Hammill Institute on Disabilities

Learning Disability Quarterly
35(4) 236–247

DOI: 10.1177/0731948712444275
http://ldq.sagepub.com
SAGE

Improving Reading of Science Text for Secondary Students With Learning Disabilities: Effects of Text Reading, Vocabulary Learning, and Combined Approaches to Instruction

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Abstract

This study examined the effects of three types of reading interventions on the science text reading of secondary students with learning disabilities (LD). Twenty 10th-grade students with LD participated in the study. Using a within-subjects design, the relative effects of three different instructional approaches—text reading, vocabulary learning, and text reading plus vocabulary learning—were examined and compared with a control condition in which participants received no instruction. The effects of the interventions on reading fluency, vocabulary knowledge, and comprehension were examined. Results revealed that the text-reading and combined interventions had a positive effect on reading fluency and vocabulary knowledge, and that the vocabulary intervention had a positive effect on vocabulary knowledge. Potential effects were found for the comprehension measures. Results imply that students' reading of science text, and knowledge of the vocabulary used in that text, can be improved with direct instruction.

Keywords

reading interventions, adolescent reading, content literacy, reading, vocabulary, comprehension

Introduction

As a requirement of No Child Left Behind Act (NCLB; 2002), students with learning disabilities (LD) are required to meet minimum academic standards, including passing state standards tests in content areas such as science. It is not surprising, then, that the majority of students with LD receive their science education in mainstream science classes (Ehren, Lenz, & Deshler, 2004) and are expected to perform to the same standard as peers without LD (NCLB, 2002).

Yet, students with LD often struggle in content areas such as science, especially at the secondary-school level, perhaps due in part to the mismatch between the reading abilities of the students and the reading requirements of their content-area classes. The reading levels of secondary-school students with LD typically lag several years behind peers, and their standardized achievement tests scores often fall at the lowest deciles of score distributions (Deshler, Schumaker, Alley, Warner, & Clark, 1982; Levin, Zigmond, & Birch, 1985; Parmar & Deluca, 1994; Warner, Schumaker, Alley, & Deshler, 1980). Adolescents with LD experience difficulties with phonics, language comprehension, and reading fluency (Fuchs, Fuchs, Mathes, & Lipsey, 2000; Vellutino, Fletcher, Snowling, & Scanlon, 2004; Vellutino, Scanlon, & Tanzman, 1994; Vellutino, Tunmer, Jaccard, & Chen, 2007). On the 2009 National Assessment of Educational Progress (NAEP; National Center for Educational Statistics, 2009, 2011), the average scaled scores in reading and science for eighth-grade students with disabilities were 229 and 122, respectively, compared with 266 and 152 for students without disabilities. Average NAEP scaled scores in reading for 12th-grade students with disabilities were 250 compared with 290 for students without disabilities. The National Longitudinal Transition Study–2 (NLTS2, 2009; Wagner, Newman, Cameto, & Levine, 2006) reports mean standard scores in the areas of reading comprehension and science were 82 and 88, respectively, for students with LD, compared with 100 for students in the general population.

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Coupled with the acute reading and academic deficits of students with LD are the academic demands of content-area classes. Textbooks continue to be a major source of instruction at the secondary-school level (Bean, Zigmond, & Hartman, 1994; Moin, Magiera, & Zigmond, 2009). Students are expected to read and acquire information independently from texts, yet high school science texts often are poorly written, lack structure, fail to provide sufficient definitions of essential vocabulary, and are inconsistently or poorly organized (Armbruster, 1984; Mastropieri et al., 2006; Mastropieri, Scruggs, & Graetz, 2003; Scruggs & Mastropieri, 2007). In addition, the readability levels of science textbooks range from ninth grade through the third year of college (Armbruster & Anderson, 1998), and science texts often includes densely worded paragraphs (Yager, 1983) containing unfamiliar, multisyllabic, and technical vocabulary words (Shankweiler, Lundquist, Dreyer, & Dickinson, 1998; Yovanoff, Duesbery, Alonzo, & Tindal, 2005). Up to 40% of students in general have difficulty acquiring relevant information from textbooks (Hock & Deshler, 2003; Lyon & Moats, 1997; Mercer, Campbell, Miller, Mercer, & Lane, 2000; Vacca, 1998); therefore, it is not surprising that students with LD experience problems with reading science texts (Cawley, Hayden, Cade, & Baker-Krooczynski, 2002).

The mismatch between the abilities of struggling adolescent readers and the reading requirements of content-area classes has led to calls for increased reading instruction in the content areas (e.g., Biancarosa & Snow, 2006; Cawley & Parmar, 2001; National Joint Committee on Learning Disabilities [NJCLD], 2008). Biancarosa and Snow (2006) and Cawley and Parmar (2001) argued that reading instruction within the content areas is necessary because skills learned in a separate reading program will not transfer automatically to the reading of content-area text. To increase content-area reading instruction, a closer collaboration between reading and content-area teachers is advocated, with reading teachers using content-area text to help students improve reading skills and content-area teachers teaching reading skills specific to their content areas. Yet, a review of the literature reveals that much must be done before the goals of closer collaboration and increased content-area reading can be achieved.

First, more research is needed on the development of effective reading interventions for struggling adolescent readers. Little attention has been devoted to improving the reading performance of struggling adolescent readers (Ehren et al., 2004), especially in the content areas. The assumption has been that early reading intervention will preclude the need for later intervention (Ehren et al., 2004; Espin, Wallace, Lembke, Campbell, & Long, 2010); however, even with effective and intensive early intervention, some students continue to struggle into adolescence and early adulthood (Ehren et al., 2004). Recent calls have been for early and continued intervention for struggling readers (Ehren et al., 2004; Espin et al., 2010; Vaughn et al., 2008) and for instruction across multiple areas of reading, including decoding, word recognition, fluency, vocabulary development, and comprehension (Ehren et al., 2004; NJCLD, 2008; O'Connor & Bell, 2004; Roberts, Torgesen, Boardman, & Scammacca, 2008; Scammacca et al., 2007).

Second, specific to the content areas, the reading research that has been done has tended to focus on comprehension and learning from text to the exclusion of other areas of reading. For example, Mason and Hedin (in press) reviewed reading interventions in science for students with LD and identified the following categories of intervention: increasing prior knowledge, using text enhancements (e.g., the use of illustrations in the text), and using strategies to identify main ideas, identify text structure, and predict and summarize information. Similar categories can be found in other reviews of science (e.g., Mastropieri & Scruggs, 1992) and history (De La Paz & MacArthur, 2003) interventions for students with LD. Less attention has been devoted in the content areas to other aspects of reading such as word recognition and reading fluency, yet it is these aspects that are likely to influence students' abilities to wade through the volume of material presented daily in their content-area classes.

Third, consideration must be given to the practicalities involved with merging content-area and literacy instruction. Content-area teachers do not feel prepared to engage in literacy instruction or to meet the needs of students who struggle with reading, and special education teachers do not have the content-related knowledge needed to reinforce the teaching of science content (Cawley et al., 2002; Greenleaf & Brown, 2007; Mastropieri & Scruggs, 1992; Moin et al., 2009). Even coteaching, which should combine the expertise of science and special education teachers, does not necessarily lead to a literacy-enhanced environment for students with LD (Zigmond, 2006). If literacy and content-area instruction are to be more closely merged, interventions must be "user-friendly"; that is, they must be simple, efficient, and inexpensive, and they must require minimal levels of expertise or training in reading and science instruction. "User-friendly" interventions can be incorporated into the existing curriculum and class/school structure, and can allow for a range of individuals (e.g., science teacher, special education teacher, teaching assistant, or even peer) to implement the interventions with fidelity. The emphasis on the development of a "user-friendly" intervention is analogous to implementation of a "standard-protocol" approach in response to intervention (RTI; Fuchs, Mock, Morgan, & Young, 2003; Vaughn et al., 2008) in which the activities for Tier 2 instruction are standardized and predetermined to ensure implementation of evidence-based practices with fidelity.

Finally, it is important to search for interventions that have a direct and immediate effect on the text-reading skills of student with LD. Although literacy instruction in content-area text may have (hopefully will have) an effect on the general-reading skills of students with LD, another goal of such interventions can be to improve the ease with which students read the text used in their content-area classes. Content-area classes are heavily text-laden, with instruction and activities based on information in textbooks (Bean et al., 1994). An intervention designed to ease the burden of struggling readers with regard to reading text in their content-area classes might prove useful. Desirable is the transfer of those skills to similar texts and tasks, and an improved understanding of the text, but the primary goal is to directly and immediately affect the ease with which students read the text they encounter each day in their content-area classes.

The purpose of the present study was to examine a reading intervention embedded in science text and focused on the skills of vocabulary, word reading, and reading fluency for adolescent students with LD. The primary goal was to determine whether such an intervention would have an immediate and direct effect on the ease with which students with LD read curriculum science text. A secondary goal was to examine whether such effects would improve comprehension of the text. The intervention was purposefully simple in nature, allowing for potential implementation by a number of different interventionists. Our study was exploratory in nature. That is, we sought to identify interventions that might show promise for improving reading of science text. If a promising intervention was to be identified, the effects of daily or weekly implementation of that intervention on the reading of classroom science text could then be examined.

Method

Participants and Setting

Participants were 20 (11 male, 9 female) students with LD in Grade 10. Participants were recruited from five high schools across four school districts within a 50-mile radius of a large metropolitan area. Students were invited to participate if they were enrolled in a regular education biology class and had a documented LD in reading according to Minnesota state criteria (evidence of a severe discrepancy between cognitive ability and reading performance). Standard scores on IQ and reading achievement assessments were available for 15 students. IQ scores came from either the *Wechsler Intelligence Scale for Children–IV* or the *Woodcock–Johnson–III Tests of Cognitive Ability* (M = 100, SD = 15) and ranged from 72 to 112 with a mean of 94.87. Reading achievement scores came from the Woodcock–Johnson–III Test of Academic Achievement (M = 100, SD = 15) and ranged from 58 to 103 with a mean of 79.73. Participants ranged in age from 15 years 9 months to 16 years 8 months; mean age was 16 years 3 months. All of the schools served students in Grades 9 to 12. Demographic information for each school is summarized in Table 1. Reading profiles for the 15 students are summarized in Table 2.

Table 1. Demographic Information for Participants' Schools

School	1	2	3	4	5
Setting information					
Total students	1,669	1,784	974	1,140	1,837
Geographic area	Suburb	Rural	Suburb	Rural	Urban
Grades served	9–12	9–12	9–12	9–12	9–12
Ethnic representation[a]					
Native American	0	0	2	1	7
Hispanic	3	1	9	2	6
Asian	10	3	6	2	6
Black	15	3	23	0	24
White	72	92	60	95	56
ELL	8.9	8.9	22	2	23
Free and reduced lunch[a]	24.6	5.6	52	18	37.6
Number of participants	5	5	5	4	1

Note: ELL = English language learners.
[a]Reported as percentages.

Table 2. Standard Reading Scores for Participants

Student	IQ	Basic reading	Fluency	Comprehension
1	72	63		
2	79	81	92	72
3	112		74	81
4	83	76	82	80
5	104	58	58	
6	99	102	98	111
7	86	77	78	93
8	101	84		90
9	106	85		
10	90	103		101
11	106		96	103
12	90	75		
13	89	74		
14	87	75		
15	108	83		

Note: No standard score information available for other participants.

Data were collected by the first author and two graduate students (referred from this point forward as "instructors") in the participants' regular school building during a time that did not interfere with their regular academic routine. Instructors were former high school special education teachers who delivered all treatment conditions and collected data on the dependent measures. The author trained the other two instructors during one 90-min session prior to the beginning of the study.

Table 3. Order of Conditions

Participants 1, 5, 9, 13, 17				
Condition	TR	VL	R/V	C
Passage	1	2	3	4
Participants 2, 6, 10, 14, 18				
Condition	VL	R/V	C	TR
Passage	1	2	3	4
Participants 3, 7, 11, 15, 19				
Condition	R/V	C	TR	VL
Passage	1	2	3	4
Participants 4, 8, 12, 16, 20				
Condition	C	TR	VL	R/V
Passage	1	2	3	4

Note: TR = text reading; VL = vocabulary learning; R/V = combined reading and vocabulary; C = control.

Design

The design employed in this study was a within-subject design in which each student participated in four conditions (three intervention and one control condition). A within-subject design was chosen because it provides more power to uncover differences when the sample size is small than does a between-subjects design. In addition, a within-subject design is ideally suited for comparing the relative effects of different interventions on performance because students serve as their own controls. A within-subject design is well suited for a study in which the effects are expected to be immediate and direct, and are not expected to carryover to the other conditions. Recall that the purpose of this study was to examine which interventions would have immediate and direct effects on the science text-reading skills of students with LD.

To control for passage effects, text passages were counterbalanced across condition. In addition, the order in which the interventions were delivered was counterbalanced across student (see Table 3 for counterbalanced order of conditions). Outcome measures were administered at the end of each instructional session.

Independent Variable

The independent variable was type of reading intervention: text reading, vocabulary learning, and combined. These three approaches were compared with a control condition in which no intervention was delivered. The materials used for the instructional sessions were four reading passages taken from four sections of a standard high school biology textbook, *Biology* (Miller & Levine, 2004), that was used in four of the five settings. Passages were 500 words in length and were chosen based on the following criteria: none of the students had had previous exposure to the material, the four topics were not related to each other, and, to minimize the level of background knowledge needed for comprehension, all of the topics came from introductory material at the beginning of each section (see Table 4 for a sample of one passage).

Text-reading condition. The text-reading intervention was designed to help students read text fluently and automatically so that they could free up attentional resources to concentrate on the meaning and content of the text (Fletcher, Lyon, Fuchs, & Barnes, 2007; Fuchs, Fuchs, Hosp, & Jenkins, 2001; LaBerge & Samuels, 1974; Mercer et al., 2000; National Reading Panel, 2000). The text-reading intervention was adapted from repeated reading interventions, which have been found to be effective for improving students' fluency and comprehension of text (see reviews Chard, Vaughn, & Tyler, 2002; Roberts et al., 2008). The intervention included components that have been shown to contribute to the effectiveness of repeated readings, including automatic word identification, reading aloud to an adult, adult modeling, error correction, and repeated reading of a text (Chard et al., 2002; Roberts et al., 2008; Therrien, 2004). Few, if any, repeated reading studies have focused on reading of science text (although the type of materials used in the studies is not always specified).

The text-reading intervention began with a word recognition activity. Ten vocabulary words were selected from each passage using one of three criteria: (a) they were listed at the beginning of the chapter, (b) they appeared in bold-faced print within the passage, and (c) they were found in the glossary at the back of the textbook. Each word was typed on the front of a 3 × 5 index card. The instructor read each word aloud after which the student read the word aloud. If the student made an error, the instructor corrected the error and asked the student to reread the word. After each word had been presented in this manner, the student read the 10 words aloud twice without instructor modeling. The instructor employed the error correction procedure as needed.

Following the word recognition activity, the student completed a read-aloud activity using the reading passage from the textbook. Each reading passage was reproduced in two forms, an instructor copy and a student copy. The student copy was the text only. The instructor copy had text plus a cumulative total of the number of words printed in the right margin. The instructor read the entire passage aloud while the student followed along on the student copy. The student then read aloud from the passage for 5 min while the instructor recorded errors. Five minutes was selected for the read-aloud activity (as opposed to having students read the entire passage) because of time constraints and to minimize student frustration with reading difficult text. As the student read, the instructor marked errors on the instructor copy of the reading passage. At the end of 5 min, the instructor applied an error correction procedure: The instructor pointed to and read aloud any word that had been read incorrectly. The student repeated the word in isolation

Table 4. Sample Instructional Reading Passage

Sample instructional passage: Divisions of the nervous system
Neurons do not act alone. Instead they are joined together to form a complex network—the nervous system. The human nervous system is separated into two major divisions: the central nervous system and the peripheral nervous system.
The central nervous system is the control center of the body. The functions of the central nervous system are similar to those of the central processing unit of a computer. The central nervous system relays messages, processes information, and analyzes information. The peripheral nervous system receives information from the environment and relays commands from the central nervous system to organs and glands. (Passage from Miller & Levine, 2004, p. 901)

and within the sentence where the word appeared. After the error correction procedure, the student again read the passage aloud from the beginning for 5 min.

Vocabulary learning condition. The vocabulary learning intervention was designed to improve knowledge of text-specific terms used in science text. A considerable number of complex, novel vocabulary words are found within science text (Groves, 1995; Scruggs & Mastropieri, 2007). To read and understand the text, it is important that students be able to read and understand the vocabulary terms in the text (e.g., International Reading Association, 2003; Scruggs & Mastropieri, 2007; Scruggs, Mastropieri, Bakken, & Brigham, 1993); yet, secondary students with LD may be limited in their science vocabulary knowledge because of limited exposure to reading science text (Gersten, Fuchs, Williams, & Baker, 2001). Knowledge of relevant vocabulary can improve a student's ability to read and comprehend content-area texts (Bryant, Goodwin, Bryant, & Higgins, 2003; Cassidy & Cassidy, 2007; International Reading Association, 2003; van den Broek, Rapp, & Kendeou, 2004).

The vocabulary learning condition began with a word definition activity. Ten words were selected for the vocabulary learning condition in the same manner as those used in the text-reading condition. Each word was typed on the front of a 3 × 5 index card. The textbook definition, a clarifying sentence intended to connect the word to background knowledge, and two probing questions were typed on the back of the card (see Figure 1). The student was shown each word one at a time as the instructor read the definition (but not the word itself) aloud. The student then repeated as much of the definition as could be remembered. The instructor prompted the student until the student was able to verbalize the definition. The instructor next used the word in a sentence and the student repeated the sentence. The instructor asked the student the two probing questions. If the student was unable to answer a question, the instructor supplied the answer and the student repeated it. This process was repeated a second time.

Meninges	Definition: Three layers of connective tissue in which the brain and spinal cord are wrapped. Sentence: My brain and spinal cord are wrapped by meninges for protection like bubble wrap protects a glass vase. Questions: 1. What is the name of the connective tissue that wraps the brain and spinal cord? 2. What do the meninges protect?

Figure 1. Sample vocabulary word card
Note: Front (right side) and back (left side).

Combined condition. The combined condition was designed to improve text reading and vocabulary learning, and included components from each of the other two interventions. Given the complex nature of science text, and the reading difficulties of students with LD, it was thought that the combined approach, with its emphasis on fluent reading and vocabulary knowledge, might prove to be more powerful than any single approach for improving the ease with which students read text.

We held time constant across the three intervention conditions; thus, activities for the combined conditions were modified somewhat. Whereas in the other two conditions, students completed activities 2 times (e.g., read 10 words aloud 2 times), in the combined condition, students performed these same activities only 1 time (e.g., read 10 words aloud 1 time). The combined condition began with a word recognition and definition activity. The same 10 vocabulary words used in the other conditions were used in the combined condition. The instructor first read each word aloud, after which the student read each word. The student then read all 10 words again while the instructor employed the error correction procedure (as in the text-reading condition). The instructor next read the definition for each word and the student repeated the definition. The instructor used the word in a sentence and the student repeated the sentence. Then, the instructor asked the student the two questions about the word. The instructor prompted the student as necessary (as in the vocabulary learning condition). Finally, the instructor read the passage aloud while the student followed along. The student then read the passage aloud for 5 min while the instructor identified errors and applied the error correction procedure in isolation and within the text. The student then read the passage again (as in the text-reading condition).

Control condition. In the control condition, students received no intervention. The instructor met with the student for approximately 15 min and administered the dependent variable measures only: the student read one science passage for 5 min, took a vocabulary matching measure, and then completed a comprehension measure.

Dependent Variables

At the end of each instructional session, three sets of measures were administered to test the direct and immediate effects of the interventions on the reading of science text. Each measure was designed to examine a different aspect of reading and understanding of text material. The first two measures, reading fluency and vocabulary knowledge, directly reflected the focus of the different interventions. The third measure, comprehension, addressed whether the interventions had an effect on students' understanding of the text passage. Of special interest was whether the interventions would produce effects only on the measures most closely aligned with the treatment, or would generalize to the other measures (see Note 1).

For the *reading fluency measure*, students had 5 min to read the passage aloud. The instructor recorded the number of words read correctly for each minute up to 5 min. The number of words read correctly was scored and entered into all analyses. For the *vocabulary knowledge measure*, students had 5 min to complete a 10-item vocabulary matching task that included the words identified from each passage. The vocabulary measure was developed by listing the 10 vocabulary words on the left side of the page numerically and 12 definitions (including two distracters) on the right side of the page alphabetically. Students were asked to match the definition to the correct term by writing the letter corresponding to a definition next to the number corresponding to its correct term. (Methods used to select text passages and vocabulary words were described earlier.) For the *comprehension measure*, students answered 10 multiple-choice questions selected from the instructional texts. The questions were developed based on Rouet and Vidal-Abarca's (2002) development of high- and low-level questioning. High-level questions were implicit questions that focused on a broad set of concepts where the answers were found within a paragraph or section of the text. Low-level questions were questions that focused on a single proposition and were found within a sentence. Each comprehension measure contained five high-level and five low-level questions. A veteran high school biology teacher previewed the questions for appropriateness of content. Multiple-choice answers for each question were developed, so one response was obviously correct, one response was obviously incorrect, and two responses were reasonable distracters.

Procedures

Each student participated in three instructional sessions (text reading, vocabulary learning, and combined) and one control session. Three different instructors (two graduate students and the lead author) implemented the treatment sessions individually with the students, using an explicitly designed instructional sequence. Sessions were conducted over the course of 4 days; two conditions were delivered in the same week for 2 weeks. Because instructional sessions were counterbalanced across condition, students were provided a different type of reading instruction paired with a different reading passage each session (see Table 4). At the end of each session, students were given the three dependent variable measures. Each instructional session lasted approximately 45 min (30 min for instruction and 15 min to collect measures on the dependent variables). The control condition took approximately 15 min to complete (15 min to collect measures on the dependent variables only).

Treatment Fidelity

A checklist of essential steps was developed from the instructional sequence to check for fidelity of implementation (see Figure 2). Each instructor audio recorded each session. Four sessions from each instructor were chosen at random and checked for fidelity by the lead author, who examined whether each step of the instructional plan had been followed in the correct order. Another graduate student, blind to the treatment conditions, independently scored the audiotaped sessions. Agreement between the lead researcher and graduate student was calculated by dividing the total number of agreements by the number of agreements and disagreements, then multiplying that number by 100. In addition to the audiotaped sessions, the lead author observed each instructor 1 time using the same checklist procedure used for the audiotapes. Fidelity of implementation was computed as the percentage of steps correctly implemented and was found to be 96.7% (range = 92%-100%).

Results

Means and standard deviations for all measures broken down by treatment condition are presented in Table 5. Data were analyzed using a one-factor repeated-measures ANOVA. A Bonferroni correction was used to control for experiment-wise error; thus, a p value of .01 was adopted for determining significance (.05 divided by 5 tests—one repeated-measures ANOVA per variable). Follow-up tests were conducted using dependent t tests for each pair of comparisons. Effect sizes (ESs) for each comparison were computed using Cohen's d where Mean 1 was subtracted

Instructional Activities

Tape Record Each Session

________State the date, time, condition #, and student ID #

Activity 1: Vocabulary learning activity

1. ________Instructor reads the word and definition aloud
2. ________Student repeats; instructor prompts as necessary
3. ________Instructor reads the sentence on the card
4. ________Student repeats; instructor prompts as necessary
5. ________Instructor asks student probing questions and corrects errors
6. ________Instructor and student go through cards one more time
7.

Measures on Instructional Passage

Reading fluency measure

1. ________Instructor reads instructions to student
2. ________Student reads through entire passage up to 5 minutes
3. ________Record wrc for each minute up to 5 min on data sheet

Vocabulary measure

1. ________Instructor reads instructions to student
2. ________Student is given 5 minutes to complete measure.
3. ________Record number of items answered correctly

Science knowledge measure

1. ________Instructor reads instructions to student
2. ________Student is given 5 minutes to complete measure
3. ________Record number of items answered correctly on data sheet

Student Reward

________ Enter name into final drawing.

Number of checked items: ________ /18 total items

Figure 2. Sample fidelity checklist for condition B: Vocabulary learning

from Mean 2, and the value divided by the standard deviation of the difference scores.

Reading Fluency

Because several students completed the entire passage before the allotted 5 min, analyses were conducted on the number of words read correctly in 3 min. Using 3 min eliminated the ceiling effects seen at 5 min, while providing a greater range of scores than that seen at 1 min. Students read approximately 280 words in 3 min in text-reading and combined conditions, compared with approximately 260 words in the vocabulary learning condition and 240 words in the control condition. Results of a repeated-measures ANOVA revealed a significant treatment effect, $F(3, 57) = 9.19$, $p = .000$. Follow-up tests revealed that students read significantly more words in 3 min in the text-reading and combined conditions than in either the vocabulary learning—$t(19) = 2.09$, $p = .05$, ES = 0.47, text reading; $t(19) = 2.21$, $p = .04$, ES = 0.49, combined—or control conditions—$t(19) = 4.36$, $p = .000$, ES = 0.97, text reading; $t(19) = 4.67$, $p = .000$, ES = 1.04, combined. However, even the vocabulary learning condition resulted in greater reading fluency than the control condition, $t(19) = 2.36$, $p = .03$, ES = 0.53. The text-reading and combined conditions did not differ from each other, $t(19) = 0.34$, $p = .74$.

Vocabulary Knowledge

Vocabulary knowledge was measured by counting the number of correct matches students made on the vocabulary measure. Students made approximately 5.5 to 6.0 correct matches in the vocabulary learning and combined conditions, compared with approximately 3 correct matches in the text-reading and 2.5 in the control conditions. Results of a repeated-measures ANOVA revealed a significant treatment effect, $F(3, 57) = 11.97$, $p = .000$. Follow-up tests revealed that students made significantly more correct vocabulary matches in vocabulary learning and combined conditions than in either the text reading—$t(19) = 2.98$, $p = .008$, ES = 0.67, vocabulary; $t(19) = 5.00$, $p = .000$, ES = 1.12, combined—or control conditions—$t(19) = 3.40$, $p = .003$, ES = 0.76, vocabulary; $t(19) = 4.97$, $p = .000$, ES = 1.11, combined. There were no differences in the number of correct vocabulary matches made between the text-reading and control conditions, $t(19) = 1.24$, $p = .23$, nor between the vocabulary learning and combined conditions, $t(19) = 0.71$, $p = .49$.

Passage Comprehension

Passage comprehension performance was measured by counting the number of correct responses on a multiple-choice passage comprehension measure. Students answered approximately 6.5 to 7 questions correctly in the text-reading condition, vocabulary learning, and combined conditions compared with approximately 6 in the control condition. A repeated-measures ANOVA revealed no significant effects for condition, $F(3, 57) = 1.61$, $p = .20$.

Discussion

Scientifically, literate students are those who can understand personal and global phenomena, critically look at the world, solve problems, and use and develop technologies in an ever-changing world (NCLB, 2002). Students who graduate from high school without such skills are at a disadvantage as they try to compete in a global society (American Association for the Advancement of Science [AAAS], 1991).

The purpose of this study was to examine the effects of various reading interventions on reading and understanding of science text for high school students with LD.

Table 5. Descriptive Statistics for Instructional Measures Broken Down by Condition

	Measures		
Condition	Reading fluency	Vocabulary measure	Passage comprehension
Text reading			
M	276.40	3.10	6.95
(*SD*)	(105.27)	(1.33)	(1.85)
Minimum	131	1	2
Maximum	498	6	10
Vocabulary learning			
M	259.20	5.40	6.60
(*SD*)	(95.73)	(3.52)	(1.70)
Minimum	114	0	2
Maximum	449	10	10
Combined			
M	279.55	5.90	6.80
(*SD*)	(105.90)	(3.04)	(1.99)
Minimum	108	1	1
Maximum	470	10	10
Control			
M	237.70	2.55	5.90
(*SD*)	(98.67)	(1.91)	(1.94)
Minimum	99	0	2
Maximum	462	7	10

Results revealed differential treatment effects on reading fluency and vocabulary learning, but not for passage comprehension. In general, effects matched intervention condition; that is, students performed better on the reading fluency measures when they received instruction that focused on text reading (i.e., text-reading and combined interventions), and better on the vocabulary knowledge measures when they received instruction that focused on vocabulary learning (i.e., vocabulary learning and combined interventions). The one exception to this pattern was that vocabulary instruction resulted in improved reading fluency when compared with the control condition, perhaps reflecting the importance of vocabulary knowledge in the reading of science text. Science text contains a large number of technical vocabulary words (e.g., Shankweiler et al, 1998; Yovanoff et al., 2005), thus, it is not surprising that knowledge about the meaning of those words would aid in reading the text fluently. It is interesting to note in this light that the opposite effect was not seen—that text reading alone did not lead to improvements in vocabulary knowledge. This latter result replicates previous research demonstrating that reading alone does not affect improvements in vocabulary knowledge. Instead, direct vocabulary instruction is needed (International Reading Association, 2003; Scruggs et al., 1993; Scruggs & Mastropieri, 2007).

For reading fluency and vocabulary knowledge, the largest ESs were observed for the combined conditions (e.g., ES = 1.04 and 1.11, respectively, when compared with control), suggesting that the combined condition holds the most promise for future research. The obtained ESs for the combined condition were the same as or somewhat larger than those seen for the isolated skill interventions (e.g., ES = 0.97 for text reading vs. control on reading fluency; ES = 0.76 for vocabulary learning vs. control on vocabulary knowledge), despite the fact that the instructional time was held constant across conditions. That is to say, the combined intervention was not only the most effective, but also the most efficient: In the same amount of time devoted to the isolated skill interventions (30 min), effects were obtained for reading fluency and vocabulary knowledge in the combined condition.

Using the guidelines set forth by Cohen (1988), the ES associated with the combined condition would be considered to be large. However, Cohen urged caution when interpreting ESs, stating that, "The terms 'small,' 'medium,' and 'large' are relative, not only to each other, but to the area of behavioral science or even more particularly to the specific content and research method being employed in any given investigation" (p. 25). Thus, it is important to consider the context and method employed to interpret the ESs. Given the fact that students with LD have severe reading and content-learning deficits compared with peers, and the fact that students received only 30 min of instruction in the combined condition, ESs of 1.04 in reading fluency and 1.11 in vocabulary knowledge could be viewed as promising, and certainly worthy of further study. However, it must be noted that in the control condition, students merely completed the reading fluency, vocabulary knowledge, and reading comprehension measures. Had students been given time to read the passage silently before completing the measures, they may have performed better in the control condition. Nonetheless, the combined intervention resulted in moderate ESs when compared with interventions not matched to the outcome measure. That is, students read more fluently in the combined condition than in the vocabulary condition with an ES of 0.47. Similarly, students identified more vocabulary terms correctly in the combined condition than in the text-reading condition with an ES of 1.12.

Any enthusiasm over the size of the effects found for the reading fluency and vocabulary instructional measures must be tempered by the lack of results seen for comprehension of the instructional passages. The obtained scores on the comprehension measure for the three intervention conditions were not much different from the scores in the control condition (6.5–7 correct vs. 6 correct), and these differences were not statistically significant. However, examination of the scores on the comprehension measure reveals a large range of scores. In the control condition, the scores ranged from 2 to 10; however, scores were fairly normally distributed—perhaps reflecting differences in students' background knowledge related to the passage topic. Within each intervention condition, the range of scores was also large (from 1 or 2 to 10); however, the large range was caused by outliers within each condition, perhaps suggesting a differential effect of the interventions on individuals. If outliers are removed in a listwise fashion (resulting in a sample size of 15), the following means and standard deviations are obtained on the comprehension measure: text reading (M = 7.27, SD = 1.53); vocabulary (M = 6.33, SD = 0.82); combination (M = 6.87, SD = 1.41); and control (M = 5.47, SD = 1.85). A repeated-measures ANOVA reveals a significant effect for condition, $F(3, 42) = 4.41$, $p = .009$. Follow-up tests reveal significant differences between the control and text reading, $t(14) = 3.15$, $p = .007$, ES = 0.82, and control and combined conditions, $t(14) = 2.43$, $p = .03$, ES = 0.63. The pattern of results with the outliers removed suggests that the text-reading and combined interventions may have, in fact, positively influenced comprehension of the text for a number of students. A replication of the study with a larger sample size could more closely examine the potential influence of the interventions on comprehension of the text.

Despite these conjectures about outliers and the structure of the measure on the comprehension results, we leave open the possibility that simple vocabulary word reading and fluency interventions may not be enough to influence understanding of science text. Understanding science text undoubtedly requires a reasonable amount of content knowledge. In a typical classroom situation, that content knowledge would be provided during science instruction concurrently with reading instruction.

In summary, a simple, 30-min intervention that is easy to implement and require little training was found to have a direct and immediate effect on the reading and understanding of content words and on the fluent reading of text drawn from the students' science curriculum. Effects on the comprehension of the text were less clear. It seemed that some students profited from the interventions while others did not. For some students more or different types of interventions may be needed to improve understanding of the text.

Implications for Practice

Several educational implications emerged from this study. First, and perhaps most important, the results imply that high school students with LD can improve fluent reading of science text and knowledge of science vocabulary if they are provided with reading and vocabulary instruction on that text. Although this result seems obvious, it is important because there have been questions raised about the likelihood that secondary students can improve their reading performance (see Deshler, 2005). In addition, there are questions about how much direct reading or vocabulary instruction students with LD receive in science classes (Apel & Swank, 1999; Cassidy & Cassidy, 2007; Vacca, 1998). Therefore, this study reveals that high school teachers may be able to effectively improve reading fluency and vocabulary knowledge by implementing research-based interventions using content-area text when working with struggling readers.

Second, teaching reading fluency and vocabulary knowledge in the same session resulted in effects equal to or larger than teaching the skills in isolation, and did so in sessions that were no longer than the isolated skill sessions. These results supports previous research demonstrating that a combination of effective interventions yields the greatest effects in reading improvement (Mastropieri et al., 2003; Swanson, 1999), and suggest that the combined approach might hold the most promise for future research.

Third, even though positive effects were seen on the instructional measures of reading fluency and vocabulary knowledge, these effects did not translate into better comprehension of instructional passages for some students. Thus, it is not possible to say based on the findings from this study that the interventions would be effective for improving science performance for students with LD. Generalized effects might be seen if the interventions were to be implemented over a longer period of time or combined with content-area instruction.

In summary, considering the exploratory nature of the study, our results imply that further investigation of a combined intervention approach in which reading fluency and vocabulary knowledge are emphasized is in order. In our study, this approach resulted in improved reading of instructional texts and greater knowledge of the vocabulary used in that text. Future research must examine whether these improvements influence comprehension of the text and transfer to improvements on texts not directly used in instruction. In addition, the effects of improved reading on performance in science classes or on state standards tests must be examined.

The rates of academic underachievement and the risk for dropping out of school for students with LD is a testament to the need for continued specialized instruction for this population. The needs of secondary students with LD are such that continued support in reading and reading-related tasks continues to be a critical need (Deshler, 2005; Kauffman, 1999). The data from this short-term study support further examination of the effects of interventions delivered to larger numbers of students over a longer period of time.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) received no financial support for the research, authorship, and/or publication of this article.

Note

1.We also administered two transfer measures—reading fluency and maze vocabulary—2 weeks after the completion of the intervention. There were problems with the construction of the maze vocabulary measure, and we found no significant group differences on either of the transfer measures. Thus, we do not report the results of the transfer measures in this article. We would note, however, that on the reading fluency transfer measure, students in all three instructional groups read more words in 3 min (between 285 and 290) than the control group (277 words); however, these differences were not statistically significant.

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