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Improving content area reading comprehension of Spanish speaking English learners in Grades 4 and 5 using web-based text structure instruction

Kausalai Wijekumar[1] · Bonnie J. F. Meyer[2] · Puiwa Lei[2] ·
Anita C. Hernandez[3] · Diane L. August[4]

Abstract Reading and comprehending content area texts is important for academic and professional success as well as life skills necessary to maintain good health and quality lifestyle. Spanish speaking English language learners have shown poor performance on high-stakes assessments in reading comprehension. The number of Spanish speaking English learners (ELs) in our schools continues to increase at a fast pace, and therefore it is imperative that we address their reading comprehension needs swiftly and effectively. The text structure strategy has shown positive results on comprehension outcomes in many research studies with students at Grades 2, 4, 5, and 7. This study is the first implementation of instruction about the text structure strategy expressly designed to accommodate the linguistic and comprehension needs of Spanish speaking ELs in Grades 4 and 5. Strategy instruction on the web for English learners (SWELL) was designed to deliver instruction about the text structure strategy to Spanish speaker English learners. A randomized controlled study with pre and post-tests was conducted with 14 classrooms at fourth-grade and 17 classrooms at fifth-grade in high poverty schools where over 85% of students were Spanish speaking bilinguals or ELs. Analysis of data using multi-level models show moderate to large-effects favoring the students in the SWELL classrooms over the business as usual control classrooms on important measures such as a standardized reading comprehension test and main idea and cloze tasks. This research has practical implications for the use of web-based tools to provide high-quality and

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✉ Kausalai Wijekumar
  K_Wijekumar@tamu.edu

[1] Texas A&M University, College Station, TX 77843, USA

[2] The Pennsylvania State University, University Park, State College, PA 16802, USA

[3] New Mexico State University, Las Cruces, NM, USA

[4] American Institutes for Research, Washington, DC, USA

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supportive instruction to improve Spanish speaking ELs reading comprehension skills.

Introduction

Reading and comprehending expository texts in English is a key to unlocking academic and professional success for many Hispanic children migrating to the U.S. Unfortunately, reading comprehension is a challenge for most monolingual English speakers and is an even bigger challenge for Hispanic children (NAEP, 2015). Schools are struggling with the challenge of improving Spanish speaking English learners'(ELs) reading comprehension of expository texts (e.g., social studies, science texts) and dealing with a constant influx of children from diverse socio-economic and academic language backgrounds into K-12 settings, designed primarily for mono-lingual instruction. At the present time, a disproportionate number of Spanish speaking ELs are likely to come from low socio-economic status (SES) and attend inner-city/low income schools (Capps et al., 2005). According to the recently released 2015 National Assessment of Educational Progress (NAEP) data, only 21% of Hispanic students in Grades 4 and 8 score at above proficient level compared to 46% and 44% of White students at Grades 4 and 8, respectively. Further, the average scores for Hispanic students at the fourth-grade level have not significantly changed since the previous assessment in 2013 and neither have scores of non-Hispanic children. This lack of reading proficiency poses a challenge for Spanish speaking ELs as they advance to higher grades where they are expected to learn from expository texts in language arts, science, and social sciences (Guthrie & Davis, 2003; Kieffer, 2008; Lee & Spratley, 2010; Murnane, Sawhill, & Snow, 2012). Comprehension of expository text is critical for academic success in school (Kamil et al., 2008; National Educational Goals Panel, 1999), further development of intellectual abilities throughout life (Ackerman, 1998), maintaining a healthy lifestyle (Dinwiddie, Zambrana, & Garza, 2014), and full participation in the democratic process.

Strategy instruction on the web for Spanish speaking English learners (SWELL) was designed to solve these important content area reading comprehension problems. SWELL provides instruction on well-researched, content-focused reading compre-hension instruction about the text structure strategy (Meyer, 1975; Meyer, Brandt, & Bluth, 1980; Meyer, & Wijekumar, 2007; Wijekumar, Meyer, Lei, Johnson, Shurmatz & et al., 2014) and taps into the power of technology to provide linguistic supports and adaptations for fourth and fifth graders (Wijekumar, Meyer, & Lei, 2016). Specific concerns addressed by the SWELL are: lack of reading comprehension strategies; lack of understanding of vocabulary in English; lack of background knowledge about text; and lack of comprehension in English. This manuscript presents findings from a recently completed under-powered multisite randomized controlled trial on the SWELL intervention with fourth- and fifth-grade children. We begin with a synthesis

of causes for reading comprehension challenges followed by a description of the SWELL intervention, research design, results, and discussion of findings.

Causes for reading comprehension challenges with ELs

Failures to make significant gains in learning and academic knowledge for English learners are largely due to problems in reading comprehension (Baker & Dalton, 2011; Proctor, Dalton, & Grisham, 2007; Shanahan & Beck, 2006). Furthermore, research suggests that problems in reading comprehension are due to limitations in knowledge of comprehension strategies and vocabulary (McNeil, 2011).

ELs lack comprehension strategies

A review of research and recommendations by Kamil et al., (2008) suggests that reading comprehension strategy instruction is important for Spanish speaking ELs. Qualitative studies found that low-literacy Latina/o readers in middle school lacked comprehension strategies (Jimenez, 1997; Jimenez, Garcia, & Pearson, 1996).

Research with fifth-grade Spanish speaking ELs has shown that comprehension is difficult to achieve even with instruction (Proctor et al., 2011). Proctor et al., presented web-based instruction to fifth graders allowing them to use a word wall to note vocabulary the children did not understand. The intervention also used summarizing as a means to promote comprehension. Their results showed that children's vocabulary knowledge increased but not their comprehension. Vaughn et al. (2009) presented instruction to seventh graders using collaborative techniques (partner discussions) and used the cause and effect text structure. The study was focused on social studies content and effects on comprehension outcomes were large (i.e., ES = .83) whereas the vocabulary outcomes were small (i.e., ES = .30). Carlo et al. (2004) studied a rich vocabulary intervention with strategies instruction including summarization and comprehension monitoring and found moderate effects on both comprehension and vocabulary measures with fifth graders. Other studies have focused on more specialized types of students or content (e.g., special education—Wanzek et al., 2013; science content—Meyer, Wijekumar, Middlemiss, Higley, Lei, Meier, & Spielvogel, 2010; Tong, Irby, Lara-Alecio, & Koch, 2014; social studies—Vaughn et al., 2017). Most of these studies with Spanish speaking ELs focused on a specific content domain (e.g., science) and none focused on comprehensive instruction using text structures to be delivered during language arts classrooms. In contrast, our primary focus was text-structure based comprehension strategies designed to promote Spanish speaking English learners' reading comprehension, as part of language arts classrooms in upper elementary grades.

ELs grapple with English vocabulary and linguistic complexity

A synthesis of research about Spanish speaking ELs suggests limitations in vocabulary poses a challenge to achieving comprehension (August, & Shanahan, 2006; Kamil et al., 2008; McNeil, 2011). Even though this is a universally agreed

upon concern, how to address the variations in academic language skills in Spanish and English is something that has not been studied frequently. Any solution to address the comprehension needs of these ELs needs to address these variations typically caused by socioeconomic backgrounds. The following profiles capture some of the challenges in addressing these needs (August, & Shanahan, 2008):

- A child who has not learned academic Spanish (e.g., growing up in poverty with illiterate parents) cannot rely on their L1 and therefore can be taught reading comprehension in English (L2) with more emphasis on the basic comprehension component skills (e.g., phonemic awareness, fluency, and vocabulary).
- A child who has received instruction in academic Spanish can be taught using Spanish as the basis for instruction and promoting transfer to English through bridges related to vocabulary and strategy.
- Even for children with good academic Spanish skills, the English language causes some challenges related to figurative language and linguistic complexity.

In summary, EL's vocabulary related problems may go deeper due to a lack of academic language skills in Spanish. For example, some ELs migrate to the US and enroll in school without sufficient native language literacy (e.g., Spanish) and lexical knowledge for effective transfer to a second language (August, Carlo, Dressler, & Snow, 2005; August, & Shanahan, 2006). Research has shown that pre-teaching complex words is useful with monolingual English speakers (Williams, 2007) and Spanish speaking English learners (Dalton, Proctor, Uccelli, Mo, & Snow 2011; Proctor et al., 2007). Supporting understanding of terms with context has also been empirically supported (Carlo et al., 2004). Thus, our goal was to develop a web-based system designed to provide instruction at the word, sentence, or passage level to learners based on their individual level of academic language proficiency in Spanish and English.

Heterogeneity of classroom composition poses challenges for ELs

Because of continuing trends towards a large influx of Spanish speaking ELs into the classrooms across the U.S. where many classroom teachers are monolingual English speakers, it is imperative that any solutions address both the child and teacher. Within a classroom there can be significant heterogeneity in socioeconomic backgrounds and academic language skills and solutions must address each child based on their specific needs. Teachers may also need assistance in delivering individualized instruction to children who are at many different points on the reading comprehension journey.

Web-based intelligent tutoring systems provide a sound platform to deliver interventions to Spanish speaking ELs with diverse linguistic and socioeconomic backgrounds (Wijekumar et al., 2016). The advantages of web-based tools include individualized instruction for each learner based on their current comprehension level, providing on-demand support and adaption to the learners' needs, and consistent and high quality instruction without relying on teacher expertise levels about teaching reading comprehension strategies or delivering instruction in Spanish. Reviews of technology and literacy show digital tools are an important resource showing promise in improving reading comprehension (Dalton & Strangman, 2006;

MacArthur, Ferretti, Okolo, & Cavalier, 2001; Moran, Ferdig, Pearson, Wardrop, & Blomeyer, 2008). Thus, our development and research focused on extending a web-based instructional tool to deliver instruction to Spanish speaking ELs.

Major challenges in reading comprehension for ELs at upper elementary grades

Another focus of this study was on the upper elementary grades where learners are required to read and comprehend expository texts. Even with the new focus on expository texts at lower grade levels (e.g., Common Core State Standards—CCSS), fourth grade is typically where children are transitioned from the learning to read phase to reading to learn from expository texts. Additionally, the pace at which they need to comprehend more complex expository texts only increases as the children move up in grade level. Thus it is important to address the comprehension needs of the children at Grades 4 and 5 in elementary schools (Chall & Jacobs, 2003). We also wanted to try and provide the instruction prior to beginning their middle-school studies. The ability of these children to successfully read and comprehend expository texts is essential to unlocking academic and professional trajectories in science, technology, engineering, and math (STEM) or other areas and breaking the cycle of poverty.

Expository texts are different from narrative texts in their vocabulary, organization, and complexity (Wijekumar, Meyer, & Lei, in press). For monolingual learners expository texts are a challenge because of unfamiliar topics and multiple differences from stories. For Spanish speaking ELs expository texts present additional hurdles due to their lack of vocabulary knowledge and linguistic complexity in addition to the unfamiliar topics. Many of these children need individualized instruction and help in understanding expository texts before they enter the middle grades. SWELL instruction in this study provides help in reading expository text with a variety of domains, including science, social studies, sports, and current events. Additionally, our focus is on providing ELs with contextual cues and on-demand translations of unfamiliar or complex words and sentences.

In summary, the state of instruction for Spanish speaking ELs in U.S. classrooms has received more attention in recent years, but many changing factors continue to impact these learners' reading comprehension outcomes. Research about other interventions and earlier design studies during SWELL development have shown many complexities in helping Spanish speaking ELs achieve their full academic potential (Wijekumar et al., 2016). Our SWELL solution was planned by synthesizing best practices (e.g., Kamil et al., 2008; Proctor et al., 2011; Vaughn, 2015) and using them with the text structure strategy instruction to meet the diverse needs of the Spanish speaking ELs in Grades 4 and 5.

SWELL intervention: aim, theoretical foundations, and empirical support

The goal of the SWELL development was to provide upper-elementary school Spanish speaking ELs instruction about the text-structure strategy to boost reading comprehension combined with supports for developing vocabulary and background

knowledge and addressing the linguistic complexity of the English language (Wijekumar et al., 2016). The SWELL web-based solution provides unique capabilities to support the wide variations in academic language skills in Spanish and English due to the socioeconomic diversity of Spanish speaking ELs.

Theoretical foundation for the text structure strategy used in SWELL

Possessing the ability to seek, select, and synthesize information, generate well-organized and carefully associated memory structures, and utilize these memories are the hallmarks of effective reading comprehension and learning. Research on expertise has consistently shown that experts have strategically organized memory structures that are hierarchical, well-associated, and chunked, providing efficiency in storage and retrieval (Chi, Feltovich, & Glaser, 1981). When reading a passage about solids, liquids, and gases, an expert physicist understands that all three are states of matter with defining characteristics, such as molecular movement, volume, and shape. This same hierarchy of ideas and associations was described by Meyer (1975) as a comparison top-level text structure. Meyer identified five text structures that were the basis for almost all discourse markers for organizing expository text and memory: *comparison, problem and solution, cause and effect, sequence, and description.*. Even though the text-structure based model of reading comprehension can be classified as domain independent, the resulting expertise in content area reading comprehension applies to domain knowledge connections. For the reading comprehension skill, learning and knowing about the text structures provides a bridge for the selection of important ideas and integrating these ideas with prior knowledge and forming a strategically associated memory structure about the content. For example, seeking the cause for a problem and connecting the solution to the root cause applies to many science learning objectives.

The impact of knowing these text structures was observed in ninth graders (Meyer et al., 1980), and recent research has shown that children can be taught how to select and encode strategic memory structures by understanding these five text structures (e.g., Wijekumar et al., 2014; Williams, Hall, & Lauer, 2004). Thus the theoretical basis for the SWELL intervention is derived from discourse markers in texts that guide the creation of strategic memory structures that serve as the foundation of all models of reading comprehension (e.g., Construction-Integration by van Dijk & Kintsch, 1983; Landscape—van Den Broek, 2005). The strategic memory encoded through the structure strategy provides a blueprint and serves as one possible explication of the situation model proposed by van Dijk and Kintsch (1983).

The strategic memory structures are part of comprehension regardless of the language (e.g., English or Spanish) with additional linkages between the ideas within the memory due to differences or similarities in the languages (e.g., connections between word knowledge in Spanish and English linked to the memory). The ideas in memory can be stored in one or both languages. The relationships between the ideas that form the strategic memory (e.g., the problem is _____ and the solutions are: _____, _____, and _____) remain the same regardless of the language. Many of the signaling words that guide the creation of these linkages

(e.g., cause) identified in the text structure strategy instruction are cognates between Spanish and English thereby increasing the likelihood that Spanish speaking ELs can take advantage of the discourse markers to aid in their comprehension.

Empirical support for the text structure strategy

The structure strategy has over 35 years of documented success in improving reading comprehension for monolingual English speakers in grade two (Williams et al., 2004), grade four (Wijekumar, Meyer, & Lei, 2012), grade five (Meyer et al., 2010; Wijekumar et al., 2014), middle grades (Wijekumar, Meyer, & Lei, 2017), and older adults (Meyer, & Poon, 2001). Recently completed efficacy trials on the text structure strategy delivered via a web-based tutoring platform to fourth, fifth, and seventh graders showed that students in the intelligent tutoring system for the text structure strategy (ITSS) classrooms outperformed students in control classrooms on standardized reading comprehension tests and researcher designed measures. At the fourth grade, the effect size on the standardized test was .18 and the effect size for main ideas was .50. At the fifth grade effect size was .20 on the standardized test and .53 on the main ideas test.

Design studies conducted for the SWELL development showed that students who received instruction in the SWELL platform about text structures made steady gains throughout the intervention compared to students who were delayed in receiving the instruction (Wijekumar et al., 2016). A single-subject design study was employed with children who were categorized as low and high on academic Spanish and English levels. Children receiving SWELL instruction in both the English Extension and the Spanish Scaffolding adaptions made gains and maintained the gains for 12 weeks.

Based on these findings, we hypothesize that the text structure strategy can be an effective tool for Spanish speaking ELs due to the strong scaffolding provided by the text structure main idea patterns, practice in identifying signaling words, classifying text structure, selecting important ideas, encoding strategic memory, summarizing, and recalling informational texts. Finally, many text structure signaling words in English and Spanish are cognates (e.g., different vs. diferente) which may facilitate Spanish speaking ELs learning and using signaling words to classify the text structure and then using the structure to select and encode strategic memory structures.

SWELL design

SWELL integrates text structure strategy instruction as a comprehension strategy and linguistic supports for Spanish speaking ELs all on a web-based platform designed to deliver one-on-one instruction for fourth and fifth-graders.

Text structure strategy as a solution to lack of comprehension strategy

The text structure strategy provides a unique solution to Spanish speaking ELs experiencing reading comprehension difficulties at the upper elementary grades. Instruction about using the text structure strategy guides the learner to look for signaling words, classify the text structure (e.g., comparison), utilize the text
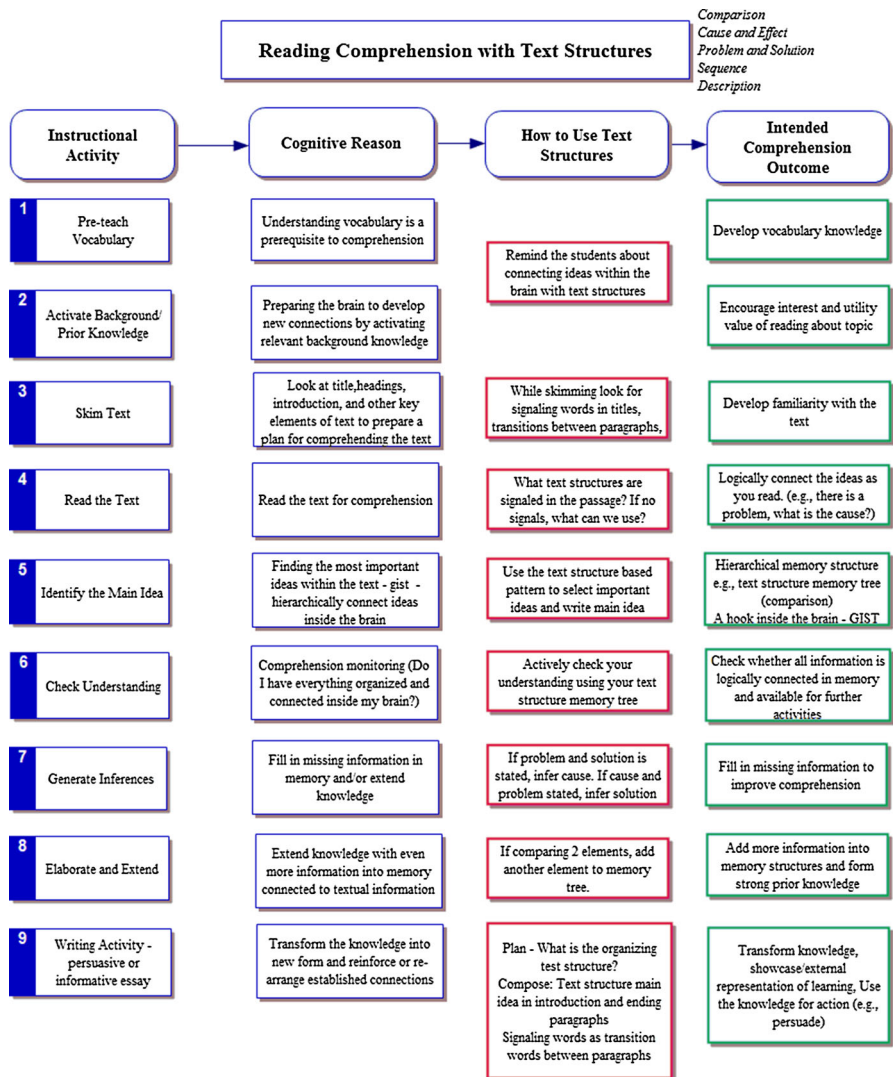
Instructional Activity	Cognitive Reason	How to Use Text Structures	Intended Comprehension Outcome

Reading Comprehension with Text Structures

Comparison
Cause and Effect
Problem and Solution
Sequence
Description

#	Instructional Activity	Cognitive Reason	How to Use Text Structures	Intended Comprehension Outcome
1	Pre-teach Vocabulary	Understanding vocabulary is a prerequisite to comprehension		Develop vocabulary knowledge
2	Activate Background/ Prior Knowledge	Preparing the brain to develop new connections by activating relevant background knowledge	Remind the students about connecting ideas within the brain with text structures	Encourage interest and utility value of reading about topic
3	Skim Text	Look at title, headings, introduction, and other key elements of text to prepare a plan for comprehending the text	While skimming look for signaling words in titles, transitions between paragraphs,	Develop familiarity with the text
4	Read the Text	Read the text for comprehension	What text structures are signaled in the passage? If no signals, what can we use?	Logically connect the ideas as you read. (e.g., there is a problem, what is the cause?)
5	Identify the Main Idea	Finding the most important ideas within the text - gist - hierarchically connect ideas inside the brain	Use the text structure based pattern to select important ideas and write main idea	Hierarchical memory structure e.g., text structure memory tree (comparison) A hook inside the brain - GIST
6	Check Understanding	Comprehension monitoring (Do I have everything organized and connected inside my brain?)	Actively check your understanding using your text structure memory tree	Check whether all information is logically connected in memory and available for further activities
7	Generate Inferences	Fill in missing information in memory and/or extend knowledge	If problem and solution is stated, infer cause. If cause and problem stated, infer solution	Fill in missing information to improve comprehension
8	Elaborate and Extend	Extend knowledge with even more information into memory connected to textual information	If comparing 2 elements, add another element to memory tree.	Add more information into memory structures and form strong prior knowledge
9	Writing Activity - persuasive or informative essay	Transform the knowledge into new form and reinforce or re-arrange established connections	Plan - What is the organizing test structure? Compose: Text structure main idea in introduction and ending paragraphs Signaling words as transition words between paragraphs	Transform knowledge, showcase/external representation of learning, Use the knowledge for action (e.g., persuade)

Fig. 1 Text structure strategy approach to promoting reading comprehension

structure to scaffold the selection of important ideas, generate a main idea/gist scaffolded by the text structure to strategically link the ideas, encode strategic memory of the text as strong prior knowledge, and use the knowledge in applications, such as writing and problem solving as shown in Fig. 1.

Instruction about reading comprehension has focused on teaching vocabulary, activating background knowledge, summarizing, generating inferences, applying the knowledge in writing, and monitoring comprehension (Kamil et al., 2008). Many of these approaches are presented in other interventions (e.g., Carlo et al., 2004; Vaughn, 2015). However, they use comprehension promoting activities such

as summarizing and comprehension monitoring as independent activities from text structure instruction. The structure strategy also uses these comprehension promoting activities but subsumes the techniques recommended by Kamil et al., under the text-structure umbrella. When instructing children about reading comprehension using the text structure strategy, the emphasis is on selecting important ideas from the passage based on the text structure, encoding the ideas into strategic memory, writing a summary using specific scaffolds based on the text structure, and monitoring comprehension by traversing the memory connections generated by utilizing the text structures (e.g., do I know the cause for the problem?). For example, when using the text structure strategy, a child reading a comparison passage is instructed to summarize using a specific scaffold—who or what is being compared? and on what basis/factors are they compared?

SWELL vocabulary and linguistic supports

Understanding the vocabulary and language is an essential prerequisite to reading comprehension (Kamil et al., 2008; Perfetti, Landi, & Oakhill, 2005). Empirical evidence abounds on the positive impact of teaching vocabulary to both monolingual (Williams et al., 2004) and bilingual learners (Carlo et al., 2004; Lara-Alecio et al., 2012; Proctor et al., 2007). These research studies provide a wide-spectrum of available options to support vocabulary development with Spanish speaking ELs including vocabulary definitions, contextual clues to assist with understanding the word meanings (e.g., pictures), breaking up long sentences into manageable smaller units, and explaining figurative language. SWELL uses the approach of vocabulary translations (i.e., hovering over a word shows Spanish translation) and sentence modifications (i.e., clicking on a sentence provides a linguistically modified sentence and/or a picture with important features high-lighted). A third option is a Spanish button that allows the reader to see and hear the entire passage in Spanish.

SWELL web-based interface

SWELL is a web-based tutor with an animated pedagogical agent intelligent tutor (I.T.) playing the part of the teacher. The system shown in Fig. 2 provides one-on-one instruction to each learner and is designed to teach children how to read and comprehend expository texts using five text structures identified by Meyer (1975). The system begins with instruction on 12 comparison text structure lessons and proceeds to 10 problem and solution lessons and 10 cause and effect text structure lessons. The final lessons cover the sequence and description text structures. The SWELL intervention has over 90 lessons ranging in readability from second to twelfth grade with assistance at the word, sentence, and passage level available in both English and Spanish.

SWELL was built on the same platform and utilizing the same interaction models as the efficacious ITSS, designed and tested with fourth-, fifth-, and seventh-grade monolingual English learners. The SWELL lessons contain many different interactions with learners beginning with I.T. modeling how he would read a
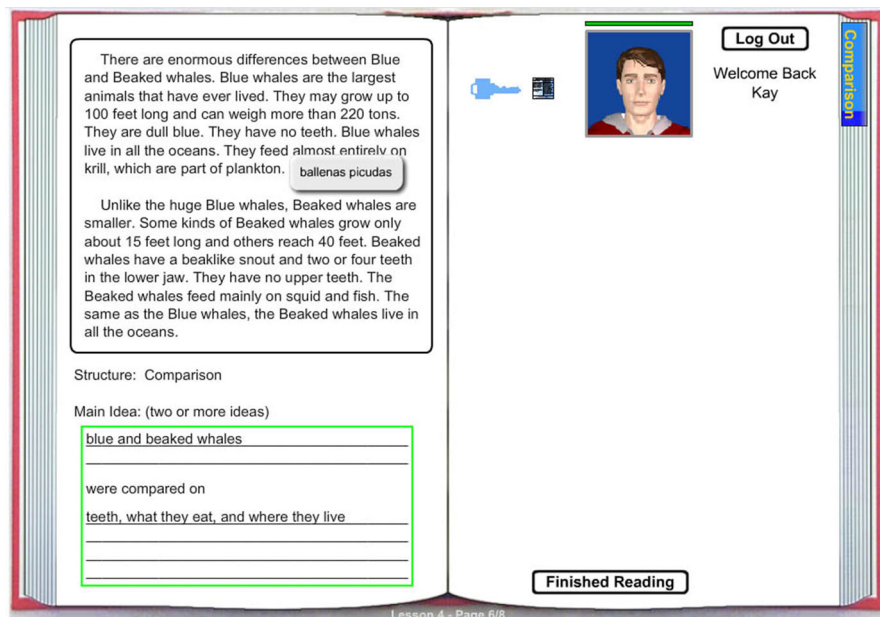
Fig. 2 SWELL software showing vocabulary assistance on hovering

passage and apply the text structure strategy. I.T. reads all the passage information and explains his way through the strategy use (e.g., "when I see the signaling word different, I know that this is a comparison passage"). When the passage and information are presented in Spanish, I.T. reads all the information in Spanish. After modeling the strategy use, I.T. also asks children to respond to different types of questions: click on signaling words in passage, write a main idea with the passage in view, complete a matrix representing the main idea of the passage, write a full-recall of the passage from memory, and respond to multiple choice questions (e.g., does this passage inform or persuade?). All student responses are immediately parsed and assessed by the system and appropriate feedback is presented to the learner (e.g., "please include who was being compared in your main idea"). The assessment depends on the type of question. For example, when students write a main idea, the response is segmented, parsed, matched for keywords, synonyms, and misspellings, and then scored using the propositional structure of the source text. Each child is allowed multiple attempts to answer each question with varying number of tries (e.g., some questions may allow 3 tries while others may have 5).

SWELL is unique in that its web-based interface was designed to reduce the cognitive demands of reading in a non-dominant language by creating two specific adaptations that address the needs of ELs: (1) *English extension*—teaching of novel vocabulary in English and providing students access to on-click assistance at the word and sentence level—paraphrasing, easy definitions, contextual cues (e.g., pictures) and linguistically easier versions of sentences.; (2) *Spanish scaffolding*—procedural instructions on using the structure strategy and practice passages

previewed in Spanish followed by English language version of the lesson (passage can be easier version in English). SWELL provides the following benefits to upper-elementary school Spanish speaking ELs:

- Instruction tailored for each learner as the system adapts to the learner's performance on each task.
- Ease of access—web-based and is available on any commonly available browser.
- Alternative presentation prompts (e.g., on-click Spanish translations for the instructions, on-click sentence paraphrasing in easier English version).
- Scaffolds that can ease the working memory demands of learning the strategy while reading for comprehension because reading in a non-dominant language places additional cognitive demands that can severely limit readers' ability to implement strategies during comprehension.
- Narration of content, instructions, practice tasks, and feedback to bridge any lexical processing gaps.
- One-to-one tutoring that can eliminate stigma associated with remedial instruction typically delivered in pull-out instruction or in a large group setting.
- Teacher information on using the structure strategy and SWELL lessons within the language arts curriculum.

This study examined the effects of the text structure strategy instruction delivered via a web-based tutor designed to address the needs of fourth- and fifth-grade Spanish speaking English learners. Based on the theoretical and empirical support presented earlier we *hypothesized that children learning to read and comprehend expository texts using the text structure strategy would outperform students who use other strategies.*

Research questions

This study was designed to answer the following primary research question. Do students in Grades 4 and 5 classrooms using the SWELL delivery of the text structure strategy, as a partial substitute for the standard language arts curriculum, outperform students in control classrooms on standardized and researcher-designed measures of reading comprehension?

The study also posed three secondary questions concerning whether the effect of SWELL delivered instruction about the text structure strategy for reading comprehension varies depending on other factors, including initial reading skills, gender, and time working in SWELL. The three secondary questions are: 1. Does the effect of SWELL on reading comprehension depend on students' initial reading level? 2. Does the effect of SWELL on reading comprehension differ between male and female students? 3. Do students who used the SWELL system for more time or answer more questions in the lessons perform better on the post-test than students who used it less?

The exploratory questions were of interest due to previous research about the role of gender, struggling readers, and instructional time on student learning outcomes

(Wijekumar et al., 2014, 2017; Tong, Lara-Alecio, Irby, & Mathes, 2011). Gender effects related to research with ELs has reported differences with younger children (Tong et al.,) and exploring the effects in this study may shed light on gender, reading comprehension, and web-based tutors.

Method

The SWELL intervention was tested in a year-long multi-site randomized controlled study. Participants were bilingual children enrolled in Grades 4 and 5 in participating districts.

Design

This study utilized an under-powered multisite randomized controlled trial design in which classrooms were randomly assigned to intervention and business-as-usual control conditions within schools (sites). A volunteer sample of 14 fourth-grade and 17 fifth-grade teachers and their classrooms were randomly assigned to the SWELL and control groups within schools. If students in the classroom were classified as bilingual but English proficient, they used the English extension version of SWELL (85.7% of participants). If the children were classified as Spanish speaking and were receiving instruction in Spanish, they used the Spanish scaffolding version of the software (3% of participants). Students who were monolingual English speakers used the English only version. For the data analysis we used only the students using the Spanish Scaffolding and English Extension versions of the SWELL software. Schools agreed to use SWELL for 45–60 min a week by substituting SWELL for language arts instruction. During the rest of the language arts instructional time students used the school's regular language arts curriculum. The control teachers followed the standard language arts curriculum for the total language arts instructional time. Total language arts instructional time was similar in both intervention and control groups (estimated as approximately 450 min each week). The research team carefully documented the language arts practices in both the intervention and control classrooms through observations, interviews with teachers, and reviews of all the textbooks used in the classrooms.

Participants

Schools were recruited from the southwestern U.S. through letters of invitation and emails to school administrators. Two large school districts initially agreed to participate but had to pull out due to changes in administration and a state take-over of schools. Additional schools were recruited after those events and three districts agreed to participate. The district administrators sent emails to all their schools asking for building level volunteers. Twelve school campuses volunteered to participate. All fourth- and fifth-grade teachers in volunteering schools were invited to participate and none declined.

The participating schools served over 88.7% of Spanish speaking ELs. The schools' overall student population was 86% socioeconomically disadvantaged (eligible for free or reduced priced lunch). These means did not vary greatly between schools. Approximately 15% of the students in participating schools were considered proficient in reading.

School computer labs were checked for availability of computers, headphones, and bandwidth for delivering the web-based SWELL software. Schools experiencing persistent difficulties with computers were provided assistance by the team to remediate problems (e.g., installing updates to the Flash software). Headphones were also provided to schools that had none for the children to use. Three schools experienced continuous interruptions in internet service.

Incentives to participate in the study included 4 h of professional development for the teachers and free use of the SWELL software for the study year as well as a second year. Additionally, classroom support research associates were provided to schools to ensure that computer labs were setup for student use.

Teachers completed their consent forms at the professional development sessions or during the site visits by the study team. All fourth- and fifth-grade students at participating schools were invited to participate. Each school mailed parental consent forms and collected the responses prior to the start of the study.

Procedure

SWELL teachers were provided with 4 h of professional development about the text structure strategy and classroom support research associates were trained on management of the software delivery. The standardized reading comprehension test and researcher designed measures were administered to both groups during September 2014.

Students in the intervention condition used SWELL for one session a week for 45–60 min each week over a 6–7 month period (October 2014 to April 2015) as a partial substitute for the language arts curriculum. At the beginning of each session, each student picked up their SWELL folder containing any instructions, username, password, and earphones and sat individually at the computer. The student opened a browser and logged in using their individual username and password. The student interacted with the SWELL program at their own pace, listening to I.T., writing their answers, getting feedback from I.T., and getting help when necessary from pop-up windows. At the conclusion of the class period, the student logged out and the system saved their lesson and page number for use at the next session.

To ensure fidelity of the treatment, the trained classroom support research associates were present at the computer lab during each SWELL session. Researchers also conducted an observation and/or interview with the control and intervention teachers during the academic year. The research associates maintained daily logs of activities and challenges during the SWELL implementation. Language arts practices, time on task, and classroom organization were documented using these methods.

The research team generated bi-weekly reports for the teachers showing student progress in SWELL. Teachers may generate the same reports themselves, but

preferred to review the progress with the research associate on site. This allowed the the research team members to guide the teachers about using the reports to monitor student progress. Teachers also received email notifications if children were gaming the system by responding to questions with blanks or nonsense answers.

Posttest measures were administered at the end of the school year (2015) under the same conditions as the pretest administration. Posttests were transcribed into a computerized scoring system and the GSRT answers were scanned and scored.

Materials

The study participants were administered paper and pencil tests within the classroom at pretest and posttest. Students assigned to the intervention group used the SWELL software for approximately 6 months.

Cognitive outcomes for research questions

Proximal and distal outcome measures related to reading comprehension were used to measure pre and posttest reading comprehension related activities. Specifically, a standardized test of reading comprehension and researcher designed measures of signaling word knowledge, main idea competency, and top-level structure of a recall of text were used in the data collection and analyses. Finally, teacher reports of Spanish proficiency and computer log data were also utilized in the data analyses.

Standardized test

Reading comprehension was measured using a standardized reading comprehension test—Gray Silent Reading Test (GSRT; Wiederholt & Blalock, 2000). The GSRT had two equivalent forms A and B with multiple-choice questions mainly about 13 narrative texts. The GSRT Form B was administered at pretest and Form A was administered at post-test. Pretest score on the GSRT was used as a covariate for data analyses and used to examine the effects of ITSS instruction on our posttest outcome measures. Cronbach's alpha for both forms of the GSRT was reasonably high (alpha = .88).

Experimenter-designed measures of reading comprehension

Two equivalent test forms were created with a comparison text (Meyer et al., 2010) and used in the SWELL design studies (Wijekumar et al., 2016). These forms were designed with exact word length, idea units, propositional structure, and were deemed psychometrically equivalent ($p = .287$) during the design studies preceding this research. The measures tested students' ability to fill-in-the-blank with comparison text structure signaling words (i.e., Cloze task), write a main idea with the passage in view, and a full recall without consulting the passage. Two comparison passages were prepared: (a) pygmy versus Emperor monkeys (administered at pretest) and (b) Adelie versus Emperor penguins (administered at posttest). Each passage had 128 words, 15 sentences, and 96 idea units. The

measures were transcribed into the computer scoring system. The computer scoring system uses the propositional analysis of ideas in the text with the hierarchical inter-relationships among ideas. These recalls and main ideas are constrained corpora of text related to the passage that the students read and thus scoring logic relies on the keywords, synonyms, relationship between ideas, and hierarchical levels of importance related to concepts within the text. Due to the focus of this study on Spanish speaking English learners and any new checks on responses that may have been fully or partially written in Spanish trained graduate research associate verified the scores. Computer-rater reliability coefficients for the measures collected for the comparison free recall and main idea tasks were high (98–99%). The written performances on the comparison main idea and free recall tasks were examined for evidence of utilizing the Wijekumar et al., top-level structure and organization. Free recalls with no evidence of hierarchical text structures were coded with top-level structure scores of 1 or 2 (called quality scores for the main idea task) of 1, similar to prior research studies (e.g., Wijekumar et al., 2014). Well-organized memory structures, included main ideas or recall organized with the same well-organized text structure as the text or another well-organized text structure (comparison, problem and solution; Wijekumar et al., 2014), were coded as top-level structure scores of 5–9. Student responses scoring a 9 presented both animals being compared, used the correct signaling words, and identified all factors on which the animals were compared. If students presented both animals compared but left out some of the factors compared, then a score of 7 or 8 was assigned. Scores of 5 or 6 were assigned to responses that used the comparison structure with one or both animals but not providing the factors on which they were compared.

Teacher reports on student Spanish and English proficiency were also collected. Teachers reported levels of proficiency from 1 to 4, where 1 meant the child was at an early stage in reading comprehension in the language and 4 meant they were strong in reading and comprehending in Spanish or English.

Computer logs from the SWELL system provided the final source of data for analysis. The system logged each child's login and logout times and questions completed. Approximately 85.7% of the students participating in this study used the English Extension version of the software. Computer logs of students' interactions showed that all students used word lookup functions of the system on average four times during each session. Further, each child interacting with SWELL clicked on approximately 2 sentences during each session. These lookup features were consistent throughout the software use.

Data analytic approach

This development study utilized an under-powered multisite randomized controlled trial design in which classrooms were randomly assigned to intervention and business-as-usual control conditions within schools (sites). Because students are nested within classrooms and classrooms are nested within schools, we ran three-level unconditional models for each outcome variable by grade level to estimate the level of dependence due to each of the school and class levels. School- and class-level intra-class correlations (ICC) for each of the pre- and post-test outcome

Table 1 School- and class-level Intra-class correlations by grade level

Outcome	Grade 4		Grade 5	
	School-level	Class-level	School-level	Class-level
Pretest				
GSRTGE	0.07	0.01	0.00	0.19
MI quality	0.00	0.23	0.10	0.06
MI competency	0.00	0.26	0.11	0.01
Comparison TLS	0.12	0.00	0.11	0.03
Signaling	0.00	0.01	0.06	0.01
Posttest				
GSRTGE	0.00	0.13	0.03	0.20
MI quality	0.00	0.25	0.03	0.13
MI competency	0.00	0.14	0.03	0.09
Comparison TLS	0.00	0.00	0.00	0.00
Signaling	0.00	0.08	0.01	0.09

measures are presented in Table 1 by grade level. As the school-level ICC values were small (no larger than .05) for all post-test outcome measures, we conducted two-level random-intercept models by grade level for each of the outcome measures to address the research questions. Due to the differential amount of missing data by outcome variables, missing data were deleted during analysis for each model to maximize the usage of available data for each outcome. We used the xtmixed procedure of STATA 13 with maximum likelihood estimation for all two-level models.

For each of the outcome variables and grade levels, we first ran a two-level unconditional model (M0) to estimate the total class- and student-level variance that could be explained by other predictors. To address the primary research question, we estimated the SWELL main effect while controlling for students' gender $(1 = \text{female}, \ 0 = \text{male})$, their pretest scores on the corresponding outcome measure, as well as their Spanish and English proficiency levels (0–4). Treatment (dummy coded: $1 = \text{SWELL}, 0 = \text{control}$) effect was tested at the class-level and all student-level covariates were grand-mean centered in the two-level random-intercept models (M1). Effect size (standardized difference) was computed by dividing the coefficient for SWELL on each of the outcome variables from the M1 main-effects model by the pooled student-level within treatment group standard deviation on the corresponding pretest. Standard deviations of pretest scores were used to standardize treatment effect because pretest scores were unaffected by treatment.

To answer the secondary research question of whether the effect of SWELL on each of the outcome measures depend on students' initial level, we added a cross-level interaction term between treatment and the corresponding centered pretest to the M1 main-effects model (M2). Similarly, we added a cross-level interaction term

between treatment and gender to the M1 main-effects model (M3) to address the secondary research question about whether the effect of SWELL on each of the outcome measures depend on students' gender. Statistically significant interactions were followed up by plotting the pattern of the interaction.

In addition, we examined whether students who used the SWELL system more perform better than students who used it less by regressing SWELL students' post-test scores on their total number of minutes used and number of questions answered in lessons for each of the outcome measures by grade level. Zero-order correlations between SWELL students' post-test scores and each of the SWELL system usage measures were also calculated to test their individual relationship with the outcome measures.

Data analysis included all available data at pretest and posttest. Many children did not bring in the consent forms until after the pretests and therefore there are more posttests than pretests in almost all classrooms. Additionally, the research team opted to conduct the GSRT test first and many classrooms ran out of time before the students could complete the researcher designed measures. As a result the GSRT has many more data points than the researcher designed measures. The research team was unable to schedule additional time for testing with the schools due to the costs of testing and available time prior to the software use. Data analysis included all answered questions and if any answers were blank that was treated as missing data.

Results

Student-level descriptive statistics for the study variables are presented in Table 2 by treatment conditions and grade levels. The corresponding class-level descriptive statistics are given in Table 3. Complete two-level parameter estimates from models M0 to M3 for the standardized GSRT reading comprehension outcome are provided in Table 4.

Primary research question

Results for the primary research question regarding treatment effect of the SWELL system on different outcome variables are summarized in Table 5. Treatment effect and the associated standard error estimates were taken from the two-level random-intercept main-effect models (M1), adjusted for students' pretest outcome scores, Spanish and English proficiency levels, and gender. Effect sizes were also calculated based on adjusted treatment effect estimates (i.e., standardized adjusted differences between SWELL and control groups). Students using the SWELL system generally made a larger gain than control students on reading posttest measures in both grade levels. The positive effect of SWELL was statistically significant on most reading outcome measures except for main idea quality and comparison top-level structure (TLS) in Grade 4, and GSRT in Grade 5. Effect sizes of SWELL on the standardized GSRT reading comprehension measure ranged from moderate (.47 for Grade 5) to large (.79 for Grade 4). Moreover, effect sizes on

Table 2 Student-level descriptive statistics by treatment condition and grade level

Measures	SWELL			Control		
	N pretest/posttest	Pretest mean (SD)	Posttest mean (SD)	N pretest/posttest	Pretest mean (SD)	Posttest mean (SD)
Grade 4						
GSRTGE	138/138	1.67 (1.31)	1.79 (1.61)	195/195	1.40 (1.23)	1.29 (0.86)
MI quality	71/85	0.96 (0.76)	1.82 (0.71)	58/81	1.19 (0.66)	1.62 (0.58)
MI competence	71/83	1.01 (0.89)	2.23 (1.10)	58/80	1.36 (0.93)	1.89 (0.90)
Comparison TLS	63/98	1.33 (1.69)	3.06 (2.17)	65/96	1.52 (1.50)	3.01 (1.93)
Signaling	65/98	4.69 (5.03)	10.97 (8.17)	65/96	6.08 (6.38)	9.59 (7.59)
Spanish proficiency level	130	0.82 (0.63)		179	1.27 (0.54)	
English proficiency level	129	0.82 (0.95)		170	0.92 (0.78)	
Gender (proportion of female)	138	0.54 (0.50)		195	0.45 (0.50)	
Grade 5						
GSRTGE	181/181	2.52 (1.91)	3.36 (3.34)	225/225	2.11 (1.54)	2.66 (2.64)
MI quality	114/149	1.25 (0.73)	1.96 (0.75)	139/138	1.51 (0.56)	1.61 (0.56)
MI competence	114/149	1.40 (0.93)	2.40 (1.08)	139/137	1.81 (0.91)	1.97 (0.94)
Comparison TLS	120/158	1.77 (1.80)	3.20 (2.08)	148/168	2.58 (1.99)	2.80 (1.86)
Signaling	120/158	7.47 (5.86)	13.63 (8.16)	148/168	9.75 (7.03)	9.95 (7.31)
Spanish proficiency level	178	1.39 (0.96)		222	1.93 (0.79)	
English proficiency level	177	1.27 (0.96)		222	1.67 (0.86)	
Gender (proportion of female)	181	0.49 (0.50)		225	0.44 (0.50)	

Table 3 Class-level descriptive statistics by treatment condition and grade level

Measures	SWELL			Control		
	N pretest/posttest	Pretest mean (SD)	Posttest mean (SD)	N pretest/posttest	Pretest mean (SD)	Posttest mean (SD)
Grade 4						
GSRTGE	14/14	1.99 (1.13)	2.29 (1.44)	18/18	1.34 (0.58)	1.23 (0.50)
MI quality	14/12	0.91 (0.60)	1.79 (0.35)	12/12	1.31 (0.52)	1.53 (0.44)
MI competence	14/12	0.96 (0.65)	2.15 (0.65)	12/12	1.51 (0.78)	1.77 (0.71)
Comparison TLS	14/12	1.34 (0.96)	3.47 (1.50)	12/12	1.53 (0.71)	3.00 (1.44)
Signaling	14/12	5.17 (4.64)	11.44 (5.52)	12/12	5.60 (3.86)	10.27 (6.31)
Spanish proficiency level	14	0.81 (0.44)		18	1.27 (0.46)	
English proficiency level	14	0.72 (0.69)		18	0.85 (0.60)	
Gender (proportion of female)	14	0.57 (0.31)		18	0.44 (0.26)	
Grade 5						
GSRTGE	14/14	3.04 (1.48)	3.83 (1.90)	13/13	2.22 (0.99)	2.45 (1.44)
MI quality	14/14	1.25 (0.51)	1.97 (0.26)	11/10	1.48 (0.18)	1.70 (0.26)
MI competence	14/14	1.38 (0.57)	2.41 (0.43)	11/10	1.73 (0.28)	2.12 (0.54)
Comparison TLS	14/14	1.60 (1.00)	3.71 (1.71)	11/10	2.38 (1.10)	2.80 (0.66)
Signaling	14/14	6.77 (3.81)	13.35 (4.70)	11/10	8.90 (3.33)	10.92 (3.47)
Spanish proficiency level	14	1.34 (0.86)		13	1.76 (0.66)	
English proficiency level	14	1.29 (0.77)		13	1.54 (0.51)	
Gender (proportion of female)	14	0.53 (0.26)		13	0.47 (0.24)	

Table 4 Multilevel model estimates for GSRT grade equivalent scores

	M0	M1	M2	M3
Grade 4				
Intercept	1.56*** (0.14)	1.26*** (0.12)	1.25*** (0.12)	1.26*** (0.12)
Spanish proficiency		0.43*** (0.11)	0.42*** (0.11)	0.42*** (0.11)
English proficiency		0.65*** (0.08)	0.64*** (0.08)	0.65*** (0.08)
Gender		0.17 (0.10)	0.17 (0.10)	0.03 (0.13)
GSRT pretest score		0.14*** (0.04)	0.10 (0.05)	0.15*** (0.04)
SWELL		1.00*** (0.16)	0.99*** (0.16)	0.98*** (0.16)
SWELL × GSRT pretest			0.15 (0.09)	
SWELL × gender				0.35 (0.21)
Random effects				
Class-level variance	0.37 (0.17)	0.16 (0.07)	0.15 (0.07)	0.17 (0.08)
Student-level variance	0.93 (0.08)	0.65 (0.06)	0.64 (0.06)	0.64 (0.06)
Grade 5				
Intercept	2.95*** (0.34)	2.66*** (0.39)	2.66*** (0.39)	2.67*** (0.39)
Spanish proficiency		− 0.31 (0.20)	− 0.30 (0.20)	− 0.31 (0.20)
English proficiency		1.99*** (0.17)	1.97*** (0.17)	1.99*** (0.17)
Gender		0.12 (0.22)	0.12 (0.22)	0.08 (0.29)
GSRT pretest score		0.22** (0.07)	0.30** (0.11)	0.22** (0.07)
SWELL		0.81 (0.45)	0.84 (0.45)	0.80 (0.45)
SWELL × GSRT pretest			−0.14 (0.14)	
SWELL × gender				0.09 (0.46)
Random effects				
Class-level variance	1.76 (0.72)	1.87 (0.69)	1.86 (0.69)	1.87 (0.69)
Student-level variance	7.43 (0.55)	4.57 (0.34)	4.56 (0.34)	4.57 (0.34)

Effect size = standardized adjusted differences between SWELL and control groups

[a]Estimates are extracted from model 1

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

signaling were large for both grade levels (.81 for Grade 4 and .65 for Grade 5). Effect sizes on other researcher-designed reading outcome measures were small to medium-large (ranged from .14 for comparison TLS to .69 for recall competency) for Grade 4 and moderate to large (ranged from .44 for comparison TLS to .77 for main idea quality) for Grade 5.

Secondary research question 1

Results from M2 provide answers to the question about whether the effects of SWELL on reading comprehension outcomes depend on students' initial reading level. Initial reading level on the GSRT did not moderate the effect of SWELL on reading comprehension measures for Grades 4 and 5.

Table 5 Treatment main effect sizes on different outcome variables by grade level

Outcome	Grade 4		Grade 5	
	Estimate (SE)	Effect Size	Estimate (SE)	Effect Size
GSRTGE	1.00*** (0.16)	0.79	0.81 (0.45)	0.47
MI quality	0.16 (0.16)	0.23	0.49*** (0.14)	0.77
MI competency	0.63* (0.25)	0.69	0.64** (0.21)	0.70
Comparison TLS	0.23 (0.42)	0.14	0.84** (0.30)	0.44
Signaling	4.67**(1.78)	0.81	4.22*** (0.98)	0.65

Treatment effect estimates and SE's are taken from the 2-level random-intercept models. Students' gender as well as their respective pretest scores, Spanish and English proficiency levels are controlled for in the models. Effect size = adjusted treatment effect estimate/pooled student-level within-treatment-group standard deviation of pretest scores

Secondary research question 2

The question about whether the effect of SWELL on reading comprehension outcomes differ between male and female students was addressed by results from M3. No statistically significant interaction between gender and treatment condition was found on any of the reading comprehension measures.

Secondary research question 3

Zero-order correlations between each of the posttest outcome measures and each of the SWELL usage measures were examined to see if there were any significant associations between amount of SWELL use and outcomes (see Table 6). The usage variables generally did not have statistically significant associations with the reading post-test outcome measures except for the small positive correlation with number of minutes for main idea quality (.33) and recall competency (.32) for Grade 5 students.

Partial regression coefficients for the two usage variables were also estimated to gauge the unique effect of each while holding the effect of the other constant. Similar to the zero-order correlations, the number of minutes used had a statistically significant unique effect on main idea quality (est = 0.0013, se = 0.0006, t_{94} = 2.23, p = 0.028), and recall competency (est = 0.002, se = 0.0008, t_{94} = 2.42, p = 0.017) for Grade 5 students at posttest, after controlling for the effect of number of questions answered. The number of questions answered did not have a statistically significant association with any of the reading outcome variables regardless of grade level.

Fidelity of implementation was high due to the consistent support from the research team. Each research team member maintained a log of all activities in the computer lab and any interactions with or questions from the teachers. These logs showed that four teachers were re-assigned during the academic year but that did not interrupt the intervention delivery. Teachers were able to review the SWELL reports and encouraged the students to work diligently on the system.

Table 6 Correlation coefficients between posttest outcome and SWELL usage measures

Outcome	Grade 4		Grade 5	
	Minute used	Questions answered	Minute used	Questions answered
GSRTGE	− 0.08	− 0.01	0.13	0.07
MI quality	0.15	0.18	0.33***	0.18
MI competency	0.08	0.17	0.32**	0.14
Comparison TLS	− 0.10	− 0.02	− 0.03	− 0.00
Signaling	− 0.11	− 0.13	− 0.03	− 0.03

Discussion

In this study, our aim was to contribute to the limited body of research on interventions designed to improve content area reading comprehension with Spanish speaking ELs in Grades 4 and 5. We employed an under-powered multisite cluster randomized trial design and have used a multi-level data analysis method to study the effects of the intervention in an authentic educational setting. In addition, we explored how pretest reading performance on a standardized test, gender, and SWELL usage affected reading comprehension outcomes. The outcomes measures included a distal standardized test (i.e., GSRT) and researcher-designed measures about signaling word knowledge and constructing good main ideas and recalls with the structure strategy. The reliability estimate of these measures was high due to the computer scoring of all measures with trained raters verifying the scores. The SWELL intervention was implemented with a high degree of fidelity with weekly use of the software in school computer laboratories supported by graduate research associates.

Positive impact of SWELL delivery of strategy instruction on reading comprehension

Our primary research question focused on the main effects of the SWELL intervention on the GSRT and researcher-designed measures of reading comprehension. Consistent with our hypothesis that Spanish speaking English learners in Grades 4 and 5 receiving SWELL instruction for 45–60 min a week for the academic year would outperform students in control classrooms, we did find small to large and meaningful effects on all measures. Most importantly, the effect size on the GSRT ranged from .47 for Grade 5 to .79 for Grade 4. The effects on the signaling word knowledge tests were strong across both grade levels.

These effect sizes on the reading comprehension outcomes are larger than those reported in recent large scale randomized studies of the English only version of the software with monolingual speakers (Wijekumar et al., 2012, 2014). The magnitude and direction of the effects are similar to findings reported by Vaughn (2015) for seventh-grade Spanish ELs and monolingual participants and stronger than the effect size of .20 on reading comprehension with eighth-grade students applying

strategies in a social science content area (Vaughn et al., 2017). The effect sizes are much larger than those reported by Proctor et al. (2011) with fifth-grade participants (both Spanish speaking ELs and monolingual English speakers). These results are powerful in the context of the intervention delivery because the research team noted that more than half the classrooms used a textbook series that encouraged children to use the first- and last-sentences of articles as their main idea. Teachers also consistently applied this textbook strategy and contradicted the instructions students received in the SWELL lessons. In light of these contradictions and in comparison to other research studies with comparable populations and grade levels, results of the current study suggest that the SWELL intervention has good potential for addressing the reading comprehension needs of Spanish speaking ELs at Grades 4 and 5.

Effects of skills, gender, and instructional time on reading comprehension outcomes

The study also posed three secondary questions concerning whether the effect of SWELL instruction varies depending on other factors including initial reading skills, gender, and time working in SWELL. Previous studies with monolingual English speakers at Grades 5 showed students who scored at the 25th percentile on the GSRT at pretest made larger gains than other students. Unlike those findings, all students in this study made similar gains regardless of initial reading level. These results may be a function of the level of support provided by the research associates and all children receiving opportunities to practice the text structure strategy with passages from different domains and reading difficulty levels, thereby allowing all children to experience growth in a similar manner. Another possible explanation for these findings may be that most students in participating schools had lower scores. Therefore, it is also possible that this study did not have sufficient statistical power to detect such interactions.

In contrast to previous studies with monolingual English speakers at Grades 4 and 5 using the ITSS software (e.g., Wijekumar et al., 2014), no statistically significant interaction between gender and treatment condition was found on any of the reading comprehension measures. The finding on the reading comprehension measure is similar to findings on science content learning where fifth-grade boys and girls equally benefited from intervention (e.g., Tong et al., 2014). Similar to the report by Tong et al., the SWELL intervention provides scaffolding and support for reading comprehension strategy and vocabulary acquisition in science and other content areas, and these similar strategies may explain the similar findings. Alternatively, these results may be an artifact of the variety of SWELL reading passages. The SWELL lessons use many topics of interest including science, social studies, history, sports, and current events. These lesson topics may be interesting to both girls and boys using the software. However, the lack of intervention by gender interactions might also be due to insufficient statistical power. If these results could be replicated with a larger sample, it would suggest that the instruction provided within SWELL may provide a good platform for instructing both boys and girls in upper elementary grades.

Finally, system usage measured by time on task and number of questions answered generally did not show statistically significant correlations between the variables and outcome measures. Previous large-scale efficacy studies on ITSS have shown small to moderate correlations between the number of questions answered and the reading comprehension outcome measures (Wijekumar et al., 2014). In this study, the implementation was much more controlled than the large-scale efficacy studies reporting higher correlations. Graduate research associates were present at each laboratory session and ensured that instructional time was spent focused on the technology use or paper lessons of the same content if the technology was unavailable (e.g., outage of internet connection due to heavy rains). This may provide an explanation for the lack of variation in usage and questions answered.

Implementation factors related to diffusion of SWELL intervention

Research associates in attendance at every SWELL laboratory time maintained weekly logs of activities during the session. Specifically, the logs were reviewed during bi-weekly team meetings to ensure smooth implementation. Three research support team members supporting three different classrooms wrote notes in their weekly log for 4 weeks noting marginalizing of the Spanish-speaking children by teachers and peers with statements, such as "we don't speak Spanish in our classrooms" and "we do not like hearing Spanish." Even though this number was less than 10% of the participating classrooms the adoption of the SWELL intervention can potentially be affected by a lack of teacher support. The SWELL intervention does not rely on active teacher support in Spanish and thus maybe helpful to teachers who do not speak Spanish. Another asset of SWELL is that all of the students in a classroom can work at the same time in SWELL, rather than some students leaving the classroom for pullout Spanish instruction. The individualized instruction and remediation within the English Extension version of SWELL are not readily seen by an individual student or across individuals within a classrooms using SWELL. Therefore, the SWELL software may alleviate some of the contextual classroom challenges Spanish speaking ELs experience.

Based on reviewing the computer logs we noted that each EL looked up on average four words and clicked on two sentences during each SWELL session. A review of the 3% of participants who used the Spanish Scaffolding software showed that they completed fewer total lessons (due to the time spent on reading in Spanish and English) but their overall performance matched those of the students using the English Extension version.

Overall, the results from this study show promise that the SWELL instruction can be an effective intervention for Spanish speaking ELs in Grades 4 and 5. The software allowed one-on-one tutoring for each child.

Limitations and future directions

The limitations of this study include the small numbers of participating classrooms and limitations related to discerning any differential effects of the Spanish Scaffolding and English Extension versions of the SWELL software. Further large-scale research studies that are sufficiently powered and implemented with fidelity are needed to draw broader conclusions about this intervention. Due to the limited number of classrooms we were unable to test for differences in the two SWELL adaptations. Future studies need to further evaluate the effectiveness of both adaptations. In this study, teachers received 4 h of professional development about the text structure strategy and using the SWELL software. The teachers were supported by trained graduate research associates in the delivery of the software. Reviews of the textbooks and classroom instruction showed that most classroom instruction contradicted SWELL instruction on writing main ideas. Future research studies should include longer professional development for teachers and possible extensions of the text structure strategy into the classroom instruction led by teachers. Further extensions to this study can compare computer delivery vs. teacher-led instruction combined with computer delivery of the text structure strategy. These types of studies can evaluate whether encouraging consistency of instruction about the utility of the text structure strategy in classroom activities related to summarizing, generating inferences, applying knowledge, and comprehension monitoring may boost the student performance further. Contextual factors related to school climate surrounding bilingualism also need to be analyzed to identify challenges and solutions to the problems so that Spanish speaking ELs can have a supportive environment to achieve success.

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