administered prior to treatment	School District's Curriculum Based Measures for fluency, sight word recognition, and comprehension
Socioeconomic status (SES)	Predominantly low SES
Ethnicity	Hispanic
Exceptional learning characteristics	Limited English Proficient (LEP) Students
First language	Spanish
Explain any selection restrictions that were applied to limit the sample of participants	No performance based restrictions applied. Some students omitted because of scheduling conflicts.
Concurrent reading instruction received in classroom	Standard district curriculum for bilingual students including reading instruction in both Spanish and English
How was sample obtained?	Volunteers were solicited from bilingual second through fourth grade classrooms

APPENDIX (Cont'd.)

Attrition Number of participants lost per group during the study Was attrition greater for some groups than others?	Thirty-six students were initially entered, two were unable to participate because of scheduling problems during pull out lab sessions
Setting of the study	Classroom for control condition, pull out computer lab for experimental condition
Design of study	Crossover design with each group receiving both treatments for one-month intervals. Students randomly assigned to group stratified by pre-test score and grade level.
Describe all treatment and control conditions; be sure to describe nature and components of reading instruction provided to control group	2004 Reading Tutor; regular classroom instruction consisting primarily of sustained silent reading along with some guided reading activities. Control condition included both English and Spanish reading activities.
Explicit or implicit instruction?	The Reading Tutor provides help on oral reading, consisting of large amounts of implicit instruction by modeling fluent reading and reading individual words. By pointing out specific instances of letter-to-sound rules (*a* here makes the sound /a/), the Reading Tutor also provides explicit instruction at the grapheme-to-phoneme level.
Difficulty level and nature of texts	Authentic text ranging in level from pre-primer through fifth grade and including a mix of fiction and non-fiction. Reading Tutor inserted short factoids to introduce some new words. Classroom instruction consisted of self-selected material during independent reading time.
Duration of treatments	20 to 25 minutes per day, five days per week. Treatment duration was one month per condition. Actual usage logged by Reading Tutor indicated students averaged 323 minutes of total usage over four week treatment (standard deviation of 45.86 minutes)
Was fidelity in delivering treatment checked?	Pull out lab supervised by principal investigator, daily contact/communication with classroom teachers.

APPENDIX (Cont'd.)

Properties of teachers/ trainers	Computer based tutor for experimental condition. Control condition primarily independent study, with minimal interventions provided by regular classroom teacher.
Number of trainers who administered treatment	N/A
Computer/student ratio	1:1
Type of computers	IBM-compatible Pentium personal computers (500 MHz) running under Windows 2000 Pro
Special qualifications	The Reading Tutor listens to children read aloud
Length of training	N/A
Source of training	N/A
Assignment of trainers to group	N/A
Cost factors	Personal computer costs ~$2000; cost of software depends on accounting for research and development costs; personnel costs limited to the experimenter supervised 10-computer lab.
List and describe other nontreatment independent variables included in the analysis of effects	Pre-test Score; Gender; Grade, strongly correlated to teacher/classroom; Treatment Month, either experimental treatment in first month or second month
List processes that were taught during training and measured during and at the end of training	N/A
List names of reading outcomes measured	School District's standard Curriculum Based Measures for fluency (total words read), fluency (words read correctly), sight word recognition (words identified automatically), sight word recognition (words decoded correctly), and comprehension (cloze test).

APPENDIX (Cont'd.)

List time points when dependent measures were assessed	April 2004, May 2004, and June 2004
Any reason to believe that treatment/control groups might not have been equivalent prior to treatments?	No; assignment to groups based on pre-test score.
Were steps taken in statistical analyses to adjust for any lack of equivalence?	Yes; Paired *T*-test used to analyze within subject data. ANCOVA analysis treated pre-test score as a covariate.
Result: 2-tailed paired *T*-test ($n = 30$)	Fluency (total words read): $p = 0.00038$ Fluency (words read correctly): $p = 0.00014$ Sight words (timed): $p = .056$
Difference: treatment mean minus control means	Fluency (TWR): Reading Tutor > control by 13.03 words per minute Fluency (WRC): reading Tutor > control by 13.10 words per minute Sight words (timed): Reading Tutor > control by 1.60 words
Effect size	Fluency (TWR): 1.16 Fluency (WRC): 1.29 Sight words (timed): 0.58
Summary statistics used to derive effect size	(Treatment mean – control mean) / (0.5 * (treatment *SD* + control *SD*)) Fluency (TWR): (17.13– 4.10) / (0.5 * (11.12 + 11.30)) = 1.16 Fluency (WRC): (17.70 – 4.60) / (0.5 * (9.83 + 10.49)) = 1.29 Sight word (timed): (3.03 – 1.43) / (0.5 * (2.66 + 2.84)) = 0.58
Number of people providing effect size information	$N = 30$. All participants except for four students who were not available for testing at least one test point (pre, mid, or post).
Length of time to code study	Uncertain
Name of coder	Robert S. Poulsen

Note: Table format and coded information specific to Reading Tutor functional descriptions adapted from Mostow et al. (2003a)

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