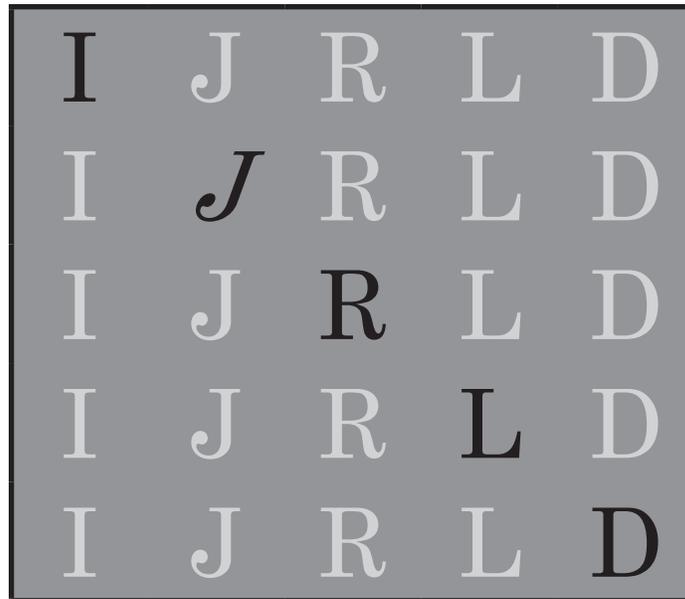


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formerly *Thalamus*
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Table of Contents

Barbara Reid: In Appreciation	3
DAVID SCANLON	
2016 William M. Cruickshank Memorial Lecture	5
From Research to Effective Classroom Practice: Progress and Obstacles to Serving Students With Learning and Attention Issues	
DAVID J. CHARD	
Improving Story Writing: Integrating the Story Mnemonic Strategy With iPad Apps for Art and Keyboarding	11
MICHAEL DUNN AND DARCY MILLER	
Effects of an Early Numeracy Intervention on Struggling Kindergarteners' Mathematics Performance	29
BRIAN R. BRYANT, DIANE PEDROTTY BRYANT, GREG ROBERTS AND ANNA-MÁRIA FALL	
Oral Reading Miscues and Their Relation to Silent Reading Comprehension in Children With and Without Learning Disabilities	47
MINYI SHIH DENNIS, BRIAN R. BRYANT, AND MARY BETH CALHOON	

Barbara Reid

In Appreciation

When the Academy decided to create this journal, one of our first tasks was to plan for its format and layout. At the very same time, Barbara Reid of Toronto, Canada, was starting out too, having just finished training as a copy editor. From the look of our cover to our style guide, Barbara helped to create the IJRLD. She was an invaluable partner to me. She learned the APA manual inside and out, researched assiduously, and happily deliberated myriad details with me as we created the new journal. Barbara was dedicated to both honing her skills and creating a journal that matched the high standards of the International Academy for Research in Learning Disabilities. She took pride in “our” journal. It was a joy to collaborate with Barbara – always in high spirits, she proudly shared stories of her family. It was also an inspiration to work with Barbara. She produced much of the second issue from her hospital bed, and all of the third. She also tried to muster the strength to work on our fourth issue. Because Barbara wasn’t sure she could complete her work in time to meet the production timeline, she selflessly gave up the task she was otherwise so looking forward to.

Sadly, we lost Barbara last winter. This issue of the *International Journal for Research in Learning Disabilities* is dedicated to Barbara Reid in appreciation for all she contributed to help found it and get it off to a successful start.

– David Scanlon, Editor

**William M. Cruickshank Memorial Lecture Delivered at the
2016 Conference of the International Academy
for Research in Learning Disabilities**

**From Research to Effective Classroom Practice:
Progress and Obstacles to Serving Students With
Learning and Attention Issues**

In June 2016, I had the honor of delivering the William Cruickshank Memorial Lecture at the annual meeting of the International Academy for Research in Learning Disabilities (IARLD). What follows is the set of questions I asked myself as I prepared the presentation and a brief of the comments that unfolded in my talk.

1. *In 1972, William Cruickshank published a paper on the issues facing the field of learning disabilities (LD) at that time. How do the issues that Cruickshank raised in 1972 compare to the issues facing our field today?*

Cruikshank wrote of three issues that were of particular concern to our field: (a) the challenge of accurately identifying LD; (b) the need to improve teacher knowledge of LD and our capacity to provide the professional support that teachers need to adequately serve children with LD; and (c) the challenges related to class action suits by families regarding access to programming.

Clearly, we have made tremendous progress, but the issues that Cruickshank listed remain relevant today despite the nearly 45 years that have passed since then. The focus of my William M. Cruickshank Memorial Lecture was on how much progress we have made on these and other challenges facing our field.

2. *What progress have we made and in what areas?*

Inarguably, much progress has been made since 1972 with respect to the status of individuals identified as having LD. One area in which we have seen progress is the public's perception of LD. According to a survey conducted by the Tremaine Foundation in 2010 (Gfk Custom Research North America, 2010), there has been a steady increase in the number of people who view individuals with LD as being just as intelligent as their nondisabled peers, with 81% of respondents reporting that they agree or mostly agree with this perception. Additionally, among respondents who are educators, 99% report that students with LD learn differently than their other students. These perceptions, while very general, suggest important development in the way people think about the impact of LD and likely their thoughts about how students with LD should be treated in school.

In a related development, we have seen tremendous progress in the way people think about the long-term impact of LD. In the past, many perceived LD as a condition that would limit one's ability to succeed in life. However, according to the National Center on Education Statistics (National Longitudinal Transition Survey-2, 2011), the majority of parents today expect their children

with LD to graduate from high school and live independently. Indeed, the overwhelming majority expect their children with LD to get a paying job. At the same time, however, respondents are less certain that their children with LD will go on to receive a postsecondary education.

Perhaps one of the areas that have progressed most rapidly over the past decades is research on LD. One example is our expanded knowledge of how to identify specific types of LD. In 1972, when Cruickshank wrote, there was a singular focus on identifying individuals with LD using a severe discrepancy approach supported by assessment tools such as *The Illinois Test of Psycholinguistic Abilities* (ITPA; Kirk & McCarthy, 1961). Since then, due to methodological limitations, the ITPA, and more recently the severe discrepancy model, has been replaced by more contextualized identification practices. For example, in the area of reading for students with LD, researchers have noted that some students have a core phonological deficit that prevents them from hearing the individual sounds in words, which, in turn, can be a barrier to learning to blend sounds into words. This finding has resulted in a significant number of interventions focused on phonological awareness as a precursor to reading development (e.g., *RAVE-O*, Wolf, 2015; *Ladders to Literacy*, O'Connor, Notary Syverson, & Vadasy, 2005). Perhaps most important, identification of the core phonological deficit apart from other conditions (e.g., specific language delays, dyscalculia) has allowed for interventions to be differentiated, moving early reading interventions from a more macro focus on phonics to the more micro focus on phonological awareness paired with phonics.

However, much work needs to be done with regard to treatments specific to particular symptoms. For example, we continue to struggle with specific interventions tailored to meet the needs of students with attention issues. In the past, we treated attention as a behavior trait and sped up our instruction to hold attention. There is growing evidence, however, that this approach may exacerbate attention problems rather than ameliorate them. In short, in many cases, instructional options for addressing LD remain general and under-determined.

Another area of progress involves the establishment of standards for research-based practices within the special education research community

(Gersten et al., 2005; Horner et al., 2005). Specifically, standards focus on the number of studies that have been conducted on a given intervention/practice, the types of methodologies employed in those studies, the number of researchers or research groups that have conducted research on the practice, and the outcomes from those studies.

Subsequently, these standards have been applied to particular practices used in special education classrooms, including repeated reading to improve reading fluency and self-regulated strategy development (SRSD) in writing (Baker, Chard, Ketterlin-Geller, Apichatabutra, & Doabler, 2009; Chard, Ketterlin-Geller, Baker, Doabler, & Apichatabutra, 2009). Such analyses have revealed gaps in the research literature and underscored the fact that many practices, even though widely implemented, have not been subject to rigorous, systematic study. For example, the research on SRSD in writing is much more systematic than research on repeated reading approaches. SRSD research comprises specific studies thoughtfully building on prior work, conducted by research teams from across the country with different populations of students.

Another advance that has impacted students with LD is a growing knowledge base on effective practices for teaching academic and noncognitive behaviors generated through research funded by the U.S. Department of Education's Institute for Education Research. Thus, the National Center for Special Education Research (NCSER) and the National Center for Education Research (NCER) have both developed guides listing practices supported by sufficient evidence to warrant their use in areas such as social behavior, literacy, and mathematics (<http://ies.ed.gov/ncee/wwc/Publication#/Content-TypeId:3>). Although not always studied specifically for use with students with LD, the practices have the potential to improve learning in the general education classroom.

Further, progress has been made in terms of helping teachers better identify students with LD who do not respond to and need additional support or intensive support through a response-to-intervention (RTI) framework with multiple tiers of instructional support (National Center on Response to Intervention; <http://www.rti4success.org/essential-components-rti>). This approach, codified in the 2004 reauthorization of the *Individuals with Disabilities Education Act*,

was meant to offer states the option to use the RTI framework rather than the severe discrepancy model used in most states. Today, RTI is the most common model for identifying and serving students with LD in public school settings.

The progress we have made as a field since 1972 is considerable. Our understanding of LD is much more sophisticated and the general public's perceptions about LD are much less limited. Additionally, we have made great strides in research on teaching and learning as well as in our understanding of the nature of education research. Many opportunities for improvement still exist, however.

3. *What obstacles and opportunities remain?*

Despite the progress illustrated above, a number of obstacles still remain in our work to improve teaching and learning for individuals with LD. One example is a persistent underfunding of education research in the United States. Since 2010, the Institute for Education Science, the research arm of the Department of Education, has not received a substantial budget increase for research. The NCSER, in particular, lost funding in 2011, and its research funding has not been restored to pre-2010 levels.

This unfortunate reality puts our hard-won knowledge about the needs of students with disabilities in general, and those with LD specifically, at risk of languishing. National advocacy groups (e.g., National Center for Learning Disabilities [NCLD]) continue to push for increased funding, but the U.S. Congress has been slow to react.

Further, although we have made strides in the public's perception of students with LD, much work remains to be done in this area. Again, according to a survey conducted by the Tremaine Foundation in 2010 (GfK Custom Research North America, 2010), 51% of adults believe that LD is a result of laziness and 55% believe that LD is caused by the home environment. The challenge is to continue to work as a community to highlight successes of individuals with LD across many domains and to work to educate the public on the causes and consequences of LD.

Another concern is that the professional LD community is diminishing. The National Center for Learning Disabilities (NCLD) in its State of LD (2014) Report noted that between 2009 and 2013, membership organizations associated with profes-

sionals working with students with LD experienced a severe decline in membership. For example, the Division for Learning Disabilities of the Council for Exceptional Children has gone from more than 5,000 members in 2010 to fewer than 2,500 members today (M. Faggella-Luby, personal communication, November 7, 2016). Similarly, many organizations that support teachers and other personnel who work with students with LD have reported several years of flat revenue. These trends seem to suggest that professionals do not believe that they benefit from these organizations or feel they can get the same services elsewhere without the cost of membership or affiliation.

Finally, I believe there is reason for concern with regard to the number and quality of teachers being prepared to work in public education, specifically to work with students with LD. According to the National Coalition on Personnel Shortages in Special Education and Related Services (<http://specialeducation-shortages.org>), 49 states report a shortage of special education teachers; at the same time, the rate of special education teachers leaving the field is nearly double that of their general education counterparts. Moreover, these challenging figures are amplified as we look at communities of poverty where 90% of districts report difficulties in finding special education personnel. Despite national and regional efforts to solve these issues, the poor working conditions and relatively low salaries combined with challenges associated with receiving credentials (e.g., tuition costs, state tests) paint a bleak picture.

4. *Why does our work remain important 45 years after Cruikshank wrote his paper about the challenges facing our field?*

Many of the reasons that made Cruikshank's work relevant 45 years ago still apply today. Individuals with LD remain negatively impacted by their condition despite the many areas of progress noted above. For example, only 38% of students with LD are reading at grade level by fourth grade compared with 72% of their peers. Further, attendance by individuals with LD in postsecondary education is only half of that of their nondisabled peers and unemployment is nearly double that of their nondisabled peers. These negative consequences of LD remain persistent and continue to deserve our careful attention.

When we turn to specific subgroups, the statistics are even more startling. People living in poverty are nearly twice as likely to be identified as having LD as the general population, and black students are more likely to be identified for special education services than the population at large. Finally, students with attention difficulties are nearly seven times more likely than their nondisabled peers to be incarcerated. For example, according to the National Longitudinal Transition Survey-2 (NCES, 2011), 55% of young adults with LD report having some involvement with the criminal justice system within eight years of leaving high school.

Finally, though far less bleak than the consequences noted above, a number of new initiatives being recommended in our field may not be beneficial for students with LD. For example, the Bill and Melinda Gates Foundation has invested substantially in the development of a Personalized Learning Initiative, designed to personalize students' learning experience based on their needs and interests (<http://k12education.gatesfoundation.org/student-success/personalized-learning/>). Many schools and school districts are embracing this idea and are working on models to implement it. However, while a personalized approach might offer enormous opportunities to meet the individual needs of students with LD, if it relies too much on self-guided learning or does not provide adequate instructional support, personalized learning may result in students languishing in content-area classes with little support from qualified teachers. Similarly, critics of education reform initiatives have

suggested that many of these programs are not responsive to the needs of students with LD (e.g., Fabricant & Fine, 2012). In the case of pay-for-success programs, for example, some critics argue that teachers and schools are rewarded for keeping students out of special education despite their eligibility (McIntyre, 2015).

In closing, the future for students with LD is clearly brighter than it was in 1972, but we have much work to do to ensure that individuals with LD are able to achieve their dreams. To that end, I encourage each member of the Academy to reflect on how he or she can contribute to each of the following:

- Advocate for and conduct high-quality research;
- Expand advocacy efforts related to public perception about LD;
- Push for reform of teacher education that includes research on effective teaching and learning practices;
- Engage in efforts to recruit, support, and retain strong general and special education teachers who can make a difference in lives of individuals with LD;
- Work to re-energize our professional community by joining professional organizations that support any of the efforts on this list.

It was an honor to be selected to deliver the 2016 William Cruikshank Memorial Lecture at the annual meeting of the International Academy for Research in Learning Disabilities. I hope this synopsis of my talk is helpful for those of you who were unable to join us in Austin.

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Improving Story Writing: Integrating the Story Mnemonic Strategy With iPad Apps for Art and Keyboarding

Abstract

Students with learning disabilities in writing often experience challenges with many or all of the components of creating text. According to the National Center for Education Statistics (2012), 95% of 8th- and 12th-grade students with disabilities failed to score within the proficient range in writing. This multiple-baseline-across-participants study investigated the use of a mnemonic strategy, STORY, integrated with art, evidence-based instruction, and technology. The results show that three participants' texts improved in level and trend for written content and quality. One participant initially improved but developed a negative trend as the intervention phase progressed into maintenance. Study outcomes extend the research on the effectiveness of mnemonic strategies for improving students' writing and demonstrate that art, evidence-based instruction, and technology have the potential to make positive contributions to writing instruction.

Recent years have seen a renewed emphasis on writing proficiency, as reflected in the writing standards in the Common Core State Standards (CCSS) (Council of Chief State School Officers and the National Governors' Association [NGA], 2010) and aligned assessments (e.g., Smarter Balanced, 2015, Partnership for Assessment of Readiness for College and Careers, n.d.). However, managing the task of writing is a significant challenge for many students. For example, assessing fourth-grade writing through a computer-based pilot program, the National Assessment of Educational Progress (NAEP) found that almost 39% of the students had low or marginal skills in writing, demonstrating a lack of correct grammar and mechanics (White, Kim, Chen, & Liu, 2015).

Students with learning disabilities in writing often experience even more challenges with many or all of the components of writing (Gonzalez-Ledo, Barbetta, & Unzueta, 2015; Harris, Graham, Mason, & Friedlander, 2008; Mather, Wendling, & Roberts, 2009). Thus, the Nation's Report Card: Writing 2011

(National Center for Education Statistics, 2012) concluded that 95% of 8th- and 12th-grade students with learning disabilities wrote at or below a basic level. The process of planning, organizing, developing a story line, generating phrases and a first draft, and finessing a final copy of text can all pose great challenges for these students (Graham & Perin, 2007a, 2007b; Mason, Harris, & Graham, 2011; Saddler & Graham, 2007; Sitko, Lane, & Sitko, 2005). Specifically, students with a learning disability in writing may have difficulty with executive function and self-regulation of skills, such as choosing a story topic, feeling confident about what a story outline and plan entails, knowing how to create connected text for a first draft, and recognizing what edits to make in subsequent drafts to render a polished text (Graham, MacArthur, & Fitzgerald, 2013; Polloway, Patton, & Serna, 2005). In addition, attentional issues can also pose challenges for these students (Morin, 2015).

Integrated within the renewed emphasis on writing proficiency in the CCSS is a call for students to use technology to manage learning and

writing tasks. The CCSS include handwriting only to the end of first grade, whereas in second and subsequent grades students are to use technology tools (NGA, 2010). Indeed, writing interventions that integrate technology have been shown to improve the writing quality and skills of students with disabilities (Carnahan, Williamson, Hollingshead, & Israel, 2012; Graham & Perin, 2007a, 2007b; Hetzroni & Shrieber, 2004; MacArthur, 2009; Silio & Barbetta, 2010; Williams, 2002; Wissick & Gardner, 2011), and many studies point to the continuing potential of technology to help students with disabilities improve their academic outcomes in writing (Ahrens, 2011; Bouck, Doughty, Flanagan, Szwed, & Bassestte, 2010; Edyburn, 2006; Englert, Zhao, Dunsmore, Collings, & Wolbers, 2007; Goldberg, Russell, & Cook, 2003; Haq & Elhoweris, 2013; Mason et al., 2011; Patti & Garland 2015; Peterson-Karlan & Parette, 2007; Sitko et al., 2005; Sturm & Rankin-Erickson, 2002).

Bouck et al. (2015) describe a variety of technology supports that show potential for writing intervention and can be integrated into writing instruction to improve outcomes for students with learning disabilities. Speech-to-text software, for example, allows students to voice their ideas while a technology device encodes the text for them, thus providing a means to manage the cognitive load of having to sequence story ideas in lieu of handwriting or typing at the same time. Finally, students with disabilities have been found to be more motivated to write when technology tools are used in instruction (Goldberg et al., 2003; Sturm & Rankin-Erickson, 2002). This is an important consideration given that motivation is a key factor in writing (Boscolo & Gelati, 2013).

Several evidence-based instructional approaches that integrate technology hold promise for teaching writing to students with disabilities. For example, self-regulatory writing practices (Graham & Harris, 2011), composition and mechanics (Edyburn, 2006; Mason et al., 2011), planning, scaffolding, and organization (Englert et al., 2007; Saddler & Asato, 2007; Sitko et al., 2005), concept mapping (Sturm & Rankin-Erickson, 2002), idea generation and organization (Carnahan et al., 2012; Hetzroni & Shrieber, 2004), and procedural facilitators (Graham & Perin, 2007b), all with a technology component, have been shown to improve the writing quality and skills of students with disabilities. However,

the key to technology integration is that it is used with evidence-based instruction.

Use of evidence-based practices in teaching writing is recommended by professional organizations and also promoted in government policies (Haynes, 2015). Several evidence-based approaches to teaching writing have yielded positive results, including strategy-regulated strategy instruction (Graham & Harris, 2005), use of mnemonics (e.g., DARE: Develop your topic sentence; Add supporting ideas; Reject arguments for the other side; End with a conclusion; Harris et al., 2008); self-talk/verbalization (e.g., TAPS: Tell the person what you liked about the paper; Ask questions about parts that are unclear; Provide suggestions for making the paper better; Share the revised paper; Mather et al., 2009); and visual imagery (e.g., oral discussion, demonstration of ideas with art, then write a draft text; Graves, 1994).

To address the writing challenges of students with learning disabilities, strategy instruction (Perin, 2013) has been found beneficial. For example, Graham and Perin's (2007a, 2007b) meta-analyses of writing instruction concluded that strategy instruction, which often includes a mnemonic, attained one of the highest effect sizes both for struggling writers and for adolescents in general. Similarly, Gillespie and Graham (2014) concluded that strategy instruction had a statistically significant impact on the writing quality of students with a learning disability.

Strategy instruction, specifically self-regulated strategy development (SRSD), offers educators and students a means to manage the instruction and learning process (Ferretti & Lewis, 2013; Graham et al., 2013; Reid & Lienemann, 2006). The instructional design of SRSD consists of six components: developing and activating background knowledge, discussing the strategy, modeling the strategy, memorizing the strategy, and practice to support the use of the strategy.

Mnemonics are effective additions to strategy instruction as they help students with meanings, understandings, concepts, and the procedures for completing tasks, often referred to as semantic memory (Yee, Chrysikou, & Thompson-Schill (2013). MacArthur and Philippakos (2010) found that using strategy instruction with embedded mnemonics improved the quality of writing and resulting text structure elements for students with learning disabilities. That is, by learning and applying a mnemonic strategy, students can approach writing

tasks in a sequential-step manner (e.g., POW: Plan, Organize, Write [POW], Saddler, Moran, Graham, & Harris, 2004; Chia-Ju & Chiang, 2014; Scruggs & Mastropieri, 2000).

One story grammar mnemonic that has provided struggling writers with an effective means to create and organize content is the WWW, W=2, H=2 mnemonic (Graham & Harris, 1989). The letters making up the mnemonic refer to questions about who is in the story, where the story takes place, when the story takes place, what happens, what happens next, how the story ends, and how the characters feel. Exploring knowledge building, teaching modeling, self-regulation strategy instruction, and the WWW, W=2, H=2 mnemonic, Saddler et al. (2004) concluded that students' use of WWW, W=2, H=2 contributed to improved story content.

Further, self-talk/verbalization (part of strategy instruction and some mnemonics) can promote improvement in students' writing skills (Fidalgo, Torranceb, Rijlaarsdamc, van den Berghd, & Álvarez, 2015). For example, the Cognitive Strategy Instruction in Writing (CSIW) (Englert et al., 1991; Englert & Mariage, 2003; Troia, 2011), which includes specific self-questions in the stages of the writing process that focus on introducing the topic and details, has been shown to help students include more elaborate content in their writing. Further, using the Think, Talk, Text mnemonic (Think about your story ideas, Talk them out loud, and then generate your written Text), Katahira (2012) found that verbalizing story ideas enabled students to make auditory idea edits before generating text, as advocated by Hayes and Flower (1980). Gardner (2000), in turn, suggested that the auditory domain can help students manage the concurrent aspects of a task such as writing. Finally, verbalizing ideas seems to facilitate automaticity in the writing process and can produce much more elaborate text (Boyle & Charles, 2010; Graham, 2008; MacArthur, 2009).

In addition to strategy instruction, mnemonics, and verbalization, visual imagery can also be helpful for effective story writing (National Center for Learning Disabilities, 2011). Thus, incorporating the arts into the process of planning for writing offers students an option to illustrate what they are thinking and compensates for spelling and text-generation difficulties. For example, with recursive planning and thinking, an image initially

thought to be simplistic can become intricate and motivating as the thought processes become more elaborate in "seeing" the image (Patterson, 2011). For writers, using art for planning can be a powerful tool given that during planning almost all of their mental energies can be devoted to the image and what it represents, with the potential of creating more elaborate content and quality text.

Purpose of the Study

The purpose of the present study was to explore the benefits of strategy instruction with a mnemonic that integrated technology and visual imagery. Specifically, the study examined the functional relationship between the STORY mnemonic (Dunn, 2015b) within strategy instruction and the content and quality of participants' typed (keyboarded) texts (and spoken/scribed story plans as a secondary/comparative measure).

Method

A multiple-baseline-across-participants design was employed to explore the use of strategy instruction with a mnemonic using technology and visual imagery. The researchers examined the effects of a mnemonic strategy (STORY) embedded in strategy instruction on participants' spoken/scribed texts (quality and content) and the number of words written over the course of the intervention. The study also explored participants' perceptions of the usefulness of the strategy (social validity) through a qualitative interview process following the study.

Setting

The study took place at a suburban elementary school in the Pacific Northwest region of the United States. The school enrollment was approximately 500 students (males, 53%; females, 47%); American Indian/Alaskan Native, 0.2%; Asian, 2.9%; Native Hawaiian/Other Pacific Islander, 2.7%; Black/African American, 1.2%; Hispanic/Latino, 16.6%; White, 62.5%; two or more races, 11.9%).

Twenty-three of the students had a learning disability and individualized education program (IEP) writing goals. Over 48% of the students par-

ticipated in the free/reduced-price lunch program and 14% received special education services. In the most recent state assessment of writing, a computer-based assessment, 42.3% of the students scored below grade level according to the assessment criteria. The study activities were carried out during the regularly scheduled reading/writing period.

Participants

Participants were recruited from the population of 23 students who had been identified as having a learning disability in the elementary school (see Table 1). The special education teacher (resource room) in the elementary school provided the researchers with a list of all students with identified learning disabilities who also had writing goals in their IEP. The teacher sent letters home with students describing the intervention and the study to elicit interest.

Four students agreed to participate in the study with their parents' consent. All four (a) were identified as having a learning disability, based on the state-mandated intelligence/achievement discrepancy method; (b) were receiving special education services; and (c) were of Caucasian race/ethnicity. According to the *Benchmark Assessment System* (Fountas & Pinnell, 2011) administered by the

school, two of the participants, Evan and Kate, were reading at the end-of-first-grade level, whereas the other two, Madoka and Nancy, were reading at the end-of-second-grade level.

Instrumentation

Writing interest interview. Prior to baseline, participants were interviewed using the Writing Interest Interview (Rhodes, 1993). The interview protocol consists of nine questions on a range of topics about writing, including the participants' understanding of writing (What is writing?), their history of writing (Who helped you learn to write?), the challenges of writing (When you are writing and you have a problem, what do you do?), the enjoyment of writing (What do you really like about your writing?), and the improvement of writing (What would you like to improve about your writing?). Emma, the intervention teacher (an education graduate student at the researchers' university), read aloud each question and scribed each participant's answer.

Curriculum-based measurement. Participants completed randomized curriculum-based measurement (CBM) probes on precise and consistent days (i.e., six CBM probes spaced across the baseline, the last three before training; at least five

Table 1
Description of Participants

Participant	Gender	Age	Standard Scores Intelligence	Reading Academic Achievement	Standard Scores in Writing Achievement	Grade Level	Level of Special Education Placement	Minutes per Week in Special Education Placement
Evan	M	9-5	88 ¹	1.9 ³	64 ⁴	4th	Resource Room	240
Kate	F	9-7	78 ¹	1.8 ³	79 ⁵	4th	Resource Room	420
Madoka	M	11-0	78 ²	2.8 ³	58 ⁵	5th	Resource Room	507
Nancy	F	10-6	83 ¹	2.7 ³	93 ⁵	5th	Resource Room	466

Note. Pseudonyms used.

¹Differential Ability Scales II (Elliot, 2007); ²Wechsler Intelligence Scales for Children IV (Wechsler, 2003); ³Benchmark Assessment System (Fountas & Pinnell, 2011); ⁴Woodcock-Johnson Tests of Achievement III (Woodcock, McGrew, & Mather, 2001); ⁵Wechsler Individual Achievement Test – Third Edition (Pearson, 2009).

spaced across the intervention phase with the first three being after training; and one in maintenance) to document change in students' writing ability during baseline and intervention phases.

The CBM assessments consisted of presenting the participants with a simple cartoon picture (different for each student and at each session). The researchers provided Emma with a folder with randomly assorted probes, which she could notate and file to ensure that no two students would do the same probe on a given day or twice during the project. In response to the probes, participants planned and wrote a story about the image or another topic of their choosing. They had 10 minutes to plan their text and 15 minutes to type it on an iPad, provided by the researchers with some initial practice sessions. These timelines reflected the authors' teaching experience of what works well for students and fit the overall 45-minute daily lesson plan.

Story content scores represented the number of WWW, W=2, H=2 (Graham & Harris, 1989) story grammar questions addressed in the participants' story texts. Many studies have used WWW, W=2, H=2 as part of writing interventions with positive effects (e.g., Zumbunn & Bruning, 2013).

The story quality rubric used was based on Harris and Graham (1996) and the 6+1 Traits of Writing (Education Northwest, 2016). Participants' story quality scores resulted from how each text compared to a 0-7 list of exemplars representing increasing levels of elaborate and finessed prose: 0 = no text, 1 = a few words; 2 = a short description of the picture prompt with incomplete sentences and no sense of story line; 3 = a short description with simple sentences but no sense of story line; 4 = some sense of a story line, no clear introduction and conclusion, and evident grammatical and syntactical errors; 5 = some evidence of an introduction, main event, and conclusion with grammar and punctuation mostly correct but no use of paragraphs or voice; 6 = evident introduction, main event, and conclusion with some use of paragraphing and voice and grammar and punctuation mostly correct; 7 = a clear introduction, main event, and conclusion with use of paragraphs and voice and almost completely correct use of grammar and syntax.

Reliability of the story quality rubric was based on the first author's published studies about story writing, Harris and Graham's (1996) model, and

the 6+1 Traits of Writing, with a reliability coefficient of .94 for fifth-grade writing (Coe, Anita, Nishioka, & Smiley, 2011).

Exit interview. At the end of the study, a short exit interview was conducted with each participant consisting of the following questions: What did you like about STORY? What would you change? Do you think other students would benefit from STORY? Have you or will you use STORY in your classroom or at home for other writing tasks? Emma read each question aloud and scribed participants' responses.

Procedures

A multiple-baseline-across-participants design was employed (Kratochwill & Levin, 2014; Kratochwill et al., 2010) consisting of a baseline phase, training phase, intervention phase, and maintenance phase. Random assignment determined each student's placement in the sequence of the study (e.g., who was first to receive training in STORY).

The operational definition of the independent variable (IV) was the STORY mnemonic strategy. The four dependent variables (DVs) were spoken and written content and spoken and written quality. Stability at baseline was defined as the last four data points demonstrating a level or declining trend. Kratochwill et al.'s (2010) criteria (e.g., level, variability, stable or negative trend during baseline, overlap, immediacy of effect) helped determine if a functional relationship existed between the IV and DVs (i.e., written story content and quality).

Independent variable. The STORY mnemonic developed by the researchers is grounded in research on language, learning, and writing instruction (e.g., Boyle & Charles, 2010; Dunn, 2015a, 2015b; Dunn & Finley, 2010; Graham, 2008; Graham & Harris, 1989; Harris & Graham, 1996; MacArthur, 2009; Patterson, 2011; Scruggs & Mastropieri, 1992; Troia, 2011; Vygotsky, 1986) (see Figure 1).

The STORY mnemonic and processes employ SRSD elements (developing and activating background knowledge, discussing the strategy, modeling the strategy, memorizing the strategy, and practice to support the use of the strategy) and emphasize questioning and verbalizing story aspects, illustrating stories using technology (e.g., iPads with the Doodle Buddy [2015]), verbalizing story

organization, reflective revisions, reading stories aloud, and obtaining feedback from others. Doodle Buddy, a digital art app, offered students colors and pre-made objects (e.g., houses, trees) to illustrate their story ideas before generating their first draft of typed text.

Teaching the application of the STORY mnemonic involved verbal and physical modeling, guided practice, and the use of cue cards. The daily lesson plan used to implement the STORY mnemonic is included in Figure 2.

STORY

Start thinking about your story by asking key questions such as Who? When? Where? What happened? What happened next? How did the story end? How did the main character feel; the other characters feel? (Graham & Harris, 1989).

Think about your answers and illustrate them on the iPad (Author, 2014).

Organize your thoughts further by verbalizing your ideas aloud and editing them as you type them.

Revise your text to make it more elaborate with descriptive words, better syntax, and grammar.

Your story is now ready for you to read it to someone, receive feedback, and make final edits.

(Dunn, 2015b)

Figure 1. Elements of the STORY mnemonic strategy.

Time (minutes)	Phase and Activity Descriptions
	Baseline
25	Students plan and write about a CBM cartoon picture (no dialogue balloons) or on another topic of their choosing (10 minutes to plan, 15 minutes to write).
	Intervention phase (45 minutes per session; after sessions of SRSD training)
3	Meet and greet.
7	Students listen to a page or two from a book; discuss the reading with the intervention specialist.
5	Spelling practice: students write 3-5 words from the reading; the intervention specialist reviews words/provide corrective feedback.
5	Writing sentences: with a picture book, the intervention specialist has students verbalize some simple sentences. The intervention specialist writes them on a whiteboard. Students copy. The intervention specialist reviews students' writing and provides corrective feedback.
	Combining sentences: The intervention specialist writes two sets of simple sentences on the whiteboard. She asks students to rephrase each pair into one combined sentence with <i>and</i> , <i>but</i> , or <i>or</i> . She writes them on the whiteboard. The students then write them.
25	Students practice applying the STORY mnemonic strategy.
	On selected days, students begin with doing a CBM probe: students do a cartoon (or personally chosen topic) story probe assessment (10 minutes to plan, 15 minutes to write).

Figure 2. Daily lesson plan.

Initial tasks. Before the start of the study, Emma completed three training sessions with the researchers on the design of the study, the SRS, the STORY strategy (e.g., modeling of materials and processes to follow), the standard lesson plan for the study, conducting CBMs, administering the writing interest interview/exit interview, and designing keyboard practice sessions. Participants met with Emma 1:1 during the school day for each session in a corner of the school library media center. All study data were collected during these sessions.

Each daily session supplanted 45 of the 60 minutes of the writing instruction typically offered in the general education classroom. The remaining 15 minutes of writing instruction in the general education classroom was not a part of this study, and the STORY strategy was not used during that time. Activities, with the use of technology (e.g., iPads, Chrome Book) for an hour per day, consisted of the following: practice and teacher feedback for prewriting using a graphic organizer; writing an authentic text based on a randomized prompt (e.g., creating a personal narrative about experiences the previous weekend); stating an opinion (introduction, reasons, concluding statement); and revising and editing with the use of reference materials.

General instructional procedures. Following participants' assent to participate in the study, Emma met with each student (always 1:1) to introduce herself and provide an overview of the purpose of the project (i.e., help students improve their story writing skills with technology tools), tell them that they would meet for 45 minutes four times per week (over nine weeks), and inform them that a pizza/sundae lunch would be offered at the end of the project as a thank-you for their participation and a celebration of their work.

During the first pre-data session, each participant met individually with Emma to complete the student assent form and the writing interest interview (Rhodes, 1993), and to practice using the keyboard to type text using the Matcha app (InterArePT, 2014), a plain text word-processing app that includes spell check and a "save to Dropbox.com" feature. Participants practiced typing by entering non-story information (e.g., directions for how to get from point A to B, a recipe for making a meal) and then practiced with the keyboard again at a second session.

Dependent variables. During baseline, participants completed a CBM (Deno, 2003) story probe

(randomized across participants). Provided with a black-and-white cartoon picture without dialogue text balloons and the keyboard, each participant was asked to write a story either about the cartoon picture or about another topic of their choosing. They had 10 minutes to plan their text and 15 minutes to type. When they finished a probe, students returned to their general education classroom.

Baseline. With an initial short greeting conversation and completion of the probe, baseline sessions lasted no more than 30 minutes. Since completing even one CBM probe would be challenging for these students with known disabilities in writing, it was deemed best that they complete a CBM probe (be assessed) every few sessions, to balance the need for baseline data with the limits of the participants' motivation.

Training. After at least five CBM probes, the participants, in sequential order as predetermined by random selection, began the training phase. In the first session, Emma discussed with each student how they felt about writing (e.g., referencing participants' answers from the writing interest questionnaire [Rhodes, 1993]) and explained how learning a new mnemonic could help them improve (develop and activate background knowledge). She then presented STORY, described what each letter of the mnemonic represented, and demonstrated the process (discuss the strategy). Emma verbalized all of her thoughts and ideas aloud, such as "I need to get my iPad and open the Doodle Buddy app to create my story plan. I need to think of a story topic. I know; I will write about my trip to the park with my son. I can draw: a sun to illustrate day time, a swing, and my son and I playing soccer. He scored two goals. He jumped for joy that he scored. A house will show that we then went home." These comments enabled students not only to see the story plan and text being created but also to hear Emma's thought processes explaining her illustrated art plan and typed text.

In Session 2 of the training phase, Emma presented STORY with an example again (model the strategy). In two or more story examples during that session, she invited the students to offer more and more input into ideas and content for the plan and text. The students reviewed the STORY mnemonic as a means of improving their recall of STORY and its sequential steps (memorize the strategy).

In Session 3 (as well as Session 4, for some participants), Emma collaborated with each stu-

dent to plan, draft, edit, and finesse more story texts (support the strategy). The aim was to help students attain independence in completing the STORY steps (independent performance). After each text, the students counted the number of words they had written (NWW) and recorded it on a chart – a step that was repeated for each story during the remainder of the study.

Emma and the researchers reviewed each student's text from Session 3. If a student demonstrated an increase of three levels over the lowest scores since Session 1 for written content and at least one level for written quality, the training phase ended; if not, one or more additional training sessions were provided until the student was able to demonstrate the required level of improvement.

Intervention. In the intervention phase, participants applied the STORY mnemonic strategy in each session. For the first four of the intervention sessions (range: 6-24), Emma provided cue cards with the STORY phrases and the WWW, W=2, H=2 questions. Participants subsequently completed the session tasks from memory.

For each session, Emma followed the designated lesson plan (1:1). She greeted the participant at the beginning of each session; read a short story or a portion thereof; discussed the text with the participant by asking questions; had the student make predictions; and, finally, reviewed a few words from the story by asking the participant to spell them on the keyboard. If the words were incorrect, Emma clarified the error and asked the participant to retype. Then, she provided two simple sentences on the whiteboard and asked the participant to combine them into one using *and*, *or*, or *but*. During the remainder of the session, the participants applied STORY.

Emma reviewed each participant's text at the end of the session and offered feedback on how the prose could better address the STORY components and be more elaborate. According to single-case design methods (Kratochwill & Levin, 2014), selected sessions were designated for the participant to complete a CBM probe. Following the last intervention session, Emma completed the short exit interview with each participant. Two weeks later, each student completed a maintenance probe.

Dependent variables scoring. When participants completed a CBM probe, Emma uploaded their spoken and typed stories as well as their plan-

ning documents or images to a password-protected Dropbox.com folder shared with the researchers as a data repository for the project. Two adults with college degrees in education were trained to score the stories. The training involved reviewing the content and quality rubrics, scoring three sample stories (not from the participants) together, independently scoring three sample stories, and, finally, comparing and discussing scores. The scorers obtained 100% inter-scorer reliability on three sample stories before scoring the study participants' stories. Scorers were told to focus on the overall text, meaning, and quality in scoring; spelling, grammar, and syntax errors were considered as a minor element.

On the days when participants had completed a CBM probe, the scorers did their initial scoring independently and then discussed the results via Skype to obtain a 100% agreement. The first author conducted reliability checks (i.e., reviewing the rubric and referencing story texts from past studies) after the scoring of every seventh day's text(s). These scores were then emailed to the researchers for graphing, analyzing trends, and making decisions about each participant's progression through the phases of the project. The number of words written (NWW) was computed by copying/pasting each spoken and typed text into Microsoft Word® and then in Microsoft Excel to obtain the average score per participant, per phase.

Maintenance. Three weeks after the completion of the intervention phase, the participants completed a CBM probe during the maintenance phase (one session). Emma did not review STORY prior to the participants completing the probe nor did she provide cue cards. Participants were asked to plan and type a story either about a cartoon picture or a topic of their choosing.

Fidelity of implementation. Treatment fidelity was ensured in two ways. The researchers and Emma discussed participants' learning and writing each day via email, text message, or phone conversation. Emma's interactions with each participant was observed by one of the researchers for 12 sessions across the phases of the study (about 33% of the sessions of the study). In addition, the designated lesson plan provided a means to note what was completed in each session. From the two types of treatment fidelity data, it was concluded that Emma completed the activities with 99% fidelity.

Results

Students' data included qualitative comments about their perspectives about writing, content and quality scores for the spoken and written texts, and qualitative comments from an exit interview about the STORY mnemonic and the processes of the project.

Writing Interest Interviews

Emma completed a writing interest questionnaire with each student (1:1) by the end of the second session. Evan expressed that he could improve in all aspects of his writing and stated that he liked to write about science topics. Kate stated that good writers practice to improve and that she wanted to be a better writer and was willing to ask for help with spelling. "This year, I can write more words, but I still need help with them. I like writing because you can discuss the good things in your life." Nancy and Madoka said that they appreciated the help that teachers provide for writing. Madoka's goal was to improve her spelling. "I like writing because I can write about what they want." Nancy

wanted to improve her punctuation skills and said, "I am getting better at spelling."

Content and Quality Outcomes

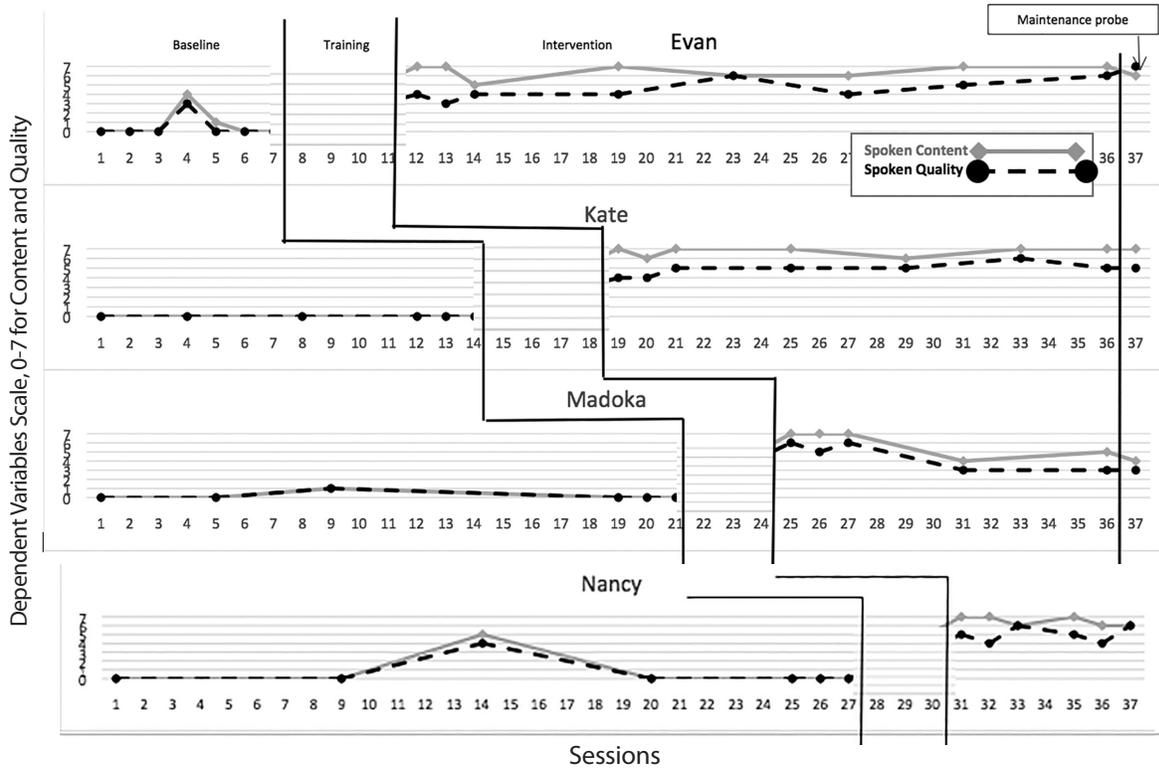
In the sessions that followed, students practiced keyboarding skills, completed the baseline phase during which they wrote stories using any previously learned strategies, completed the training phase to learn STORY, and participated in the intervention phase where they applied the mnemonic strategy. An example STORY product is illustrated in Figure 3. The final session represented a maintenance phase and was held three weeks after the completion of the previous session.

The participants' changes in story content and quality for both spoken and written (typed) texts across the timeline of the project are illustrated in Tables 2 and 3. The participants chose to write about the cartoon prompt for 60% of the sessions while choosing their own story topics for 40% of the sessions. Participants' number of words written is included in Table 4.

Spoken Story	Visual Story Plan	Typed Story Text
<p>A girl and her mom were going to pick out a tree. They saw that most of the trees were already decorated. They picked a tree and tied it on their car. When they got home, all they had to do was put it on the stand. Then they had to eat dinner and get ready for bed.</p>		<p>A tall girl and her littl mom were going to pick out abig tree. They saw that most of the trees were already decorated. They picked a tall tree and tied it on the car. When they got home, all they had to do was put it in the stand. Then they had to eat a bug dinner and get ready for bed.</p>
<p>Then they woke up and opened the presents. When they first got up, their dad got home because he was at work. They didn't know that he still had one more present for before they had to go to bed. The girl got a stuffed animal and three iPads. The boy got some books and two laptops. The family was happy.</p>		<p>Then they woke up and opened the presents. When they first got up, their dad got home because he was at work. They didn't know their dad still had one more present for before they had to go to bed. The girl got a stuffed animal and three ipads. The boy got some books and two laptops. The family was happy and went to bed.</p>

Figure 3. Kate's session 35 story plan and text.

Table 2
Spoken Content and Quality Scores



Note. All names are pseudonyms.

Table 3
Written Content and Quality Scores

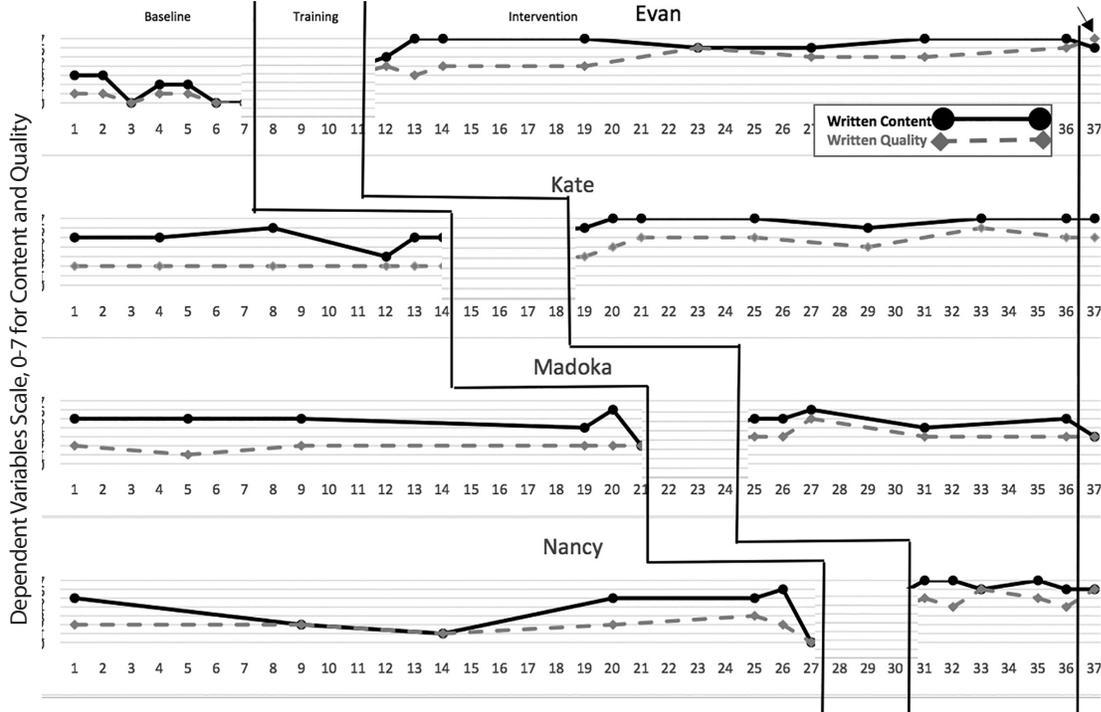


Table 4
Mean Number of Words Written by Phase and Story Type

	Practice Keyboarding	Baseline Text		Intervention Text		Maintenance Text	
		Spoken	Typed	Spoken	Typed	Spoken	Typed
Evan	12	62	9	121	97	69	116
Kate	112	4	64	60	81	82	98
Madoka	47	12	45	130	67	150	137
Nancy	158	57	45	87	73	82	100

Session 31 spoken:

I'm playing a game in my room at the moment called Pokémon Y. I deleted my original file, so I can't have different nicknames. I do not know why I deleted my saved file. I have the whole world face palm. Plus, I was so far. There is actually two other reasons why. One reason is that I wanted my Pokémon to be a higher level. I wanted different Pokémon. I know those are pretty good reasons, but not enough of a reason to delete the file when I'm at the elite four. I feel angry.

Session 31 typed:

I am playing Pokemon y in my light blue room at the moment and I deleted my original game file so I can have different have nicknames. Have the whole world face palm pulse I was so far there is 2 other reason why. One reason is that I wanted my Pokemon to be a higher level. I wanted different Pokemon. I know those are pretty good reasons, but not enough of a reason to delete the file when Im at the elite four. I feel very angry.

Figure 4. Madoka's session 31 spoken and typed texts.

In the practice keyboarding scores, Evan and Madoka had the lowest scores but demonstrated an increasing mean across phases. During baseline, Madoka, Kate and Nancy spoke more text than they typed; Evan did not. During the intervention phase, Evan and Nancy typed less text. In maintenance, only Madoka typed less text than she spoke. Madoka's Session 31 spoken and typed texts, provided in Figure 4, offer an example from near the end of the intervention phase.

Spoken and written content. Evan, Kate, and Nancy increased in level and trend for spoken and written content from baseline to intervention, whereas Madoka increased in trend by the intervention phase for spoken but not for written content. All four participants had 100% non-overlapping data for spoken content; Evan had 100% non-overlapping data for written story content compared to Kate, Madoka, and Nancy,

who had 86%, 0%, and 92%, respectively.

Spoken and written quality. Improving quality is challenging given the collective aspects of sentence creation, word choice, story structure, flow of ideas, and so on, involved. Yet, all four participants demonstrated a noticeable increase in level and trend for spoken quality by the intervention phase; Madoka was the only one who had a negative trend. Kate and Madoka had 100% non-overlapping data between baseline and intervention phases for spoken quality. Evan and Nancy had 93% and 83% non-overlapping data, respectively.

Evan and Nancy demonstrated a noticeable increase in level of written quality by the intervention phase. Kate's and Madoka's intervention-phase change in level was positive by one point. All four participants had 0% overlapping data for written quality.

Exit Interviews

In individual interviews at the conclusion of the study, the participants commented that they liked using STORY and found it useful for similar tasks in their schoolwork. Evan said, "I like to draw, and having a picture to look at made thinking about what to write easier for me." Kate mentioned that STORY helped her include more descriptive words in her writing. "I would add a step to STORY: Check your spelling after typing." Madoka and Nancy thought that STORY would be helpful for other children who have difficulty with writing.

Discussion

The findings from this study support the body of research on the effectiveness of mnemonic-strategy instruction for helping students with a learning disability in writing improve their writing skills (Graham & Perin 2007a, 2007b; Perin, 2013; Reid & Lienemann, 2006) and add to the literature about the use of self-regulated strategy development (SRSD) (Graham, MacArthur, & Fitzgerald, 2013) in learning and applying the STORY mnemonic strategy with technology apps. Although it comes as no surprise that evidence-based instructional approaches (e.g., SRSD) improved student learning, it is interesting to note that the use of art in planning and keyboarding to generate text contributed to the outcomes; however, it is not clear how much these two factors influenced the outcomes or what specific elements of writing they impacted. Therefore, while these findings extend the literature base by indicating that art and technology may be important elements of instructional strategies for improving writing skills, further research on their impact on writing is warranted.

The participants' progress demonstrated relative stability from early in the intervention phase throughout the sessions. For example, it was encouraging to see that STORY helped these students with learning disabilities demonstrate gains after only three to four training sessions. Strategy instruction, as can be assessed in a single-subject design study, can make a positive difference for students with learning disabilities in writing (Ferretti & Lewis, 2013; Graham et al., 2013; Kratochwill, & Levin, 2014; Kratochwill et al., 2010; Perin, 2013; Reid & Lienemann, 2006). All four participants' CBM probe data improved

with spoken and written texts in content and quality, but only three participants (Evan, Kate, and Nancy) demonstrated a functional relationship across the four dependent variables.

Madoka increased her performance in level for spoken content and quality as well as written quality, but written content proved to be a challenge for her, as all of her data overlapped with baseline. It is interesting that she improved in level of spoken content and quality as well as written story quality (e.g., idea generation, word choice, spelling, sentence creation, story structure), a more difficult component of writing than content (e.g., answering and stating who, when, where). Yet, she did not sustain a positive trend as the intervention phase continued. Emma noted that Madoka tended to fixate on one or a few details while writing, as illustrated in her Session 31 story. To fully understand why students like Madoka continue to have difficulties with some aspects of writing after learning and applying evidence-based instructional tools such as STORY, further research is needed.

The data on the participants' NWW support the researchers' assumption that the participants would type more text as the phases of the study progressed. Indeed, Evan's, Kate's, and Madoka's spoken stories included larger NWW counts from baseline to intervention to maintenance. Nancy's NWW increased from baseline to intervention, but her maintenance total was five words fewer than the previous phase; yet her spoken content and quality scores increased in level, and she had 0% overlapping data compared to baseline.

The conclusion that may be drawn from these data is that students become more focused as they write so as to make each word and sentence count, as demonstrated in the intervention and maintenance phase data. Alternatively, some students have difficulty expressing ideas well with words. For example, Madoka typed many words (e.g., 67 or more), but they did not progressively translate well to improved content and quality.

Participants demonstrated improvement in content and quality while using technology. With initial practice and continued use of the STORY mnemonic across the sessions, participants' composition of more elaborate texts improved. Specifically, Evan commented that using Doodle Buddy to draw was helpful.

Implications for Practice

The results of this study offer insights into how to promote improvement of the writing skills of students with learning disabilities. First, the study highlights the multifaceted nature of learning disabilities in writing. Writing is a challenging domain, but with ongoing practice and teacher interaction, student performance can improve. Teachers should implement as daily practice a review of and references to published stories, working with words and sentences, modeling, guided practice, including examples of how writing-skills practice can help with various forms of writing (e.g., story narrative, informational, and argumentative/persuasive) (NGA, 2010).

Through focused intervention with teacher modeling, guided practice, and students developing independence in managing the writing task, students in this study enhanced their writing (Graham & Harris, 2005). In doing so, they increased the number of words written (NWW) and learned to develop word-choice skills that improved both content and quality. In practice, these approaches can be further explored.

Also, technology tools (e.g., mobile devices) offered students access to practice tools and imagery supports, providing an example for the field of how these tools can be used. Infusion of the arts, such as visual media, gives students an opportunity to benefit from visual cues, an evidence-based practice for students with learning disabilities (National Center for Learning Disabilities, 2011).

Technology tools allow writing tasks to be more current and reflective of students' world today (Bouck, Meyer, Satsangi, Savage, & Hunley, 2015). Students see people around them using technology tools, so using these tools in their school work will not only seem natural, but also potentially motivating and engaging. Further, technology helps alleviate the task of generating text as it reduces the visual-motor integration challenges that often impact handwriting and manuscript printing for students with learning disabilities. In short, keyboarding helps free mental energy for idea generation, storyline planning, and creating elaborate text.

Limitations and Future Research

The participating school assessed students for a learning disability, but those types of assessments are typically more focused on reading than writing, so it is difficult to gauge the extent of participants' writing "disability." However, as illustrated, students' written work during baseline demonstrated a need for learning and using the STORY mnemonic. The existence and widespread use of a multidisciplinary evaluation with a focus on writing could help teachers understand students' writing strengths and weaknesses and, therefore, better focus their instruction. For example, in-depth writing assessment data might have offered more insight into Madoka's change in scores across the project.

The students' choice of writing about the assigned topic (the cartoon) for 60% of the sessions and writing about a topic of their own choice for 40% of the sessions present possible confounds to study results, including such factors as familiarity with the topics, motivation, and previous writing experiences impacting the results more than the independent variable. Future research in this area, therefore, will need to control for these potential confounding variables to ascertain their impact on interventions.

Conclusion

Writing is a multicomponent process – from idea generation to planning to final copy – during which an interaction of strategies occurs. As reflected in this study's results, students demonstrated gains in story-writing content and quality. The contributions to participants' improvement of (a) the novel use of technology, (b) fluency with typing on a virtual keyboard, or (c) merely not having to write with a pen and paper, remain unclear. While participants' spoken vs. typed texts offer some insight into the differences, more research on their thoughts at each stage of the process would be beneficial for developing effective writing interventions.

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Effects of an Early Numeracy Intervention on Struggling Kindergarteners' Mathematics Performance

Abstract

The purpose of this study was to investigate the effects of an early numeracy intervention delivered by kindergarten teachers to students identified as having mathematics difficulties. A multigroup growth-modeling-with-random-assignment-to-intervention-condition design was employed. Thirty-two teachers were randomly assigned to the treatment or comparison condition. A total of 71 students participated in the study, 47 in the treatment group and 24 in the comparison group. Results indicated that the treatment condition students outperformed comparison students ($g^* = .99$) and demonstrated statistically significantly higher scores on all proximal measures of early numeracy. Also, about 80% to 100% of the variance was accounted for at the student level. Performance on distal measures was less impressive, with no significant differences between groups; the effect size was .44. Teachers rated components of the intervention highly, reflecting strong teacher satisfaction.

Researchers have recently demonstrated that early mathematics achievement at the kindergarten level to some extent predicts later academic performance (Jordan, Kaplan, Ramineni, & Locuniak, 2009). For example, Morgan, Farkas, and Wu (2009), in their analyses of the Early Childhood Longitudinal Study-Kindergarten Cohort (ECLS-K; National Center for Educational Statistics [NCES, 2004]) database, found that the learning trajectories of students with mathematics problems in the fall and spring of kindergarten continued to show slower mathematical growth throughout their early academic careers.

These findings do not mean that children who are slow to learn early mathematics skills are destined to struggle throughout their academic careers. However, given an overall persistent pattern of low mathematics performance for some students compared to typically achieving students (NCES, 2015), it is not surprising that students who struggle

with early mathematics number sense attainment have difficulty obtaining more complex mathematical skills and concepts (Stinson, 2004; Wu, 2001).

Although some students who enter kindergarten demonstrate an adequate understanding of early number concepts, others lack the informal knowledge of mathematics that contributes to primary level mathematic success (Bryant et al., 2011). According to Wilson, Revkin, Cohen, Cohen, and Dehaene (2006), for example, children with mathematics difficulties exhibit a variety of fundamental mathematical problems, including difficulties with counting, recalling arithmetic facts, and representing quantity and/or linking quantity to symbolic number representations. Because early mathematics ability is predictive of later achievement, early intervention in numeracy concepts and skills should be available for all students who exhibit mathematics difficulties (Bryant et al., 2011; Morgan et al., 2009).

Research on the Development of Number Sense Interventions

Although lagging behind early reading intervention research, in recent years, early numeracy interventions, which incorporate practices to promote number sense (i.e., fostering an understanding of the “conceptual relationships between quantities and numerical symbols” [Griffin, 2004, p. 39]), have become more prevalent for younger students. For example, in one study, Clarke et al. (2011) compared the performance of 56 kindergarten students who participated in a combination of core instruction and a supplemental intervention (ROOTS) to peers ($n = 64$) who participated in core instruction only. Results on the *Test of Early Mathematics Ability-3* (TEMA-3, Ginsburg & Baroody, 2007) demonstrated that students receiving the combined approach (i.e., core plus supplemental instruction) made significantly greater gains than those receiving core instruction only. Further, students identified as being at risk (i.e., those performing below the 40th percentile on the TEMA at pretest) in the treatment group significantly outperformed their at-risk comparison counterparts on the TEMA ($t = 3.29, p = .0017, g = .24$). In a more recent study (Clarke et al., 2016) with a larger sample (29 kindergarten classrooms randomly assigned to the treatment [ROOTS] or comparison condition), similar findings were noted, with Hedges’ g effect sizes of .38 for the TEMA standard score and .30 for the *Early Numeracy-Curriculum Based Measurement* (Clarke & Shinn, 2004).

In another study, Jordan, Glutting, Dyson, Hassinger-Das, and Irwin (2012) examined the effectiveness of a targeted small-group number sense intervention for high-risk kindergarteners from low-income families. Children were randomly assigned to one of three participant groups. The first group received a number sense intervention; the second group received a language intervention; and the third group was a business-as-usual comparison group. Interventions lasted 30 minutes each and were administered three times per week; in all, 24 lessons were taught. The intervention and comparison groups each were taught the same core mathematics curriculum; during the mathematics intervention, comparison students engaged in typical kindergarten activities such as learning centers or special subjects instruction.

Immediate posttest results on the Number Sense Brief (NSB) (Jordan, Glutting, Ramineni, & Watkins, 2010) revealed that the group that received the number sense intervention performed better than the comparison group, with positive effect sizes (most Cohen d s were medium to large) on measures of number sense and general mathematics. Further, following the administration of the NSB and the *Woodcock-Johnson III Tests of Achievement (WJ) Form C Brief Battery: Applied Problems and Calculation* subtests (Woodcock, McGrew, Schrank, & Mather, 2007) eight weeks after the intervention concluded, results remained similarly positive. According to the authors, no significant differences were found between language and comparison groups on either of the mathematics measures.

In a more recent study, Dyson, Jordan, Beliakoff, and Hassinger-Das (2015) randomly assigned 126 kindergarten children to one of three groups. The first group ($n = 44$) was administered a number sense intervention followed by a number fact practice session. The second group ($n = 40$) received the same number sense intervention, followed by a number list practice session. Finally, the third was a business-as-usual comparison group ($n = 42$). The interventions were delivered in a small-group setting over twenty-four 25-minute lessons for an eight-week period. The comparison group received 30 minutes of mathematics time to supplement their core instruction. Immediately following the intervention, and eight weeks later, measures of number sense, arithmetic fluency, and general mathematics calculation achievement were administered. Results showed that although not always significantly different, the treatment groups performed better than the comparison groups based on a computed Hedges’ g of greater than .25, which is viewed as an indication of effective educational practice (What Works Clearinghouse, 2014; http://ies.ed.gov/ncee/wwc/pdf/wwc_version1_standards.pdf).

Thus, evidence is mounting regarding the ability to improve the number sense performance of kindergarten students who are at risk for mathematics difficulties. Given the growing evidence of effective early numeracy interventions, the essential components of such practices should be examined.

Essential Features of Early Numeracy Interventions

Essential features of intervention have been identified and incorporated into research protocols as a result of an increasing number of studies on early numeracy improvement for struggling students and informed by previous key syntheses of effective mathematics practices (e.g., Gersten, Beckmann et al., 2009; Gersten, Chard et al., 2009).

Specifically, researchers have recommended that prevention and intervention efforts include verbalizations of cognitive strategies (Fuchs & Fuchs, 2001), as well as physical (concrete) and visual (pictorial) representations of number concepts (Bryant et al., 2011, 2014; Fuchs & Fuchs, 2001; Gersten, Chard et al., 2009).

In addition, findings from studies on students with mathematics difficulties support the use of explicit, strategic instruction in procedural knowledge and conceptual understanding, such as the commutative property of addition and counting strategies (Baker, Gerstein, & Lee, 2002; Bryant, 2005; Clarke et al., 2016; Gersten, Jordan, & Flojo, 2005). Notably, practices such as cognitive modeling/thinking aloud make transparent for struggling students ways of approaching difficult problems through the use of visual representations and precise mathematical language. All students, and especially those with mathematics difficulties, can benefit from ample opportunities to practice (e.g., guided practice, distributed practice) using visual representations (e.g., number lines, manipulatives, mathematics models) and mathematics vocabulary, as modeled by their teachers, to discuss concepts and solve problems in small groups and individually (Greenes, Ginsburg, & Balfanz, 2004). Additionally, effective teachers use questioning strategies to help students connect representations and verbal and symbolic statements (Clements & Sarama, 2004).

The Present Study

As noted, studies have provided compelling evidence showing that young children's early numeracy understanding can be improved and supporting the importance of teachers at the primary level focusing on mathematics foundation skills that set the stage for later mathematics success. Yet,

more research is needed to inform the field about effective practices to enhance the performance of young students who manifest difficulties with mathematical concepts and number sense. Not only should efforts be made to increase the performance of concepts and skills targeted for interventions, evidence is also needed to show whether students can generalize or transfer this knowledge to broader mathematics assessments that measure overall mathematics achievement.

Finally, it is important to understand teachers' perspectives, or satisfaction, about the interventions they are teaching. According to Wolf (1978), *social validity* refers to the extent to which participants (i.e., the teachers in this study) delivering behavioral and academic interventions find them acceptable in terms of the goals of the intervention, the appropriateness of the procedures, and the importance of the treatment implications.

One would be hard pressed to dispute the claim that, for young students, demonstrating improvement in critical academic areas is "socially important." As Cooper, Heron, and Heward (2007) observed, social validity involves efforts (e.g., interventions) that can make a socially significant change in an individual's life. Thus, the degree to which teachers attribute improved student performance to a specific intervention indicates their perspective about the social validity of the intervention lessons.

The purposes of the present study were three-fold: (a) To present the findings on the effects of a supplemental intervention on performance on an early numeracy measure; (b) To determine the effects of the intervention on subjects' performance on a mathematics achievement test that broadly measured mathematics concepts and skills; and (c) To determine the degree to which teachers perceived the early numeracy intervention as being socially valid.

The following three research questions guided the study:

1. Did students receiving the early numeracy Tier 2 supplemental intervention demonstrate improved performance on progress monitoring measures of early numeracy mathematics compared to students receiving business-as-usual mathematics instruction with no particular intervention? We hypothesized that students in the treatment group would outperform students in the business-as-usual comparison group.

2. Did students receiving the early numeracy Tier 2 intervention demonstrate improved performance on a distal standardized measure of a broad array of mathematics concepts and skills compared to students receiving business-as-usual mathematics instruction? We hypothesized that there would be no differences between groups on the distal measure because we did not directly teach the skills and concepts measured on the test.
3. To what degree was teacher satisfaction observed on the teacher survey of the practices contained in the lessons? We hypothesized that the treatment teachers' satisfaction would be high, on average, as a result of the specific instructional design and delivery practices that included in the lessons.

and were participating in a statewide response to intervention (RtI) supplemental early mathematics intervention. The schools were located in major metropolitan, urban districts.

At each school, classroom teachers administered an early mathematics measure, the *Texas Early Mathematics Inventories - Progress Monitoring* (TEMI-PM; Texas Education Agency/University of Texas System [TEA/UTS], 2008a), used for universal screening purposes, to students from intact classrooms who had received institutional review board (IRB)-approved consent to participate in the study were. Students qualified for the study if they received a total score below the 25th percentile, based on Texas statewide normative data. All students received mathematics instruction in the general education classroom; students who received mathematics instruction in a bilingual classroom were not part of the study. Because of their young age, none of the students had been identified as having a learning disability but were identified as having mathematics difficulties based on the results of the screener (TEMI-PM, 2008a). Table 1 shows the demographic characteristics of the participants who completed the intervention.

Method

Participants and Setting

A total of 71 kindergarten students participated in the study. Students attended 16 schools in Texas

Table 1
Participant Demographics for Treatment and Comparison Groups

Demographic Category	Total N = 71	
	Treatment N	Comparison N
Gender		
Female	23	7
Male	24	16
Missing	-	1
Ethnicity		
African American	6	4
Hispanic	30	2
Caucasian	11	15
Missing	-	3
Free/Reduced-Price Lunch		
Yes	27	18
No	20	3
Missing	-	3
EL/LEP		
Yes	12	3
No	35	19
Missing	-	2

ELL = English Language Learners; LEP = Limited English Proficient; N/A = Information not available.

Teachers

A total of 32 teachers, 16 treatment and 16 comparison, across 16 schools participated in the study. All teachers were female, were certified by the state of Texas to teach kindergarten classes, and were deemed highly qualified according to *No Child Left Behind* reporting criteria, in effect at the time of the study. Six teachers held master's degrees; two held teaching certification through alternative licensure; the remaining teachers held bachelor's degrees and were certified through their college/university teacher certification program; one teacher was African American; the remaining teachers were White.

As a project designed to validate the intervention and assessments for use in programs such as RtI, classroom teachers administered all tests and implemented the interventions. Not all RtI programs use teachers as interventionists; however, in this study teachers were responsible for testing and the delivering the intervention to ensure that interventionists were certified teachers who knew the students well.

Research Design

A multigroup growth-modeling-with-random-assignment-to-intervention-condition design was employed. Teachers were randomly assigned to the treatment or comparison condition. Of the 71 students participating, 47 were in the treatment group and 24 in the comparison group. The approximately two-to-one ratio was established in negotiations with participating school principals, who requested that as many students as possible be assigned to the treatment group (Bryant et al., 2011). Three students (all from the intervention group) were lost to attrition during the course of the intervention.

Measures

TEMI-PM (TEA/UTS, 2008a). The TEMI-PM is a researcher-developed measure that was commissioned by the state education agency for use by Texas teachers. The TEMI-PM includes versions for kindergarten and first and second grade, all of them standardized on more than 1,700 students at each grade level across the state of Texas. The kindergarten version consists of three alter-

nate, equivalent forms that are administered in the fall, winter, and spring, respectively. Each form is composed of four 2-minute timed subtests that are group-administered and involve numbers ranging from 0 through 20 to conform to Texas standards for instructional content.

The first subtest, *Magnitude Comparison*, contains 64 items. Students look at two numbers that appear side-by-side in a box in their student booklet (a vertical dotted line separates the two numbers) and are given 2 minutes to circle the bigger of the two numbers, or both numbers if they are the same. Alternate-forms reliability ranges from .76 to .85, with a median of .81. Similar measures are available online (www.interventioncentral.org/htmldocs/interventions/cbmwarehouse.php). The test is similar to Clarke and Shinn's (2004) *Quantity Discrimination Measure Verbal 1-20*.

For *Number Identification*, the second subtest, students look at rows and columns of squares and count the number of squares shown. Students then circle from four response choices the answer that shows "how many." The 2-minute subtest includes 28 items. Reliability coefficients range from .75 to .83, with a median of .78. Number identification tasks have appeared on many early mathematics tests (e.g., *KeyMath-3* Connolly, 2008; *Woodcock-Johnson Revised*, Woodcock, McGrew, Schrank, & Mather, 2007; and Clarke and Shinn's, 2004, *Number Identification Measure 1-20*).

Number Sequences, the third subtest, contains 42 items. Students look at a three-number sequence; one number of the "counting by ones" sequence is missing and is represented by a blank. The missing number may be either the first, second, or third number of the sequence. Students are given 2 minutes to look at four response choices and circle the one that represents the missing number. Reliabilities range from .81 to .85, with a median of .84. The skill of identifying missing numbers in a sequence is often found on tests that assess number sense. Also, missing number tests are available online (<http://www.interventioncentral.org/curriculum-based-measurement-reading-math-assessment-tests>); also, Clarke and Shinn (2004) include *Missing Number Measure Blank Varied 1-20* as one of their early mathematics screening measures.

For the fourth subtest, *Quantity Recognition*, students look at randomly placed dots, ranging

from one to six dots, clustered near one another and circle the response choice (1, 2, 3, 4, 5, or 6) that corresponds to the number of dots shown. Students are given 2 minutes to complete as many of the 70 items as they can. Reliabilities range from .72 to .84, with a median of .80. Kaufman, Lord, Reese, and Volkman (1949) used the term *subitizing* to describe the rapid, correct, and self-assured judgment of the quantity represented by small numbers of items. Several researchers, including Benoit, Leshalle, and Jouen (2004), have used formats similar to *Quantity Recognition*.

Finally, the Total Score is calculated by summing the raw scores of all four subtests. The alternate-forms reliability coefficients for the kindergarten TEMI-PM Total Score range from .88 to .92, with a median of .89. In addition, area under the Receiver Operating Characteristic (or ROC curve) values for the fall form of the TEMI-PM Total Score was .80, demonstrating good predictive power (Minitab, n.d.) for the criterion measure, the *Stanford Achievement Test* (10th ed.) (SAT-10; Harcourt Assessment, 2003).

Texas Early Mathematics Inventories-Outcome (TEMI-O; TEA/UTS, 2008b). The TEMI-O was co-normed with the TEMI-PM. The kindergarten version consists of a single subtest, *Mathematics Problem Solving* (MPS), which asks students to respond to 34 items that assess a broad array of mathematics concepts and skills (e.g., counting and cardinality, number and operations, geometry, measurement and data, National Council of Teachers of Mathematics [NCTM], 2006; National Governors Association Center for Best Practices and Council of Chief State School Officers [NGACBP/CCSSO], 2010). The teacher provides a stimulus prompt (e.g., “Look at the first box. Rasheeda was given two big buttons and one little button by her aunt. Her aunt asked her, ‘How many buttons do you have now?’ Now look at the other boxes. Mark the box that shows how Rasheeda used a ten frame to find the answer.”), and students are to select from three response choices the one that provides the answer to the prompt. Coefficients alpha across forms reported in the TEMI-O Technical Manual (TEA/UTS, 2008c) for kindergarten for Forms A, B, and C, respectively, were .87, .84, and .83.

Prior to administering the measures to students in the fall, members of the research team went to

schools to train participating kindergarten teachers on the administration of the TEMI-PM and the TEMI-O. Upon completion of each testing cycle (fall, winter, spring), teachers turned in the test protocols to the school liaison for the project, who mailed them to the project coordinator. There were approximately three months between each assessment time period: fall, winter, and spring. For each administration of the TEMI-PM and TEMI-O, a commercial data entry company entered item responses into a data file on computers (guaranteed 98% accuracy), and the lead author electronically scored items in preparation for data analyses.

Teacher satisfaction survey. A teacher satisfaction scale was constructed consisting of 18 statements that focused on content of the lessons, alignment of the content with state standards, procedures for teaching the lessons, and benefit for students. The items were chosen based on Wolf’s (1978) definition of social validity (i.e., goals of the intervention, the appropriateness of the procedures, and the importance of the treatment implications). The survey was designed in an electronic, online platform (<https://surveystation.austin.utexas.edu>); teachers responded to each of the items using a Likert-type scale with ratings ranging from 1 (Strongly Disagree) to 5 (Strongly Agree). Internal consistency reliability for the teachers’ social validity scale was .77.

Fidelity of Implementation

Fidelity, which refers to the act of measuring how well an intervention is being implemented compared to the original intervention design, is a vital component of an intervention study. The project coordinator and the school liaison conducted the fidelity observations. The coordinator conducted the first observation in November, which was one month following the training workshop. The school liaison conducted the second observation in December, and the coordinator conducted the third observation in February or March. Prior to conducting the second fidelity observation, the school liaison attended a webinar on fidelity observation and read a brief article on the importance of fidelity as part of an intervention.

In all, each teacher was observed for 3 sessions for the 22-week dosage of the intervention to assess

adherence to the intervention. Quality performance indicators included (a) following the scripted lessons for the content (e.g., uses manipulatives and teaches strategies as stated); (b) implementing the instructional procedures (e.g., reviews background knowledge, provides modeling, provides corrective feedback); and (c) managing student behavior and materials (e.g., obtains and maintains student attention, intervenes quickly to redirect behavior). Performance indicators were rated on a 0- to 4-point scale, in which 0 = Very Poor (Adhered very little or not at all to scripted instructions), 1 = Poor (Adhered to some but not much to scripted instructions), 2 = Fair (Adhered to much of the scripted instructions) 3 = Good (Adhered mostly to scripted instructions), 4 = Excellent (Adhered perfectly to scripted instructions).

Mean overall results across all teachers showed the following: 1st observation: 3.00, 2nd observation: 4.00, and 3rd observation: 3.40. After each observation, results were shared with the teachers, and suggestions for improvement, if any were needed, were discussed. Overall results across grades and times showed a moderate to high degree of fidelity in the implementation of the lessons.

Procedures

Professional development and just-in-time resources. Researchers provided a full day of professional development (PD) for the interventionists and each school's liaison (e.g., counselor, lead grade-level teacher). Participating kindergarten teachers were brought to a central training location. The training included a review of the lessons and materials, an opportunity to view a video of teachers implementing the lessons, and time to practice the lessons under the guidance of the workshop leaders. The interventionists were also given the lessons and accompanying materials, including copies of the student booklets. In addition, training was provided on how to administer the TEMI-PM and TEMI-O, which the teachers were responsible for administering. The schools' liaisons, in turn, were responsible for providing TEMI-PM and TEMI-O administration instructions to the comparison group teachers using the training procedures utilized during the full day of PD.

When they returned to their schools to start the intervention, just-in-time resources were made

available to treatment teachers and school liaisons. These resources included webcasts or newsletters. Webcasts were conducted on topics (e.g., progress monitoring) that the project coordinators and school liaisons thought were important based on their site visits and classroom observations, respectively. A project coordinator from the research team visited the interventionists twice during the school year. Coaching was provided by the project coordinator as further PD as needed to each teacher. These visits also included a fidelity check and meeting with the project's liaison or principal.

Early numeracy intervention. Teachers in the treatment group were responsible for teaching the supplemental intervention during their already designated small-group (three or four students) instruction time. Intervention dosage consisted of 4 days per week for 25 to 28 minutes over the course of 23 weeks.

The supplemental intervention was developed with an emphasis on early numeracy concepts and skills. Specifically, the curriculum included identifying and writing numerals; counting, ordering, and comparing quantities; identifying part-part-whole quantities; making groups; and solving simple change problems with the result unknown. Visual representations were used as scaffolds to help students develop and build knowledge of concepts, operations, and properties (e.g., commutative property, associative property). Specifically, the visual representations were intended to help students construct connections between mathematical concepts by using manipulatives (e.g., connecting cubes, base-10 materials), pictorial representations (e.g., 10 frames, dot configurations for facts, place-value models), and symbolic representations, which are critical components of conceptually based instruction (Baroody, 1990; Clements & Sarama, 2009; Gersten, Beckman, et al., 2009; Hiebert & Wearne, 1992; NCTM, 2006; Sarama & Clements, 2009). Vocabulary development was also an important aspect of the intervention. A glossary with words and their definitions was included to help teachers as they taught the mathematical content.

The instructional design and delivery of the lessons consisted of the critical features of explicit instruction that have been validated in numerous studies with struggling students (e.g., Bryant et al., 2011; Fuchs et al., 2001; Swanson, Hoskyn, & Lee, 1999). The features included a teaching rou-

tine consisting of modeling, guided practice, and independent practice (progress monitoring); error correction procedures; pacing; opportunities for meaningful practice (e.g., with visual representations); examples; and review.

Finally, daily activity level progress monitoring was conducted during independent practice at the end of each lesson. Teachers gave students four oral or written problems to determine their response to instruction on each lesson; that is, whether they met the lesson's objective. Students had to demonstrate accuracy on three out of four of the problems to consider the lesson successful for that student.

Comparison classroom practices. Sixteen teachers served as interventionists for the comparison groups. Classroom practices for the comparison group varied, depending upon the school. Yet, all programs focused on kindergarten Texas Essential Knowledge and Skills (TEKS; <http://ritter.tea.state.tx.us/rules/tac/chapter111/ch111a.html>) content, which involves skills and concepts in number and operations. Examples of instructional content for the TEKS include (a) counting forward and backward to at least 20 with and without objects; (b) reading, writing, and representing whole numbers from 0 to at least 20 with and without objects or pictures; (c) counting a set of objects up to at least 20 and demonstrating that the last number said tells the number of objects in the set regardless of their arrangement or order; and (d) recognizing instantly the quantity of a small group of objects in organized and random arrangements.

Most comparison group teachers provided additional supportive instruction for the lessons that were being taught daily to the whole class. A combination of explicit, systematic instruction and inquiry-based instruction was typically used, although the extent to which each was employed varied by teacher. In short, the content taught was fairly consistent across schools, but the manner with which information was presented varied. Very little progress monitoring (i.e., record keeping of consistent formative evaluations) was observed.

Results

Descriptive results for treatment and comparison classrooms at pretest and posttest are summarized in Table 2. As illustrated, no statistically

significant pretest differences were found between students in the intervention and comparison groups, suggesting pretreatment equivalence on all of the measures, including Magnitude Comparison ($\beta = -1.11$, $SE = .63$, $p = .08$; β – standardized coefficient), Number Identification ($\beta = -.05$, $SE = .56$, $p = .93$), Number Sequence ($\beta = -.12$, $SE = .36$, $p = .74$), Quality Recognition ($\beta = -.83$, $SE = 1.55$, $p = .57$), TEMI-PM Total Score ($\beta = -2.43$, $SE = 2.01$, $p = .23$), and the TEMI-O Mathematics Problem Solving ($\beta = 1.12$, $SE = 1.53$, $p = .26$).

To evaluate the statistical significance of group differences, we fit multilevel models (MLwin 2.10; Rasbash, Steele, Browne, & Goldstein, 2004), nesting students in classes and estimating effect at the classroom level (see Table 3). Family-wise error associated with multiple comparisons was controlled using the Benjamini-Hochberg correction (Benjamini & Hochberg, 1995), and effect sizes were estimated as the ratio between the model-derived treatment coefficients and the unadjusted pooled within-group standard deviation across conditions at posttest (i.e., Hedges g with small sample correction, henceforth indicated as Hedges g^*). The regression coefficients represent the performance difference between treatment conditions at posttest, controlling for pretest differences.

Effects on the Early Numeracy Progress Monitoring Measures

The kindergarten treatment group outperformed the comparison group on Magnitude Comparison ($\beta = 11.39$; g^* of .73), Number Identification ($\beta = 3.77$; $g^* = .95$), Number Sequences ($\beta = 5.46$; $g^* = .76$), Quantity Recognition ($\beta = 9.77$; $g^* = .96$), and the TEMI-PM Total Score ($\beta = 31.97$; $g^* = .99$). Approximately 84% of the total variance was at the student level for Number Sequences, Number Identification, Quantity Recognition, and Total Score. One hundred percent of the variance in Magnitude Comparisons was at the student level.

Effects on the Early Numeracy Distal Measure

According to Glass (1965), “Statistical significance is the least interesting thing about the results. You should describe the results in terms of

Table 2

Means and Standard Deviations for Fall and Spring Results on the TEMI-PM and TEMI-O for the Kindergarten Sample ($N = 74$)

Measures	Pretest		Posttest	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
TEMI – PM MC				
Comparison	3.67	3.16	23.33	14.46
Treatment	2.54	2.25	33.94	16.16
TEMI – PM NS				
Comparison	.83	1.24	9.38	6.86
Treatment	.62	1.07	14.53	7.33
TEMI – PM NI				
Comparison	1.83	2.26	9.79	4.04
Treatment	1.80	2.31	13.55	3.94
TEMI – PM QR				
Comparison	6.04	5.84	21.6	10.20
Treatment	5.34	5.91	30.94	10.20
TEMI – PM TS				
Comparison	12.38	9.51	64.1	28.92
Treatment	10.30	7.66	93.0	33.49
TEMI – O MPS				
Comparison	10.79	5.69	21.09	4.09
Treatment	12.76	6.65	24.23	5.09

Note. TEMI-PM = Texas Early Mathematics Inventories-Progress Monitoring; MC = *Magnitude Comparison* subtest; NS = *Number Sequence* subtest; NI = *Number Identification* subtest; QR = *Quantity Recognition* subtest; TS = *Total Score*; TEMI – O = Texas Early Mathematics Inventories-Outcome; MPS = *Mathematics Problem Solving* subtest.

measures of magnitude – not just, does a treatment affect people, but how much does it affect them” (cited in Kline, 2004, p. 95). Although the TEMI-O Mathematics Problem Solving group difference was not statistically significant, the Hedges’ g effect size was .44 ($\beta = 2.12$). Further, the total variation in Mathematics Problem Solving was distributed throughout the model, with 81% at the student level and 19% at the classroom level.

Teacher Satisfaction

We explored the social validity of the interventions by asking teachers to complete a rating scale

about the lessons’ content and the instructional components and delivery. The average ratings were consistently high based on a 5-point scale (5 = Strongly Agree) (Median average = 4.57, ranging from 2.33 to 4.93). The statement with the lowest rating (2.33) focused on mathematics vocabulary, “The lessons need to provide more explicit instruction in mathematics vocabulary.” The statement with the highest average rating (4.93) addressed the teachers’ perspective about whether their students were benefiting from the lessons, “Overall, my students are benefiting from the lessons.” The median average score indicated that teachers were satisfied with the lesson, suggesting that they perceived the intervention lessons as social-

Table 3
Fixed and Random Effects for Models of TEMI-PM and TEMI-O in Kindergarten Sample

		Fixed Effects	
	Predictor	Estimate	Hedges' <i>g</i> (<i>g</i> [*])
TEMI – PM MC	Intercept	22.818 (3.17) ^a	
	Pretest	.677 (.72)	
	Treatment ^b	11.385 (3.927)*	.73
TEMI – PM NS	Intercept	9.197 (1.58)	
	Pretest	1.079 (.74)	
	Treatment	5.457 (1.965)*	.76
TEMI – PM NI	Intercept	9.742 (.821)	
	Pretest	.418 (.197)	
	Treatment	3.772 (1.016)*	.95
TEMI – PM QR	Intercept	21.154 (2.083)	
	Pretest	.609 (.199)	
	Treatment	9.765 (2.583)*	.96
TEMI – O MPS	Intercept	21.632 (1.069)	
	Pretest	.457 (.070)	
	Treatment	2.123 (1.346)	.44
TEMI – PM TS	Intercept	61.34 (6.55)	
	Pretest	1.478 (.428)	
	Treatment	31.968 (8.137)*	.99
		Random Effects	
		Variance	Percent of Total Variation
TEMI – PM MC	Level 1 (individual)	262.031	100%
	Level 2 (class)	.000	0%
TEMI – PM NS	Level 1 (individual)	45.09	80.35%
	Level 2 (class)	11.02	19.65%
TEMI – PM NI	Level 1 (individual)	15.54	84.22%
	Level 2 (class)	2.91	15.78%
TEMI – PM QR	Level 1 (individual)	101.66	84.34%
	Level 2 (class)	18.87	15.66%
TEMI – PM TS	Level 1 (individual)	1026.251	86.76%
	Level 2 (class)	156.589	13.24%
TEMI – O MPS	Level 1 (individual)	19.825	81.22%
	Level 2 (class)	4.584	18.78%

Note. ^aStandard errors are in parentheses; ^bReference group is comparison; * Statistically significant after Benjamini-Hochberg correction; *g*^{*} = Effect sizes were estimated as the ratio between the model-derived treatment coefficients and the unadjusted pooled within-group standard deviation across conditions at posttest. TEMI-PM = Texas Early Mathematics Inventories-Progress Monitoring; MC = *Magnitude Comparison* subtest; NS = *Number Sequence* subtest; QR = *Quality Recognition* subtest; TEMI – O = Texas Early Mathematics Inventories-Outcome; MPS = *Mathematics Problem Solving* subtest.

ly valid for their intended purposes (i.e., improving student mathematics performance in early numeracy concepts and skills). Survey items, along with the teachers' average ratings and standard deviations, are reported in Table 4.

Discussion

Successful mathematics performance in the area of early numeracy concepts and skills is fundamental

for more advanced mathematics instruction at the elementary and secondary levels. However, some kindergarten students demonstrate difficulty learning the foundational concepts and skills, and thus could benefit from interventions that supplement core instruction. Such practice is particularly imperative because low mathematics performance at the end of kindergarten has been shown to predict the continuation of low performance into the elementary grades (Jordan et al., 2009; Morgan et al., 2009).

Table 4
Results of Teacher Social Validity Satisfaction Survey

Survey Statement	<i>M</i>	<i>SD</i>
The lessons' mathematical content is aligned to the state standards: number/operation; patterns, relationships and algebraic thinking; problem solving.	4.40	1.06
The scope and sequence of the lessons for each skill are appropriate for my grade.	4.73	.46
The instructional content (warm-up, 1 lesson for K, 2 lessons for first/second grades) is an appropriate amount of content for the students to learn during the designated lessons: not too much for the allotted time.	4.47	.64
Student understanding of the skills being taught in each lesson is enhanced by the use of concrete (e.g., cubes, rods) and pictorial (e.g., number line, 100s chart) materials to represent concepts.	4.80	.56
There are appropriate amounts of practice with concrete, pictorial, and abstract representations.	4.73	.46
The lessons need to provide more explicit instruction in mathematics vocabulary.	2.33	.82
Warm-ups provide helpful practice on skills.	4.40	.51
The instructions and "teacher talk" help me teach the lessons effectively.	4.67	.49
Modeling/Modeled Practice: The modeling clearly demonstrates the skill or task.	4.80	.41
Guided Practice (GP): The instruction provides the student with sufficient and appropriate practice.	4.53	.64
Independent Practice (IP): The lessons provide opportunity for student to perform the activity independently so that I can evaluate student learning.	4.80	.41
The error correction procedures provide helpful ideas for correcting errors.	4.60	.63
There is sufficient time allotted for each part of the daily lesson.	4.27	.88
The materials for the lessons are manageable (not too much to change across the lessons and thus eat up time).	4.07	1.03
The Independent Practice progress monitoring activity provides sufficient information to help me decide if the student learned the instructional content presented.	4.47	.83
The daily check sheet is a useful tool to help me "at a glance" determine how individual students are progressing daily.	3.93	1.03
The Aim Checks provide helpful information about student progress with instruction.	4.80	.41
Overall, my students are benefiting from the lessons.	4.93	.26

This study examined the effects of Tier 2 interventions on early numeracy concepts and skills delivered by classroom teachers in kindergarten to students who were identified as having mathematics difficulties and teacher satisfaction about the intervention.

The interventions consisted of instructional design and delivery features found to produce positive academic outcomes for struggling students (e.g., Swanson et al., 1999) along with practices that contribute to mathematics performance (e.g., visual representations, mathematics vocabulary instruction).

Effects of the Intervention on Early Numeracy Performance

For the first research question, overall results on the TEMI-PM were generally favorable. That is, students in the treatment condition outperformed the comparison students ($g^* = .99$) and demonstrated statistically significantly higher scores on the TEMI-PM Total Score and all four subtests. These findings are similar to those of Clarke et al. (2016), who found an effect size of .30 and statistically significant difference between groups favoring the treatment group as measured by the EN-CBM.

The hypothesis that students in the treatment group would outperform students in the business-as-usual comparison group was confirmed. Thus, when provided intervention targeting specific early numeracy concepts and skills, young students seem to benefit from this supplemental instruction, a finding that is encouraging considering the prospect of further math struggles without intervention (Jordan et al., 2009; Morgan et al., 2009). Additionally, about 80% to 100% of the variance was accounted for at the student level. These findings are educationally significant and clinically meaningful according to What Works Clearinghouse (2014) guidelines (http://ies.ed.gov/ncee/wwc/pdf/wwc_version1_standards.pdf).

Although these scores are positive indicators for the effects of the intervention for the treatment group, we cannot ignore the potential of false positives when identifying young children with risk status; thus, we undoubtedly must attribute some of the possible effects to expected growth for typical students. Overall, the results are encouraging

and show promise for the intervention. The positive effects for the Magnitude Comparisons subtest were particularly important because this aspect of mathematics may be a good indication of future understanding and performance with place value (Gersten et al., 2012). For young children who are entering formal schooling and demonstrating mathematics difficulties, critical numeracy concepts and skills paired with the use of mathematically correct vocabulary potentially can help them benefit from intervention that may reduce further mathematics difficulties. For example, findings from the National Mathematics Advisory Panel (NMAP; 2008) stressed the importance of providing early intervention that uses effective instructional practices in the primary grades, especially for at-risk students.

Effects of the Intervention on Broad Mathematics Concepts and Skills

For the second research question, the effects of the intervention on the TEMI-O MPS, a broad measure of mathematics performance, were analyzed. The findings were educationally significant ($g^* = .44$), but the group difference was not statistically significant. Although disappointing, we were not surprised by these findings, because the intervention was not focused on a broad range of mathematics concepts and skills (e.g., geometry, measurement) as measured by the TEMI-O MPS. Thus, the hypothesis of no significant differences between groups was confirmed. Students' ability to generalize their knowledge of early numeracy concepts and skills to broader mathematics measures remains an area that warrants more research to determine how students can learn generalizations that will enable them to transfer knowledge to novel measures and other mathematics topics.

Teacher Satisfaction With the Early Numeracy Intervention

In response to the third research question, teachers generally reacted favorably to the lessons. It is important that lessons such as those used in this study incorporate positive instructional features that combine to promote student growth. In the area of mathematics instruction, general education elementary classroom teachers may not have received

training on the features of instructional delivery included in the lessons because more emphasis is placed on a constructivist approach to mathematics teaching in general education teacher preparation programs. Thus, it was encouraging to find that the teachers responded well to the elements of effective instruction (e.g., modeling, checking for understanding, multiple practice opportunities) that were incorporated into the lessons. The hypothesis that the treatment teachers' satisfaction, on average, would receive high ratings because of the instructional design and delivery practices that were included in the lessons was confirmed.

Limitations and Future Research

Although the study was well designed and implemented, three primary limitations need to be addressed in future studies. First, additional fidelity observation are warranted. We collected fidelity data three times; future research efforts should examine fidelity more often to ensure that the intervention is being administered as intended. Relatedly, no data were collected on inter-observer agreement with the fidelity ratings. Second, additional observations of comparison group instruction should take place so that comparisons can be made more precisely across interventions. Third,

social validity data should be gathered from students who are participating in the intervention, in addition to the perspectives of their teachers. Their perspectives about the lessons are equally valid as their teachers' views.

Educational Implications

Findings from this study demonstrate that students who are struggling with early numeracy concepts and skills can benefit from Tier 2 intervention; thus, both the amount of instructional time applied and the intervention components hold promise for future intervention work for struggling students. Noteworthy, the classroom teachers were responsible for delivering the intervention to small groups of students rather than a mathematics interventionist who pulls students from various classrooms for intervention work. The classroom teachers in this study received intensive professional development at the onset of the intervention program and coaching during the school year (albeit on a limited basis) from project staff. The overall findings suggest that teachers can be effective interventionists even in the early stages of adopting and implementing a new intervention for at-risk students when the program is part of their daily mathematics routine across the school year.

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Oral Reading Miscues and Their Relation to Silent Reading Comprehension in Children With and Without Learning Disabilities

Abstract

Oral reading fluency (ORF) has been widely used as a measure of students' overall reading competency. However, accuracy, or words correct per minute (wcpm), derived from ORF testing may not reveal all aspects of a student's reading abilities. The present study investigated the oral reading miscue patterns of students with and without learning disabilities (LD). In addition, the predictability of oral reading miscues on silent reading comprehension performance was examined. Using the Gray Oral Reading Tests-Fifth Edition miscue coding system to categorize students' oral reading miscues, study findings suggest that there are differences in the oral reading miscue patterns of students with and without LD. Moreover, two miscue categories, function similarity and meaning similarity, significantly predicted silent reading comprehension performance. The discussion focuses on how incorporating oral reading miscue analysis along with rate and accuracy can add a layer of information to help teachers in their decision-making for instructional alignment.

Oral reading fluency – the ability to read connected text quickly and accurately – has received considerable attention in recent years, largely because its critical role in reading instruction has been recognized by the National Reading Panel (National Institute of Child Health and Human Development, 2000). The importance of reading fluency lies in its pivotal role in coordinating the reader's cognitive processes that underscore automatic word recognition, rapid syntax structure identification, and lexical and text comprehension (Pikulski, 2006). The level of accuracy and speed in oral reading reflects the extent to which one can efficiently recognize and sound out printed words at the graphophonic, syntactic, and semantic levels (Kim, Wagner, & Foster, 2011). Thus, reading fluency is affected by multiple language skills, including the ability to quickly identify groups of words that form meaningful grammatical units (Jenkins, Fuchs, van den

Broek, Espin, & Deno, 2003; National Institute of Child Health and Human Development, 2000).

Recognition of the critical role of oral reading fluency as a general outcome measurement has spurred its use for monitoring students' overall reading competency (Ridel, 2007). A number of curriculum-based measurement (CBM) tools such as AIMSweb (Pearson, 2009), Dynamic Indicators of Basic Early Literacy Skills (DIBELS; Good & Kaminski, 2002), and Informal Reading Inventories (IRI; Johnson, Kress, & Pikulski, 1987) all include oral reading fluency (ORF) components.

Different ORF measures may use different procedures to measure reading fluency. For example, in one method the child reads a passage aloud for one minute, and the examiner notes any oral reading errors. The percentage of words read correctly or the total number of words read accurately at the end of one minute (words correct per minute [wcpm]) is

calculated. An alternative approach involves a reader reading an entire passage while the examiner marks reading errors. The total amount of time taken to read the entire passage is marked, and the rate and accuracy are then calculated.

Regardless of the procedure used to measure ORF, the fluency index (either wcpm or rate and accuracy) serves as a measure of overall reading competency at the level at which the passage is written (e.g., 193 wcpm for a third-grade-level passage). When teachers use the fluency index to track students' reading performance, they may use the data as an impetus to alter their teaching strategy if their students' rate of growth does not meet the desired growth trajectory. Indeed, student performance has been shown to be maximized when teachers analyze student performance and develop individually tailored instructional programs accordingly (Stecker, Fuchs, & Fuchs, 2005). However, fluency index measurement alone is insufficient when it comes to informing individualized instruction, because the index may not reveal the student's strengths and needs in relation to the factors that affect ORF performance. As a result, researchers have suggested that teachers conduct diagnostic analyses in conjunction with using progress monitoring tools (Fuchs, Fuchs, & Hamlett, 2007).

Within the context of ORF testing, a diagnostic and qualitative analysis is typically conducted through miscue analysis. An analysis of miscue patterns during oral reading may capture different levels of students' graphophonic, syntactic, or semantic processing that reflect the reading strategies the students used to process print. As such, an oral reading miscue analysis may provide useful information for planning an individualized intervention program.

Oral Reading and Miscue Analysis

Most reading specialists and elementary teachers are familiar with and regularly use oral reading error analysis in the context of running records (Bean, Cassidy, Grumet, Shelton, & Wallis, 2002). By most accounts, Gray (1915, 1920) was among the first to focus on oral reading analysis when he wrote his *Standardized Oral Reading Passages* and used them and other reading materials to study reading rate (i.e., number of words read in a specified period of time). In his 1920 paper, Gray not-

ed the oral reading mistakes students made while reading aloud but made no mention of any type of error analysis.

A decade later, Monroe (1932) took oral reading analysis a step further by identifying several types of common oral reading errors (e.g., faulty vowels and consonants, sound addition and omission, and letter reversals) that could shed light on idiosyncratic reading patterns. In describing Monroe's and other later efforts at oral reading error analysis, Leu (1982, p. 422) noted that such analysis made the following assumptions:

1. Proficient reading equals exact oral reading.
2. Oral reading errors interfere with reading comprehension.
3. The number of oral reading errors that a person makes is related to their reading comprehension.

Finally, K. Goodman approached reading from a linguistic perspective. He preferred the term *miscues* to *errors* because he believed that reading is a process in which readers respond to three types of linguistic cues: graphophonic, syntactic, and semantic (K. Goodman, 1964, 1965). When a reader produces oral reading that departs from what was provided in the text, the reader is believed to be missing one or more of the linguistic cues (K. Goodman, 1969, 1973). Therefore, analyzing the linguistic cue that was missed by the reader can help teachers gain insight into the student's reading process. K. Goodman and colleagues devoted several years to creating a classification system for identifying and categorizing oral reading miscues (K. Goodman, 1969, 1973; Y. Goodman, Watson, & Burke, 2005). Throughout the remainder of this article we use the term *miscue* suggested by K. Goodman rather than *error* for students' deviations from print during oral reading.

Oral reading miscue analysis has been criticized, both in print (see McKenna & Picard, 2006, and K. Goodman's 2006 retort; Moats, 2000) and online (DeRosa, 2010). Yet, miscue analysis remains a popular and widely used means of examining oral reading and informing instruction. Wiederholt and Bryant (1986) incorporated a modified version of Goodman's miscue analysis system into their *Gray Oral Reading Test-Revised* (GORT-R), and it continues to be included in the latest edition of the test, *Gray Oral Reading Test-Fifth Edition* (GORT-5; Wiederholt & Bryant, 2012).

Regardless of whether reading professionals use the term *errors* or *miscues*, most would agree with what Fowler, Shankweiler, and Liberman wrote over 30 years ago: “The errors children make in oral reading provide a window through which we may view special problems of learning to read” (1979, p. 243). The window may not always be crystal clear, but oral reading miscues provide clinicians and diagnosticians with a perspective of a student’s skills underlying oral reading fluency.

Studies on Oral Reading Miscues

Several studies have explored whether there is an association between students’ level of language development and their oral reading miscue patterns. For example, Laing (2002) compared the miscue patterns of third graders with language delays with those of students having typical language development. Using a 12-category miscue system, Laing suggested that third-grade students with typical language development made more miscues that were meaningfully consistent with the original text than their counterparts with lower-than-average language abilities. Further, Gillam and Carlile (1997) compared miscue differences made by students with specific language impairment to those of their typically developed counterparts. Four miscue categories were used: graphophonemic, syntactic, semantic-pragmatic, and self-correction. Their findings suggested that typically developing participants had significantly higher percentage miscues that were graphophonemic, syntactic, and semantic-pragmatic similar to the print; they also had a higher percentage of self-corrected miscues.

In a third study, Cambourne and Rousch (1982) compared oral reading miscues produced by readers ranked by their teachers as the top 5%, middle 5%, or bottom 5% of their age-grade reading group. Participants were asked to read a passage deemed suitable for students’ reading level by their teachers, and their oral reading miscues were subsequently categorized using a 24-category taxonomy. The results of the study showed that the proficient readers concentrated on sense and grammatical flow rather than the graphic and phonemic aspects of print. In contrast, the less proficient readers paid more attention to the physical aspects of print.

In summary, even though various miscue coding systems were used in previous studies to categorize students’ oral reading miscues, these studies reached the same conclusion; that is, students with typical language development made more miscues that preserved the meaning of the text than students with impaired language development. However, the results were inconclusive regarding whether students with lower-than-average language development made more graphophonemic miscues. For example, the Cambourne and Rousch (1982) study, although alluding to differences in miscues made by students with different levels of reading proficiency, suffers from a lack of a refined and systematic approach to yield a valid comparison among groups (i.e., no standardized approach to grouping students).

Purpose and Research Questions

Because qualitative analysis of students’ oral reading miscues can contribute to an understanding of students’ graphophonic, syntactic, and semantic processes during oral reading, miscue analysis may provide more precise information for addressing students’ individual needs as a means of improving their reading performance (K. Goodman, 1964, 1965, 1969, 1973). Such a level of individualization is especially critical for students with learning disabilities (LD) because these students are more likely to experience difficulties in reading (Kame’enui, Good, & Harn, 2005) linked to graphophonic, syntactic, and semantic processes during reading (Perfetti, 2007; Simmons, Kame’enui, Coyne, Chad, & Hairrell, 2011; Wise, Sevcik, Morris, Lovett, & Wolf, 2007).

Therefore, the purpose of the present study was to extend previous research (e.g., Cambourne & Rousch, 1982; Gillam & Carlile, 1997; Laing, 2002) to a distinct group of students by examining the oral reading miscues of students with LD. The following research questions were investigated:

Research Question 1: Is there a difference in the miscue patterns displayed by students with or without LD using the *Gray Oral Reading Test-Fifth Edition* (GORT-5) deviation coding system?

Research Question 2: Which GORT-5 miscue category best predicts students’ silent reading comprehension performance?

Method

Participants

Participants were selected from a subject pool of 280 students from grades 3 through 5 in two suburban schools in the western United States. Among the 280 students, 36 had identified LD using the state of California LD identification criteria, whereby students are assessed by multidisciplinary teams using a discrepancy-based model to determine whether they have a severe discrepancy between their intellectual

ability and achievement in oral expression, listening comprehension, written expression, basic reading skill, reading comprehension, mathematical calculation, or mathematical reasoning for LD diagnosis (California Code of Regulations §3030).

These 36 students were matched with counterparts without LD using the following variables: age, gender, and ethnicity. English language learners were not included in the study. A summary of the demographic information for the 72 students (36 students from each group, LD and non-LD) in the study is presented in Table 1.

Table 1
Student Demographic Information by Groups

	N	Male	Age Mean (SD)	African American	Asian	Hispanic	White	TOSCRF Mean (SD)	GORT-5 Fluency Scale Mean (SD)	GORT-5 Comprehension Scale Mean (SD)
LD	36	25	10.75 (1.01)	1	2	13	20	87.29 (8.44)	7.67 (2.89)	5.95 (1.91)
Non-LD	36	25	10.62 (0.97)	1	2	13	20	104.50 (10.19)	11.61 (2.50)	10.93 (2.31)

Measures

The *Test of Silent Contextual Reading Fluency* (TOSCRF; Hammill, Wiederholt, & Allen, 2006) and *Gray Oral Reading Test-Fifth Edition* (GORT-5; Wiederholt & Bryant, 2012) were administered to the participants. The TOSCRF was used to measure students' silent reading comprehension performance; GORT-5 was used to code and categorize their oral reading miscues.

Test of Silent Contextual Reading Fluency (TOSCRF). The TOSCRF (Hammill et al., 2006) is a standardized, norm-referenced test that is designed to measure the silent reading ability of children between the ages of 7 and 18. The test adopts a word chain technique by using words in a series of brief printed passages without providing spacing or punctuation within the passages. As exemplified in the test manual, the students are asked to read and draw lines between each word of the passage such as the following:

AYELLOWBIRDWITHBLUEWINGSSATON-MOTHERSPRETTYHAT.

According to Hammill et al. (2006), the TOSCRF measures a wide range of silent reading skills, including word knowledge, syntax and morphology knowledge, and silent reading comprehension. The TOSCRF has high alternate-forms reliability ($r = 0.82 - 0.93$) and very high interscorer reliability ($r = 0.99$). The examiner's manual reports that the TOSCRF has moderate to large correlation with other reading fluency and comprehension measures (> 0.55).

Gray Oral Reading Test-Fifth Edition (GORT-5). The GORT-5 (Wiederholt & Bryant, 2012) is an individually administered, standardized, norm-referenced test that measures oral reading rate, accuracy, fluency, and comprehension. The test was standardized on 2,556 students from 34 states between the age of 6 years, 0 months and 23 years, 11 months. In addition to providing normative scores for its subtests and composites, the GORT-5 offers a system for qualitatively analyzing oral reading miscues across five categories, as discussed later. Evidence for the following five forms of reliability is reported for the GORT-5: coefficients alpha, alternate-forms reliability (immediate

administration), alternate-forms reliability (delayed administration), test-retest, and interscorer reliability. Average reliability coefficients across ages for each type of reliability are reported as 0.93, 0.93, 0.77, 0.82, and 0.99, respectively. Considerable evidence supporting the validity of the GORT-5 is provided in the examiner's manual.

Procedures

Test administration. Both the TOSCRF and the GORT-5 were administered by 10 examiners who were experienced substitute teachers. They were either working on their teacher certifications or had already obtained their credentials. Prior to testing, the first author trained the examiners on how to administer each test. After the training, the examiners practiced with each other as the first author checked for fidelity. A reliability check on adherence to direction and scoring conducted after the training yielded an interscorer agreement of at least 90% across examiners.

All participants were administered the TOSCRF and the GORT-5 by the examiners at the students' schools. Following the GORT-5 standardized administration procedure, examiners asked participants to read each passage aloud as carefully and quickly as possible, and told them that after each passage reading they would be asked questions about what they had read. Examiners timed the students' reading and marked each miscue with a slash. After each passage was read, the examiners recorded the number of miscues and the total time each participant spent reading a specific passage. Upon completion of each passage, students were asked five open-ended comprehension questions. Entry points, basals, and ceilings were applied according to the instructions provided on the GORT-5. All students' oral reading was audio recorded for further miscue analysis.

Miscue system. The miscue system developed by the authors of the GORT-5 was used to categorize the students' oral reading miscues. The GORT-5 uses five miscue categories: meaning similarity, function similarity, graphic/phonemic similarity, multiple sources, and self-correction. Three of the miscue categories, meaning similarity, function similarity, and graphic/phonemic similarity, are consistent with K. Goodman et al. (1969, 1973) and Y. Goodman et al.'s (2005) miscue categories: semantic, syntactic, and graphophonic.

1. **Meaning Similarity:** A miscue is coded as "meaning similarity" if it does not significantly change the meaning of the sentence (e.g., "'Immediately' the murmur from the hive was amplified." for "'Instantaneously' the murmur from the hive was amplified.").
2. **Function Similarity:** A miscue is coded as "function similarity" if it does not change the grammatical form of the word and fits within the context of the sentence (e.g., substitutes a noun for a noun or a verb for a verb in a sentence; thus, the sentence makes syntactic sense: "A 'bat' is perched on a fence." for "A bird is perched on a fence.").
3. **Graphic/Phonemic Similarity:** Words labeled "graphic/phonemic similarity" miscues include miscues of which some portion (e.g., affixes, roots, vowel sounds, or consonant sounds) of the response is aligned with the target word (e.g., affixes similarity: "remove" for "return"; roots similarity: "merrily" for "merry"; vowel sounds similarity: "wait" for "stay"; consonant sounds similarity: "come" for "cat").
4. **Multiple Sources:** Words labeled "multiple sources" are miscues fitting more than one miscue category (i.e., any combination of meaning similarity, function similarity, and graphic/phonemic similarity). For example, if a student read, "A bird is 'sitting' on a fence" for "A bird is perched on a fence," the miscue, "sitting," is marked as "multiple sources" because it meets the criteria for both "meaning similarity" and "function similarity."
5. **Self-Correction:** A word is coded as "self-correction" if it is initially a miscue but the student self-corrects it within three seconds without any prompts or help from the assessor (e.g., "The mounted ... mountain loomed ahead" for "The mountain loomed ahead").

Although there are other possible miscue categories (e.g., insertion and omission), we did not code miscues outside of the miscue categories provided by GORT-5.

Scoring. The scorers, the authors, and a graduate student listened to the audio files recorded during the test administration and transcribed (orthographically and phonetically) the miscues students produced as they read. For each student across all passages read (GORT-5 basal and ceiling rules dictated first and last passage read), miscues

were coded, and the number and kind of miscues were summed across all passages.

The total number of miscues differed from student to student based on the number of passages read, in compliance with the GORT-5 basal and ceiling rules. To account for this, analyses were conducted using proportional data; that is, the number of miscues in each category was divided by the total number of miscues made (e.g., number of meaning similarity miscues ÷ total number of miscues).

Interrater reliability. Thirty-five percent of the passages read were randomly selected for the interrater reliability check. The scorers coded the readers' miscues independently, and the miscue coding was checked point by point. The interrater reliability was derived using the following formula: Interrater reliability = total agreement ÷ (total agreement + total disagreement) 100%. An interrater reliability of 95.6% was obtained.

Analyses and Results

To answer the first research question, a multivariate analysis of variance (MANOVA) was conducted to examine differences between the two groups in terms of the types of miscues produced during oral reading. Although MANOVA allows testing for the difference in two or more vectors of means, using MANOVA to analyze proportional data is problematic because such data do not satisfy the normality assumptions of analysis of variance (Stevens, 1992). Therefore, prior to statistical analysis, miscue types computed as percentages were transformed using arcsin transformations of the square root of the percentages. These transformations were computed to stabilize and normalize the proportion distribution, "so that all proportions will have equal variances and follow a standard normal distribution" (Rossi, 2012, p. 86). The untransformed group means and standard deviations for the percentage of oral miscue types are shown in Table 2.

Table 2
Group Mean Percentages and Standard Deviations for the Total Miscues by Categories

	LD	Non-LD
Meaning Similarity	8.17% (3.66)	11.68 % (5.44)
Function Similarity	7.91% (3.71)	13.80% (5.52)
Graphic/Phonemic Similarity	59.20% (12.32)	43.54% (13.64)
Multiple Sources	12.39% (4.14)	18.04% (5.23)
Self-Correction	12.33% (4.63)	12.93% (6.60)

The results of the MANOVA revealed a significant multivariate main effect, Wilks' $\lambda = 0.65$, $F(5, 66) = 4.99$, $p < 0.001$, $\eta^2 = 0.16$. Power to detect the effect was 0.98. Given the significance of the overall test, the univariate main effects were examined. Significant univariate main effects were obtained for the meaning similarity miscues for students without LD compared to those of students with LD, $F(1, 70) = 13.08$, $p < 0.05$, $\eta^2 = 0.14$; function similarity miscues for students without LD compared to those of students with LD, $F(1, 70) = 8.58$, $p < 0.01$, $\eta^2 = 0.10$; multiple sources miscues for students without LD compared to those of students with LD, $F(1, 70) = 12.47$, $p < 0.01$, $\eta^2 = 0.13$; and graphic/phonemic similarity miscues for students with LD compared to those of students with-

out LD, $F(1, 70) = 14.97$, $p < 0.05$, $\eta^2 = 0.15$. No significant difference was found for self-correction. Stevens (1992) suggested that the value is medium when it is 0.06 and large when it is 0.14. The results of the MANOVA in the current study suggested a large effect size for the multivariate main effect and medium effect sizes for univariate main effects.

To explore the predictability of the five miscue categories as defined in GORT-5, a correlation matrix was computed to show the correlation between students' TOSCRF standard scores and miscue categories. As illustrated in Table 3, meaning similarity, function similarity, and graphic/phonemic similarity were significantly correlated with TOSCRF scores. It is notable that graphic/phonemic simi-

Table 3
Correlations Between Miscues and TOSCRF Scores at Two Grade Clusters

	1	2	3	4	5	6
1. TOSCRF		.41*	.58***	-.49***	.23	-.13
2. Meaning Similarity			.24	-.60***	.52**	-.26
3. Function Similarity				-.76***	.61***	-.01
4. Graphic/Phonemic Similarity					-.65***	-.26
5. Multiple Sources						-.13
6. Self-Correction						

* $p < .05$; ** $p < .01$; *** $p < .001$.

larity was negatively correlated with the TOSCRF score, signifying an inverse relationship between this category and silent reading comprehension.

A hierarchical multiple-regression analysis was run to further examine the predictive power of each of the GORT-5 miscue categories. Given that the sample consisted of students spanning three grade levels (i.e., grades 3-5), the initial model in the regression was student age. For the second model, the miscue categories were entered as predictor variables. Evaluation of assumptions indicated that normality, linearity, homoscedasticity, and independence of residuals assumptions were met.

The results from the hierarchical multiple regression are provided in Table 4. As illustrated, age was not a significant factor in predicting TOSCRF standard scores: Model 1 yielded a p value of 0.246 for the F chance in the model. Model 2, however, was significant at $p < 0.01$. A closer examination shows that meaning similarity and function similarity were significant predictors of silent reading comprehension. Multiple sources, graphic/phonemic similarity, and self-correction failed to make a significant predictive contribution.

Table 4
Hierarchical Regression Analysis for Variables Predicting TOSCRF Scores

Model and Variable(s)	B	$SE B$		
Model 1				.000
Age	.71	.813	.008	
Model 2				.421
Age	0.49	.619	.213	
Meaning Similarity	7.38**	4.89	.55	
Function Similarity	6.54**	2.93	.24	
Graphic/Phonemic Similarity	-5.09	3.16	-.62	
Multiple Sources	2.677	3.91	.086	
Self-Correct	-1.96	2.52	.082	

* $p < .05$; ** $p < .01$; *** $p < .001$.

Discussion

Previous research indicates that reading fluency is a significant indicator of overall reading competence, especially when measured by the rate and accuracy of reading text (Kim et al., 2011; Schilling, Carlisle, Scott, & Zeng, 2007). However, rate and accuracy alone provide little diagnostic information useful for instruction planning.

In this study, we first used the five GORT-5 miscue categories to investigate whether students with LD produced different miscue patterns than students without LD. Second, we explored whether the results from these miscue categories were predictive of comprehension performance.

As shown in Table 2, graphic/phonemic similarity accounted for the highest percentage of oral reading miscues made by both groups of students during oral reading. However, further examination showed differences between the two groups in their use of and dependency on different types of miscues. The most frequent miscues made by the students with LD fell in the graphic/phonemic similarity, self-correction, and multiple sources categories, whereas the most frequent miscues made by students without LD were graphic/phonemic similarity, function similarity, and meaning similarity. Specifically, significant differences were seen in the reliance of the students without LD on meaning similarity, function similarity, and multiple sources miscues compared to students with LD.

Replacing words with grammatically correct words in sentences (function similarity miscues) implies that even when their oral reading deviated from the original print, students without LD were more likely to quickly identify groups of words that form meaningful grammatical units and preserve the language structure of the print. This finding is consistent with earlier work showing that language skills, including syntactic knowledge, affected students' reading fluency (Jenkins et al., 2003). In addition, this finding also supports Cambourne and Rousch's observation (1982) that proficient readers are more apt to pay attention to grammatical flow of print as they read. Therefore, our findings corroborate those of earlier studies indicating that fluent readers are more sensitive to language patterns and better able to manipulate the structure of language than their less fluent counterparts.

The more frequent occurrence of meaning similarity miscues in the group of students without LD demonstrates that these students were more likely to either intentionally substitute original print to facilitate their comprehension (e.g., "park" on a limb for "perched" on a limb) or unintentionally replace the original print without compromising the original meaning of the text (e.g., "a" group of parents for "one" group of parents). Either way, these students showed use of good comprehension strategies, an understanding of the text, and were able to substitute contextually accurate words without compromising comprehension. This supports Samuels' (2006) findings that readers are considered fluent if they decode and monitor their comprehension in an automatic fashion.

Implementing multiple sources miscues can reflect the extent to which a reader uses different reading strategies to access print (Wiederholt & Bryant, 2012). Our finding shows that students without LD, during oral reading, were more inclined to use grapheme-phoneme correspondences along with the other structures of language for sense making. This corroborates a report from the National Reading Panel (National Institute of Child Health and Human Development, 2000) suggesting that fluent readers typically possess a higher level of language skills than their peers who have reading difficulties. It also supports the finding of Gillam and Carlile (1997) that students with typical language development make more miscues in the semantic-pragmatic category than students with language impairments.

The highest percentage of miscue observed in students with LD was graphic/phonemic similarity, and there was a significant increase in the percentage of this type of miscues compared to students without LD. This finding is not unexpected given that students with LD tend to have impairments at the letter-sound correspondence level, in particular in word identification and phonological processing (Kame'enui et al., 2005; Schatschneider, Fletcher, Francis, Carlson, & Foorman, 2004; Torgesen, 1999).

In all, our results indicate that the miscues produced by students without LD were more closely aligned to the semantic and syntactical structure of the words and sentences. This suggests that, compared to students with LD, students without LD appeared

better able to process the language units and monitor their comprehension in a more automatic fashion. By contrast, the relatively higher percentage of graphic/phonemic similarity miscues made by students with LD suggests that these students were more inclined to rely on letter-level processing (i.e., orthographic, phonological features of words) and less likely to detect the relational meanings among the words or the sentences as they read. Although there are plausible explanations for the lack of awareness of relational meanings in words or sentences demonstrated by students with LD during oral reading, including lack of language proficiency (Kim, 2015), visual sequential memory differences (e.g., Scheiman & Rouse, 2005), and deficits in working memory (Nation, Adams, Bowyer-Crane, & Snowling, 1999; McVay & Kane, 2012), our study cannot confirm the cause of such observations.

We also explored the predictability of miscue categories on participants' silent reading comprehension performance using hierarchical regression analyses. Using TOSCRF standard scores as the outcome measure and the five miscue categories as the predictors, meaning similarity and function similarity miscues emerged as significant predictors of the TOSCRF scores even when students' age was controlled for. This result is interesting, as it is counterintuitive to find that any miscue category would predict comprehension performance. One possible explanation is that producing miscues in the meaning similarity and function similarity categories reflects an ability to understand the meaning of the text and identify grammatical categories of words while reading. Because of this preservation of the semantic and syntax structure when meaning similarity and function similarity miscues are produced, it might be possible that meaning similarity and function similarity miscues, to a certain extent, reveal language skills that are considered critical for overall reading competency (National Institute of Child Health and Human Development, 2000; Nunes, Bryant, & Barros, 2012).

Practical Implications

A number of observations can be made that have implications for reading teachers. However, it is important first to note that, although miscue analysis has been related to whole language (Giles,

2006), this need not be the case, and miscue analysis can be of benefit to all teachers of reading. Harris and Sipay (1980) long ago noted the differences between those who advocate top-down, bottom-up, and interactive models of reading instruction. Even acknowledging these differences, there is a commonality across the models. That is, most reading experts, regardless of persuasion, would agree that reading is a language-based activity that has comprehension as its sole purpose. Most "bottom-uppers" would agree that the purpose of word-study instruction, for example, is to foster accurate decoding, which then provides the opportunity to read with understanding. And most "top-downers" would not argue against the importance of word-recognition abilities. It is with this understanding that miscue analysis can be a contributory factor to any reading instruction.

In planning reading instruction for students with LD, every piece of information available creates a more complete picture of students' strengths and weaknesses. In addition to the use of rate and accuracy, miscue analysis brings a layer of information that helps teachers' decision-making for instructional alignment by providing a clearer insight into students' knowledge in specific areas.

As demonstrated by the results of this study, able readers made more meaning similarity and function similarity miscues than those with LD. Additionally, function similarity and meaning similarity miscues were significant predictors of silent reading comprehension. These findings suggest that students' knowledge of grammar and knowledge of written language play a role in reading comprehension. Our findings show that able readers tended to have a good grasp of language function and were able to substitute words while staying within the correct grammatical category (i.e., noun for noun; verb for verb; adjective for adjective) and preserve the meaning of the text. Poor readers, on the other hand, demonstrated much fewer function similarity and meaning similarity miscues, suggesting that they were less likely to detect the syntactic and semantic structure of language.

Because the ability, or lack thereof, to detect the syntactic and semantic structure of language during oral reading may be linked to working memory capacity, with which attentional control is mediated (McVay, & Kane, 2012; Nation et al., 1999),

or language proficiency level (Kim, 2015), the instructional implication of these findings points to the importance of addressing any limited areas in working memory or language skills.

However, because working memory training does not necessarily lead to improvement in reading skills (Randall & Tyldesley, 2016), another possible instructional approach to improving students' awareness of the syntactic and semantic structure of language is to make certain that they understand that, as a language activity, decoded grapheme combinations must make sense. For students who appear to have syntactic difficulties in oral language, activities using the maze technique (Shin, Deno, & Espin, 2000) may be beneficial. Such activities involve selecting a passage that is at the student's instructional or independent reading level and omitting key words that have syntactic relevance. Three response choices are provided among which the student selects the one that best fits syntactically. Activities such as these can be used to demonstrate that reading is a language-based activity and that syntactic irregularities in print should be reconciled. Furthermore, students who make few meaning similarity miscues, yet have low rate and accuracy levels, most likely do not have an understanding of what they read and, therefore, would profit from comprehension instruction.

Miscues associated with graphic-phonemic similarity are also important. In that regard, the focus should be on identifying the word part that is being misread and checking for consistency. For example, consider the student who misreads *take* as "tack." Initial inspection might target the vowel-consonant-e syllable pattern (V-C-e) as a focus of instruction. Before doing so, however, it would be important to look at the entire passage to see if the student made similar miscues when presented with other vowel-consonant-e syllable patterns. Too often reading teachers spend undue energy teaching word patterns that are identified in miscue analyses, even when overall competence has been achieved (at least as demonstrated by correct word identification elsewhere in the passage). The point is this: Teachers should examine graphic-phonemic miscues in the light of consistency throughout the exercise and not isolated miscues.

Finally, as noted, able readers made more miscues that appear in multiple categories than did students with LD. This may signify that able

readers understand that reading is a meaningful language-based activity that relies on decoding words by making grapheme-phoneme correspondences. Many students with LD could benefit from this knowledge by emphasizing both the sense-making aspect of reading and word-level skills acquisition.

Limitation and Future Research

The most significant limitation of this study is the failure to control the readability level of the passages read by the participants. Thus, the types of miscues produced may be the function of the difficulty of a given text. Because the passages ranged from basal to ceiling passages, the passages a student read can cross over from his/her independent level to frustration level. Logically, the miscue analysis can yield more meaningful instructional information when it is carried out using the student's instructional level passages; however, the findings from the present study can still inform the use of miscue analysis for instructional planning. Although it would be helpful if future research further explored group differences in miscue categories using passages at different readability levels, the results of the present study nevertheless showed that students with LD demonstrated different miscue patterns compared to their peers without LD. Using miscue analysis in addition to calculating rate and accuracy may more accurately reveal strengths and instructional needs of students with LD.

Another limitation of the study is that students were not matched for educational environment (e.g., teacher, reading instructional method). Although matching students with and without LD for educational environment is difficult because students with LD typically receive additional or pull-out specially designed reading instruction or special accommodations as required by the Individuals With Disabilities Education Act (2004), controlling for educational environment at least at the school level may lead to more valid comparisons of student performance in miscues. Future research, therefore, should address the educational environmental factor to reveal a clearer picture of student reading performance and miscue patterns.

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