A Teacher Technology Tango Shows Strong Results on 5th Graders Persuasive Writing

Kay Wijekumar
Karen R. Harris
Steve Graham
Pui-Wa Lei

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Abstract

A central goal of upper elementary schools is improving students' skills to write persuasively using source materials. This study focused on three essential areas of writing at the upper elementary grade levels. First, children learned skills to read and use source materials through the web-based intelligent tutoring system for the text structure strategy (ITSS), select key ideas in the text, generate main ideas, and write summaries. Second, teacher-led instruction about planning and writing persuasive essays was delivered using the self-regulated strategies development (SRSD) model. Third, fifth-grade students mastered persuasive writing skills using the We Write tools. The We Write computer tool is a teacher-led system choreographing the roles of the teacher and technology to achieve maximum instructional impact. Teachers received practice-based professional development with coaching and modeling to implement the intervention. In a randomized trial with seven schools and their fifth-grade classrooms, this approach was effective in improving students' writing. Results show that after six weeks of text structure instruction on the web using ITSS, effect sizes on writing quality and planning were .30 and .77. After an additional 12 weeks of SRSD-based writing instruction effect size on planning quality was 1.60 and writing quality 2.29. These strong results can inform the design of technology-supported writing interventions for elementary grade students.

A Teacher Technology Tango Shows Strong Results on 5th Graders Persuasive Writing

Introduction

Writing is a complex task that requires the skilled integration of knowledge about writing, content, strategies, motivation, and technology tools. Teachers (National Council of Teachers of English, 2004), researchers (Bangert-Drowns, Hurley, & Wilkinson, 2004; Graham & Hebert, 2010; Hebert et al., 2013), and businesses (National Commission on Writing, 2004, 2005, 2006) have documented the importance of writing for academic, professional, and life-long success. Unfortunately, evidence from state and national assessments of writing and employer reports present a sobering picture of poor writing skills for children in K-12 schools. Even though evidence-based writing practices (e.g., Graham et al., 2012a) are available to solve these writing problems, poor writing scores persist year after year. A lack of content knowledge linked to reading comprehension challenges, the content of K-12 writing instruction (Graham et al., 2012b), teacher knowledge about writing pedagogy (Brindle et al., 2016; Jesson et al., 2018; Koster et al., 2017; McMaster et al., 2018), and ineffective or inappropriate use of technologies (Li et al, 2015) may be causing the problems. The primary focus of the current development and research study is on improving fifth-grade students' persuasive writing with source materials by solving this vexing problem with a multi-faceted teacher-managed web-based intelligent tutoring system named We Write.

We Write is a teacher technology tango, choreographing teacher roles with web-based tools (e.g., extended modeling, practice tasks, assessments, feedback) designed to improve fifth-grade students' persuasive writing with source materials (Wijekumar et al., 2016, Figure 1). Using textual evidence persuasively to respond to a prompt is a complex task. The task requires

elementary grade students to read analytically, choose appropriate evidence, plan the essay, and then use the writing process to navigate the composing and revising task. This single task requires a multitude of student skills (e.g., reading, writing, and self-regulation) that are often not taught or not taught in conjunction. Teachers face a daunting task in teaching these skills. They must assess students' prior knowledge, teach through modeling, present practice activities, conduct formative assessments to gauge mastery of learning, provide feedback, and customize the next steps in the instructional cycle (see Table 1 and Figure 2). In such complex instructional situations, the promise of web-based tools to support student and teacher needs is compelling (Wilson & Czik, 2016). This project focuses on instruction to promote each skill at each writing phase with nuanced developmentally and computationally appropriate technologies to facilitate learning for elementary grade students.

We Write addresses student needs combining *learning to read* source text using the intelligent tutoring system for the text structure strategy (ITSS) instruction (Wijekumar et al., 2014) and *learning to write* with Self-Regulated Strategies Development (SRSD) writing instruction (Harris et al., 2008, Figure 1). We Write harnesses a multitude of technologies (e.g., Automated Writing Evaluation –AWE, Teacher Supported Essay Scoring, Intelligent Tutoring Systems - ITS) to support the recursive phases of SRSD instruction (e.g., modeling, scaffolding, continuous assessment of mastery, feedback). Teachers received *practice-based professional development (PBPD)* designed to improve fidelity of implementation. Teacher PBPD utilized the six stages of SRSD instruction adapted to teachers with materials and examples from their classrooms to promote implementation fidelity.

This manuscript presents results from a randomized controlled trial utilizing the We Write teacher-led and computer supported lessons for the intervention group and a business as usual control group. The primary research questions guiding this study were:

1. Do students in grade 5 classrooms using the We Write intervention as a partial substitute for the standard language arts curriculum outperform students in control classrooms on persuasive writing quality?
2. Do students in grade 5 classrooms using the We Write intervention as a partial substitute for the standard language arts curriculum outperform students in control classrooms on planning?

The study also posed two secondary questions concerning whether the effects of We Write vary by baseline writing skills and student characteristics related to gender and bilingual status.

To set the current study in context, we first present the background on elementary writing instructional needs. We then examine the theoretical and empirical foundations of the intervention, followed by results from a randomized controlled trial of We Write.

Background on Elementary Writing Instruction and Web-based Solutions

Recommendations to promote elementary grade writing

Effective writers employ a myriad of skills, exhibit the will needed to execute and orchestrate the use of these skills when writing, and draw upon the appropriate knowledge to compose a gripping story, a letter of application, or an academic essay. They navigate the writing process through multiple phases (e.g., planning, composing, and revising) that entail the simultaneous coordination and targeted implementation of cognitive and motivational skills (Braaksma et al.,

2004; Graham, 2018). Unfortunately, this can be a daunting challenge for elementary grade students.

In fifth grade (the focus of this study), students learn how to write persuasively or present opinions with reasons and information from source materials (e.g., (National Governors Association Center for Best Practices & Council of Chief State School Officers, 2010). Evidence from the National Assessment of Educational Progress (NAEP) shows that only 33% of grade 8 and 24% of grade 12 students performed at or above the "proficient" level (defined as solid academic performance) in writing (NAEP, 2015). Further, 74% of grade 8 and 73% of grade 12 students scored at or below the "basic" level, denoting only partial mastery of the writing skills needed at these grade levels. Poor writing prevents students from successfully displaying their knowledge in academic settings and limits their ability to engage effectively with text and promote reading comprehension (Hebert et al., 2013). Fifth grade is also the gateway to middle grades, where there is increased rigor and expectations for writing. Consequently, teaching students in fifth grade the skills and strategies needed to write persuasively with source materials is vital for their academic and future success.

Author and colleagues (Graham et al., 2012a) synthesized writing research and presented four recommendations to teach "elementary school students to be effective writers." Recommendations included daily time devoted to writing, teaching children to use the writing process, focusing on skills such as word processing, and creating an engaged community of writers. Graham et al., (2012b) concluded in their meta-analysis of 13 writing interventions retrieved from 115 documents that strategy instruction resulted in the largest effect size using standardized difference (ES = 1.02). They further reported that, “adding self-regulation to strategy instruction (ES = 0.50), text structure instruction (ES = 0.59), and teaching transcription

skills (ES = 0.55)" (p. 879) can improve elementary students' writing skills. Research shows that strategy instruction, extended practice, and feedback can improve writing (Berninger et al., 2015; Bouwer et al., 2018; Boykin et al., 2019; Graham & Perrin, 2007; Kellogg & Raulerson, 2007; Limpo & Alves, 2013; Wissinger et al., 2021; Yamac, 2020). Based on these findings and recommendations, We Write uses text structure instruction for reading and the SRSD model for writing instruction focusing on strategy instruction, self-regulation, transcription skills, and motivation.

Web-based tools to improve elementary persuasive writing

The complex task of writing persuasively with source materials requires students to (a) read and select important ideas, (b) plan the essay carefully by addressing the topic, audience, and purpose of persuasion, (c) compose the essay using the plan and a multitude of other skills (e.g., handwriting or typing, spelling), (d) revise the essay to ensure effective persuasion along with strong academic language, proper grammar, and punctuation, (e) and self-regulate the entire process by perceptively devoting attention to every aspect of the task. Teachers navigating the instruction about these skills must promote the mastery of all these nuanced skills by (a) assessing students' prior knowledge on many aspects of writing, (b) teaching through cognitive modeling (i.e., making their thinking process transparent to the students), (c) presenting practice activities, (d) conducting formative assessments to gauge the mastery of learning, (e) providing feedback to the learners, and (f) customizing next steps in the instructional cycle (e.g., re-teaching students who have not mastered the skill).

Consequently, We Write development began with calibration of computer-based writing tools to the SRSD driven learning goals to support elementary grade students and instructional

support needs of teachers (Wilson et al., 2019; Yamac et al., 2020). The focus was also on the pedagogical value of the unique tool for a particular skill at the opportune time in the instructional cycle, providing appropriate, effective, and efficient (i.e., just in time) support. The web-based tools included scaffolds that were appropriate for fifth-grade students. Leveraging the available computer tools, cohesively integrating them into the instructional setting (Tate et al., 2016), and minimizing the teacher's workload was the ideal solution (Wijekumar et al., 2016; Wilson & Czik, 2016). Computer tools reviewed included web-based intelligent tutoring systems, intelligent game-based learning environments (e.g., Writing Pal, Roscoe et al., 2014; Roscoe et al., 2019), word processing tools (Mahlow & Dale, 2014), automated essay scoring (AES) tools (Pearson Intelligent Essay Assessor – Landauer 2003; Project Essay Grade - PEG, Wilson & Czik 2016; Wilson et al., 2019;), writing support tools (Summary Street – Franszke et al., 2005), and expert systems developed to improve writing (Williams & Beam, 2019). Meta-analyses on the effects of these tools on writing quality have presented mixed results.

A majority of the studies testing these tools focus on middle and high school levels or college students. The few designed for elementary grade students focus on grammar, punctuation, and other component skills of writing and rarely concentrate on the complex, interrelated skills required for elementary grade students. Stroble et al., (2019) reported that recent developments have:

> "triggered debates about such issues as the reliability of scoring engines (Attali, 2013) and their pedagogical value and desirability (Li, Link, & Hegelheimer, 2015). Cotos (2015) warns of the potential misuse of AES and AWE systems as substitutes for human instruction and formative feedback, pointing out the potential of rhetorical feedback to scaffold *thinking about writing* rather than generalized feedback based on standards. " (p. 34)

Stroble et al., further reported that "Researchers have suggested that learners need ample opportunities for practice and high-quality timely feedback which clarifies what good performance is and feeds forward into future work (Nicol & Macfarlane-Dick, 2006; Sambell, McDowell, & Montgomery, 2013; Yang & Carless, 2013)" p.34. Table 1 summarizes these findings with recommendations that match writing tools to the specific writing needs, phases of writing and take advantage of the best of the tools and the best of the teacher.

As Strobl et al., (2019) indicated, most of the available writing tools often use automated writing evaluation systems (AWEs) to provide summative assessment and feedback to learners. As shown in Table 1, developing a web-based writing instructional tool for elementary grade students is particularly challenging due to (a) a multitude of writing component skills instruction required (e.g., genre, content selection, organization, note-taking, grammar); (b) need for constructive feedback on component skills; (c) shorter writing samples produced by younger learners (Latent Semantic Indexing – LSI, typically require 300 words or more to produce an effective assessment); (d) open-ended nature of student responses to writing prompts; and (e) balancing the cost and value of using complex computationally intensive applications with their utility in improving writing. Complex computational tools may not be helpful for many of the basic activities to support elementary grade students. Additionally, writing instruction in the early years must provide the necessary depth and breadth of assessment of all knowledge and skills to provide sound developmentally appropriate scaffolding with feedback and support to promote mastery of these essential skills and build efficacy for writing.

Design of We Write

We Write is developed on three foundational strands related to ITSS for reading, SRSD writing, and practice-based professional development as shown in Figure 1.

ITSS for reading – Theory & Empirical Evidence

Reading comprehension and writing employ the same cognitive constructs and are symbiotic processes (Hebert & Graham, 2011; Wijekumar et al., 2016). The clearest handwriting, correct spelling, and proper grammar cannot overcome a deficit of good ideas synthesized from sound content knowledge or the ability to seek and synthesize information to use in writing. Research has shown that writing promotes reading comprehension and good reading comprehension is a necessary skill for effective writers (Bangert-Drowns, Hurley, & Wilkinson, 2004; Graham & Hebert, 2010; Hebert & Graham, 2011). Powerful writers signal their intent to the reader through discourse markers and the organization of text (Meyer, 1975). Readers who tap into the writer's intent can identify the important ideas within the text, logically connect these ideas, form strategic memory of the text, generate inferences, and transform their knowledge (Bogaerds-Hazenberg et al., 2020; Wijekumar et al., 2012; Wijekumar et al., 2014; Wijekumar et al., 2017). These skills are essential co-requisites for effective writers. Therefore, any intervention to improve writing skills in upper elementary grades must address the learners' reading comprehension challenge.

ITSS used the text structure model of reading comprehension that promotes top-down processing of text, selection of important ideas from the text, logically connecting these ideas using five text structures and nested structures (i.e., comparison, problem and solution, cause and effect, sequence, description), and ultimately creating associative knowledge transformation in memory. The text structure model presents a transparent child-friendly scaffold for students to understand how to generate main ideas and during writing (e.g., selecting the causes and effects while reading a passage about approaches to becoming a fit kid).

Recent randomized controlled studies on ITSS in elementary grade levels present accumulating evidence of the system's efficacy in promoting reading comprehension on standardized tests and researcher-designed measures (Wijekumar et al., 2012; Wijekumar et al, 2014). Meta-analysis of 44 studies showed that effect sizes on outcomes were related to question types (Hedges' $g = 0.25$), summarization ($g = 0.57$), and recall ($g = 0.37$) (Bogaerds-Hazenberg et al., 2020). Wijekumar and colleagues (Wijekumar., 2017) present evidence that understanding discourse markers, classifying text structure using the signals, selecting important ideas using text structure sentence stems, generating main ideas, and extrapolating inferences promote comprehension. Wijekumar et al., (2014) conducted a large scale efficacy study in 128 5th grade classrooms and reported that adjusted posttest scores were significantly higher for students in ITSS classrooms than their control counterparts on researcher-designed measures such as written main idea quality (ES = .53) and comparison total recall (ES = .32).

ITSS for Reading – Application in We Write

Within We Write, the web-based ITSS instructed students to identify discourse markers (i.e., transition words), classify text structures (e.g., in contrast, to suggest comparison text structure), select important ideas, encode strategic memories, generate main ideas, and summarize the text. ITSS includes multiple grade-appropriate expository text passages with activities, customized feedback based on student responses, and adaptive lesson sequencing based on mastery of the text structure strategy. If a student cannot identify the signal words or write the main idea, the system provides another practice example with additional scaffolding to the student.

Main ideas and summaries generated (by applying the text structure strategy) may serve as a good introduction or ending to an essay. The main idea organized using a cause and effect

pattern makes an excellent introduction for a persuasive essay, e.g., I like to be a fit kid *because* it allows me to stay healthy and active. The signal words and discourse markers can serve as transition words in the essay. Ultimately, the reader begins to understand how an author organizes their writing and turns that knowledge around to improve their writing.

During the We Write intervention provided in the present study, fifth-grade students completed approximately 15 ITSS lessons on the comparison, cause and effect, and problem and solution text structures before beginning the SRSD based writing instruction. ITSS lessons include reading grade-appropriate passages, clicking on signal words (e.g., due to or because for cause and effect text structure), classifying the text structure, writing the main idea using the pattern for the text structure (e.g., the cause is _____ and the effects are _____), and extending the main idea to a summary by adding supporting details.

Briefly, students accessed ITSS with a unique username and password. Each week they logged in to the web-based tutor and completed as many lessons as possible during a 45-minute block of time. Each student progressed at their own pace. Students completed five comparison, five cause and effect, and five problem and solution lessons during the six-week delivery of the We Write reading component. Each lesson took approximately 20 minutes to complete, and students performed three important activities during that time. First, they clicked on the signal words in the passage and received feedback. Then they classified the text structure based on the signal words and could consult an online bookmark if assistance was needed. Once they identified the text structure correctly, they received instruction on how to write the main idea using specific patterns for each text structure. Again, as the students completed their activities, the software scored their responses using parsers, spell checks, synonym checks, the semantic structure of the text, and regular expressions. Customized feedback was provided to the learner

based on their attempt sequence, activity type, and correctness of the response. Students had the opportunity to attempt each question multiple times and the system provided progressively more detailed feedback to the learner with each try. Additional details about ITSS are presented in other recent publications (e.g., Wijekumr et al., 2014; Wijekumar et al., 2017).

SRSD for writing – Theory and Research Support

The SRSD model for writing was developed and refined with 40 years of research by Harris and colleagues (Harris et al., 2008). Within We Write, SRSD provides the foundation for instruction about learning to write, focusing on mastering the skills, strategies, and motivation surrounding writing persuasively. SRSD-based instruction focuses the writer's attention on genre-specific rhetorical structures to achieve knowledge transformation during the writing and promotes efficacy towards writing. The approach was customized to the developmental needs of the upper elementary grade students, thus, ensuring that students are not burdened with unachievable goals. Instead, the instruction and expectations follow six recursive stages (i.e., develop background knowledge, discuss it, model it, memorize it, support it, independent practice) to ensure that all children have mastered each skill. The approach also ensures that students have the time and resources necessary to reflect on their learning improvements, thus building confidence in writing. SRSD has successfully improved writing quality at all grade levels and is deemed an evidence-based practice (cf. Baker, Chard, Ketterlin-Geller, Apichatabutra, & Doabler, 2009; Graham & Perin, 2007; National Center for Response to Intervention, 2011). Meta-analyses of research reports show that effects are strong and positive in all instances for improving writing quality, length of writing, and planning (Graham et al., 2012b).

SRSD was explicitly designed to address the complex nature of writing and the difficulties most students experience learning to write. Multiple theories and lines of research

were, and continue to be, drawn on to develop an intervention responsive to the affective, cognitive, and behavioral demands writing makes on all children (Harris & Graham, 2009).

Research indicates that SRSD for writing is effective with students representing the full range of writing ability in a typical fifth-grade class. SRSD has had the strongest impact of any strategies instruction approach in writing (cf. Harris & Graham, 2009; Harris et al., 2009). The effectiveness of SRSD has been tested in 82 studies (29 true experiments and 53 single-subject design studies) with a wide range of students. Graham and Perin (2007) reported an average weighted *ES* for writing quality of 1.15 for true-and quasi-experiments conducted with students in grades 4 to 8. Another meta-analysis (Graham et al., 2012) found that quality of persuasiveness increased almost two standard deviations when students were taught a persuasive planning/drafting strategy via SRSD (for all genres, the ES = 1.75). Thus, We Write utilized the SRSD model for writing to develop persuasive writing skills with fifth-grade students.

We Write instruction – teacher-led instruction choreographed with web-based tools

Within We Write, SRSD was used to teach students persuasive writing strategies that helped them think about and determine their position on a topic (e.g., how to be a fit kid) and consider their audience as they weigh and select arguments for their essays. Following the SRSD stages, the first lessons focused on developing background knowledge about persuasive writing. Teachers instructed students and actively engaged with learners to identify facts and opinions, understand different genres, and memorize mnemonics for writing. An essential part of the SRSD lessons included the teacher modeling how to evaluate and weigh evidence throughout the writing process and revise a persuasive argument for a specific purpose and audience (e.g., write

a letter to convince peers to become a fit kid). A series of six basic teacher-led lessons with supporting computer lessons were developed and used in this study.

Iterative design studies established the most effective and efficient choreography between the teacher-led and web-based lessons. The ideal interaction model presented teacher-led lessons followed by computer lessons. The computer lessons carefully extended the instruction delivered by the teacher and assessed student mastery of the content.

Each lesson cycle began with a teacher-led lesson that lasted approximately 45 minutes. The teacher accompanied the students to the computer lab during the same class period or after. Students logged into the software using their username and password. During the first four computer lessons designed to match the teacher-led lessons, students engaged in activities such as watching a video refresher on mnemonics and receiving instruction about facts vs. opinions. Figures 3 and 4 show sample activities where students extend their teacher-led lesson on the computer and get additional practice on the topic. Students also responded to multiple-choice or short-answer questions on the computer during the first four lessons. Student answers were scored using regular expressions with spell checkers and synonym replacements. If the students showed mastery of the content, the system presented enrichment lessons for the rest of that class period. If students failed to master the content, additional videos or instruction were presented to the learner. After the 45-minute computer lesson, the teachers logged in to the teacher dashboard and monitored student progress, as shown in Figure 5. During this review, teachers could group students who did not show adequate progress to present additional small-group instruction. If students demonstrated mastery of the content, the teacher approved their progress to the next lesson.

During the fifth lesson, teachers modeled the planning and note-taking process. Students practiced note-taking on the computer with additional prompts during the computer activities and received immediate feedback on their mastery of the skill. During the final two lessons, students planned and composed their essays in the classroom and then completed their compositions on the computer. Students self-scored their essays using the computer self-assessment and revised the essay if necessary. The essay was then submitted to the teacher for the assessment using audio and written feedback. Teachers used the teacher dashboard to provide audio and written feedback on student essays composed on the computer. Because the feedback on the quality of ideas, appropriateness of the students' arguments for the audience, and motivation was of utmost importance for elementary students, the teacher feedback was a vital component of the We Write system. The research team decided not to use natural language processing tools to score and present feedback to these upper elementary grade students. Instead, the teacher dashboard included audio feedback and easy scoring of essay parts (e.g., topic sentence, reasons)

In summary, the We Write computer lessons presented modeling videos to extend the teacher-led lessons, multiple practice activities with assessments, immediate scoring, and feedback. The system also contained enrichment activities for students displaying mastery of the content. If students needed additional practice to master skills, there were different activities presented to them. Decision trees were used to adapt instruction for students with enrichment or remedial activities. For example, if students learned how to identify the components of a sample essay during the teacher-led instruction, the computer lesson presented similar transfer activities with varying levels of difficulty. For persuasive writing, a mnemonic T-Topic, R-Reason (3), E-Explain Reasons (3), and E-Ending were taught, and students were asked to pick out the topic, reasons, explanations, and ending in essays (see Figures 3 and 4). If students performed well on

the task, they transitioned to other challenging activities (e.g., sentence combining). If students failed to master the task, they viewed the modeling videos again and completed additional practice activities with different essay samples.

Regardless of the success or the failures during the computer lesson, the teacher reviewed the student progress on a teacher-management dashboard and gave the green light for students to move forward or choose alternative activities for students who were not successful. This cycle was repeated until every child mastered the skills for each lesson within the persuasive writing sequence of lessons.

We Write PBPD for teachers – Theory and Research Support

Elementary grade teachers have to coordinate many instructional, practice, assessment, and feedback tasks to promote students' mastery of persuasive writing. Teachers operate within a context where reading receives the lion's share of instructional time and a lack of pre-service preparation on how to teach writing (Wijekumar et al., 2016). Textbook reviews showed that writing instruction was sporadically presented throughout the school year, and most of the instruction focused on grammar, punctuation, vocabulary, and spelling (Beerwinkle et al., 2018).

SRSD required a shift in mindset, instructional approach, ensuring mastery for all students, and careful use of assessments to inform instruction and small group instruction. We Write required the coordination of teacher-led lessons and web-based lessons. Thus, the practice-based professional development (PBPD) for teachers was delivered approximately one month before the academic year, with two days devoted to SRSD writing instruction and six lessons. The first day of PBPD focused on an overview of SRSD and research evidence, followed by a review of each teacher-led lesson and fidelity checklists. Teachers were assigned homework to construct writing prompts and gather writing samples for review on the second day. During the

second day, all the writing lessons were reviewed and practiced. Teachers worked in small groups where they modeled, reflected, and received feedback on the delivery of each lesson. Teachers also reflected on their own students' needs, writing skills, and differentiating instruction for learners. Web-based tools for these activities were presented immediately preceding the start of the school year.

The third day of PBPD delivered during the first week of the academic year was devoted to the web-based activities, teacher-dashboard, reports, and assessment of essays with audio feedback. PBPB was designed and delivered using grade-level writing samples from local schools, customized mnemonics, and time devoted to resolving implementation logistics (e.g., days of the week and times when teacher-led lessons were delivered and computer lab time). During the school year, the teacher received four additional days of in-classroom modeling and co-teaching opportunities with members of the research team.

Research Design and Methods

An under-powered randomized controlled trial was applied to test the efficacy of the We Write intervention with fifth-grade students. The primary research questions guiding this study were:

1. Do students in grade 5 classrooms using the We Write intervention as a partial substitute for the standard language arts curriculum outperform students in control classrooms on persuasive writing quality?
2. Do students in grade 5 classrooms using the We Write intervention as a partial substitute for the standard language arts curriculum outperform students in control classrooms on planning?

The study also posed two secondary questions concerning whether the effects of We Write vary by baseline writing skills and student characteristics. These questions were based on previous research with SRSD that striving writers make significant gains in writing quality with sound instruction. Research has also shown that gender and bilingual status correlated with writing outcomes for students in elementary grades. The two secondary questions were:

1. Do the effects of We Write on student writing quality and planning vary based on initial writing skills?
2. Do the effects of We Write on writing quality and planning differ by students' sex or bilingual status?

Participants

The participating schools served 73% of children who were eligible to receive a free or reduced-price lunch. The schools also served 53% minority, 65% Spanish speaking English learners, per student expense was $13,667, and had a student to teacher ratio of 15:1. The sample included 464 5th grade students from 21 classrooms and 7 schools (the treatment group had 299 students from 12 classrooms 4 schools, the control group had 165 students from 9 classrooms 3 schools). Participating teachers included 14 teachers with an average years of service of 12.2. Some teachers taught two sections of writing classes. All but two of the teachers were female and two were white and 12 were Hispanic.

Procedures

After schools agreed to participate in the study, the team visited the school and reviewed implementation logistics with the school leadership. Classroom teachers were invited to

participate in the study and sign a consent to participate. All teachers in participating schools agreed to participate. Two months before the academic year, intervention group teachers received the two-day PBPD. Consent forms were mailed to the homes, and students with parent consent completed a pretest in the first month of the academic year. The study began with a pretest followed by six weeks of instruction using the ITSS software to teach fifth-grade children how to select and encode strategic memory utilizing the cause and effect and problem and solution text structures. Posttest 1 was conducted after this first segment of the intervention. Subsequently, the SRSD component of the We Write intervention was delivered for approximately 12 weeks, led by the teacher and supported by web-based lessons. The research team conducted two classroom fidelity observations. Posttest 2 was administered after the SRSD writing segment was delivered to the students. Each testing session used a noise-free cafeteria setting. The research team administered all assessments within a 90-minute block of time. Order of administration:

1. Instructions for tests read aloud to students
2. Writing prompt presented with planning page & 26 line ruled essay writing page

The business as usual (BAU) control classrooms continued to use their school's recommended English language arts curriculum. Control classrooms followed the same testing procedures and classroom fidelity observations.

Measures

Writing prompts. Three equivalent persuasive writing prompts were created before the study implementation (i.e., fit kids, bike helmets, water conservation). The equivalence between forms was established in a prior study (Wijekumar et al., 2014).

Expository science texts about a specific topic (e.g., fit kids, bicycle safety) provided facts and information on the topic and presented them as a source text for each persuasive prompt. Students were then asked to first plan and then write a persuasive essay to convince their classmates to wear a bike helmet, become a fit kid, or conserve water. Writing topic difficulty was equated during a previous data collection effort. All children wrote about bike helmets at pretest, conservation of water at posttest 1, and fit kids at posttest 2. Before essays were scored, they were typed (preserving student errors). Scoring was completed by two trained raters who received two full days of anchor point-based training. Scores and training grouped example essays and discussions until the raters' agreement was over 95%. The writing sample was scored for writing quality at all three-time points using a holistic writing scale (reliability between two raters was 0.83). Students' planning notes were scored for planning quality. These two measures served as outcomes.

Fidelity of implementation

Teacher implementation tracking. Each teacher completed the fidelity checklist for each lesson. Trained observers conducted four classroom observations using a tablet-based observation tool. Approximately 64% of observations showed fidelity to the lesson plans and matched the teachers' self-reported fidelity. The rest of the observations showed some adherence to the lesson plans, but teacher adaptations were appropriate for students. Teacher use of the We Write dashboard was monitored from the logs. Each teacher reviewed the student progress by running progress reports weekly. Four teachers regularly used the computer essay grading tool to provide feedback. Others reported providing written feedback on paper.

Computer logs. The web-based system logged all student interactions, time on task, lessons completed, and correctness of student responses. Student logs showed that most students completed the activities and assessments for lessons 1 to 5 easily. The average usage time each week was 25 minutes. During the last We Write lesson, teachers opted to use paper format for the final essays instead of using the computer for submission and grading. Students still completed their note taking and planning on the computer (for this final lesson but wrote the essay on paper). Consequently, student time on the last few computer lessons was less than 10 minutes per week (weeks 10 to 12).

Control classroom teachers were observed during two scheduled sessions in their language arts class time. All observations showed teachers presenting instruction on reading, and none taught SRSD style writing during the observed time slot. Approximately 32% of the control classroom teachers used writing within the class time for short constructed responses (e.g., write a summary of what you just read). The research team consulted each school principal and teachers about the observations and to clarify the writing strategies that were taught in the schools. Principals reported that writing instruction was usually scheduled more consistently towards the end of the school year for approximately 10-12 weeks. The writing curricula presented by the schools included two approaches. The workshop model of writing instruction was used by two schools and the rest used a plan-write-revise approach that focused on creating a web of ideas that was then used to compose an essay. Revision instruction included strategies for capitalization, punctuation, and grammar.

Data analysis

We used a randomized controlled trial (RCT) to examine the treatment effects of We Write on writing quality and planning. In this RCT, schools (i.e., sites) were randomly assigned to treatment conditions. Due to the nesting of students in teachers within schools, 3-level random-intercept models were analyzed to address the research questions. In this 3-level model, students' sex, bilingual status, and pretest scores were included at the student-level; class average pretest scores were included at the classroom-level; and treatment condition was analyzed at the school-level. For the primary research questions about treatment efficacy, we analyzed each of the outcome measures (writing quality and planning) at each of the posttests (posttest 1 after ITSS and posttest 2 after SRSD) as a function of treatment condition (1 = We Write, 0 = control) while controlling for students' sex (1 = female, 0 = male), bilingual status (1 = bilingual, 0 = English monolingual), student-level pretest (group-mean centered), and class-level pretest (grand-mean centered). Treatment effect sizes were calculated using partial coefficients for We Write from this main-effects model divided by the pooled within-group student-level standard deviation of the outcome in question.

The secondary research questions about moderation effects were addressed by adding appropriate product terms to the main-effects model. Specifically, interaction terms between We Write and pretest scores at both student-level and class-level were added to address secondary research question 1. For secondary research question 2, moderation of We Write by students' sex and bilingual status were tested by including their product terms in the main-effects model. Patterns of statistically significant interactions were described.

Results

About 31% of participants did not participate in the pretest and 54% in posttest 2. Posttest 1 was optional because many teachers were reluctant to take instructional time for additional testing.

Missing test data were all related to the bilingual status, and missing posttests were related to pretest scores. Due to the differential amount of missing data by outcome variables, missing data were handled by listwise deletion during analysis to maximize sample size for each model. Observed variables related to missing were controlled for in the analyses. Descriptive statistics for the variables of interest are given in Table 2 by treatment conditions. Students in the We Write condition had a slightly higher mean on writing quality but lower mean on planning than control students at pretest. In general, students who received We Write performed better than students who did not on both writing quality and planning at both posttest 1 and posttest 2.

Primary research questions

Students in the We Write condition, after receiving ITSS alone, appeared to perform better than students in the control condition on planning (b = .97, p < .05) but not on writing quality (b = .38, p > .05). Holding pretest scores, sex, and bilingual status constant, students who received ITSS instruction on average scored .77 standard deviation units higher on planning than those who did not. This effect size was considered moderate to large. However, the effect of ITSS instruction on writing quality was small (ES = .30) and not statistically significant. With the additional SRSD intervention, students in the We Write condition performed statistically significantly higher than students in the control condition on both planning (b = 2.65, p < .01) and writing quality (b = 2.95, p < .001). Participation in We Write resulted in large effect sizes on students' writing planning (ES = 1.60) and writing quality (ES = 2.29) after adjusting for initial writing skills, sex, and bilingual status. Table 3 summarizes the treatment effects on writing outcomes.

Secondary research questions

Although participation in ITSS did not result in a statistically significant main effect on writing quality, there was a significant interaction between class-level pretest and treatment (b = -4.33, p < .05). Classes with below-average initial writing quality scores tended to benefit from receiving ITSS instruction but not classes with above-average initial scores (see Figure 6). However, this interaction should be interpreted with caution as the control group sample size was small for posttest 1. Initial writing skills at student- or class-level did not appear to moderate the effect of We Write on writing quality at posttest 2 or on either posttest of planning.

Regarding moderation effects of student demographic variables, English monolingual students tended to benefit more from We Write participation than bilingual students in writing quality at posttest 2 (b = -1.41, p < .05; see Figure 7) but not at posttest 1. Students' sex did not appear to moderate the effect of We Write on writing quality or planning on either posttest occasion.

In addition, we explored changes in the experimental group over time by running a 3-level model of measures nested in students nested in classrooms. Consistent with the descriptive statistics reported in Table 2, the change was not linear. Holding students' sex and bilingual status constant, participants in the experimental group did not score significantly differently between pretest and posttest 1 (i.e., after receiving ITSS alone) on either writing quality or planning. As expected, students scored statistically significantly higher on posttest 2 (after receiving We Write instruction) compared to pretest or posttest 1 on both writing quality (by 1.97 points from pretest and 2.13 points from posttest 1) and planning (by 2.72 points from pretest and 2.95 points from posttest 1). Moreover, there was a statistically significant interaction between bilingual status and measurement time on writing planning. As shown in Figure 8, bilingual and English monolingual students did not differ significantly on writing planning at

pretest (Time 1). However, bilingual students improved their planning scores after receiving ITSS instruction at posttest 1 (Time 2) but not their monolingual peers. Both bilingual and monolingual students had significant improvement in writing planning after receiving the We Write instruction, and the gap observed in posttest 1 (b=1.417, p<.01) narrowed slightly at posttest 2 (Time 3; b=1.29, p<.01).

Discussion and Conclusions

A primary goal of this study was to evaluate whether students using the We Write intervention with 15 ITSS lessons, six teacher-led SRSD writing lessons, and web-based lessons would outperform control classroom students using the regular classroom instruction on writing. The intervention was delivered over six weeks for reading using ITSS and an additional 12 weeks devoted to SRSD writing. To our knowledge, the combination of text structure instruction followed by SRSD has not been used before this study.

Empirical contributions

Findings from the first study provide support for the We Write intervention components and the teacher-led and computer-supported learning modules. The computed effect sizes were similar in magnitude to other research studies on the SRSD based writing approach. Graham and Perin (2007) reported an average weighted *ES* for writing quality of 1.15 for true-and quasi-experiments conducted with students in grades 4 to 8. Graham et al., (2012) found that quality of persuasiveness increased ES = 1.75 when students were taught SRSD planning and drafting strategies. In the current study, effect sizes for writing planning (ES = 1.60) and writing quality (ES = 2.29) were above the range. These effect sizes were larger than those reported for other types of writing interventions, including different writing strategies, adding self-regulation to

strategy instruction, text structure instruction, teaching transcription and grammar skills, and collaborative writing (e.g., Limpo & Alves, 2013; de Schmedt et al., 2020).

This study was also the first time web-based text structure instruction using ITSS preceded SRSD instruction about writing. The intermediate posttest immediately after reading comprehension instruction showed modest increases in writing planning but small overall effect on writing quality. The culmination of ITSS + We Write SRSD teacher-led and web-based resulted in larger effects than most previous implementations and shows promise. The larger effect sizes may also result from the lack of any systematic and evidence-based approach to writing instruction observed in the control classrooms. Furthermore, the effect of the complete We Write package appeared to be consistent for both male and female students regardless of student- or class-level initial writing skills, although the effect was slightly larger for monolingual than bilingual students. The small number of significant interactions could be due to the relatively small sample sizes. The missing data factors were also a challenge with the findings. Still, overall the results show promise for this type of teacher-led and computer-supported systematic reading and writing instruction.

Theoretical contribution

Consistent with previous research on SRSD, this study provides further evidence that strategy instruction with the added computer component can improve persuasive writing quality. Most learning and cognitive theories are typically used in classroom teacher-led instruction or web-based learning environments independent of each other. We Write utilizes the most practical web-based tools to support the teacher-led instruction allowing the teacher time and resources for instruction and assessments. Students can rely on both the teacher and web-based lessons to

boost their learning. The We Write intervention embedded software applications for both instruction and assessment in support of elementary writing instruction.

From the perspective of technology and learning, cognitive theories of multimedia learning (Mayer, 2009) focus primarily on software-based instruction. The current study has extended that theory to include extensions of teacher-led instruction and formative assessments to inform teacher-led instruction. In typical technology interventions, the instruction is fully delivered by the computer or replaces some instructional time (e.g., Wijekumar et al., 2014). The teacher's role in either approach is flexible but not required. Teachers may periodically review progress reports but do not have a defined role in the implementation. Recent research findings show that this may lead to contradicting instruction between the computer and the teacher (Wijekumar et al., 2020). Within We Write, the teacher's role was carefully choreographed and left little room for any divergence in content and strategy instruction. The results show promise for this type of intervention. Moreover, the web-based tools supplement and further extend teacher-led instruction thereby evening out any implementation inconsistencies among teachers.

Practical, real-world contribution

Schools have invested billions of dollars in purchasing computers with the hopes of improving learning for students. Schools are also carefully monitoring their benchmark assessments so that they can intervene with students when necessary. We Write presents an integrated platform that provides instruction, assessments, feedback to students, and opportunities for teachers to carefully monitor student mastery of all the necessary writing component skills. The use of computer lessons to support teacher-led instruction reduces the instructional burden on the teachers. The computer-based formative assessments provide strong support for teachers to make sound instructional decisions on which students mastered the content and needed additional

instruction. Without the computer tools, teachers would have to administer, score, and make the decisions in quick succession to keep the lessons moving along. The teacher dashboard with the classroom at a glance provided essential data to help in the decisions.

The use of computer tools was welcomed by some teachers and was a burden to others. Some teachers used computer supports to enhance their instruction. Approximately a third of the teachers relied primarily on the computer to provide all the instruction. The PBPD for the SRSD writing lessons was quite different for teachers used to teaching grammar, spelling, and mechanics during the writing class sessions. Without teacher modeling, in the teacher-led lessons, students found it challenging to learn primarily from the computer modeling lessons. The struggling teachers were also not used to receiving frequent computer-based assessments for students and were unclear about using the data to group students for further instruction. Many teachers were unused to mastery learning. Overall, the professional development sessions may need to be expanded and delivered in chunks allowing time between chunks to absorb the SRSD framework. A more detailed implementation plan will be necessary to address school guidelines about when writing should be taught.

In measuring writing quality, most rubrics focus on the development and organization of ideas and the use of conventions. Even though the CCSS presents a strong case of utilizing text structures for reading comprehension, no such connection is made for writing. The scoring rubrics for writing do acknowledge transition words and organization but have never included text structure organization to score the development and organization of ideas. This study provides some support for using ITSS and text structures in support of reading in preparation for persuasive writing.

Limitations and Future Directions

This study had some limitations related to the small number of classrooms and missing data. Many of the participating schools served transient families in high-poverty schools. As a result, there were many absences and challenges during data collection. Future studies should use a fully powered design that can provide more robust causal conclusions from the study. Follow-up data collection to minimize missing data will also be necessary. Managing the testing time and seeking approval for multiple data collection times is an important consideration when negotiating school participation in such studies. Some students wrote their full essay on the planning page in the current study and then walked away from the testing because they were fatigued from the writing task. Since writing is a time-consuming task, future studies will need to administer the measures with multiple breaks with time for planning separated from time for composing.

The SRSD intervention focuses on student mastery of content. Teachers and administrators participating in this study were not used to devoting 45 minutes twice a week to writing instruction early in the academic year. Most participating teachers reported that they did not typically engage in essay writing until the end of the academic year. Implementation fidelity (teacher-led lesson) was not ideal (observed fidelity scores for treatment classrooms ranged from 45% to 85% with a median at 62%). As observed fidelity scores had a strong linear association with class-average change scores from pretest to posttest 2 ($r = .79$ with planning change scores and .86 with quality change scores), the relatively low fidelity in this study might have attenuated the attainable treatment effect sizes. Implementation barriers to writing interventions must be carefully monitored and acknowledged for the larger-scale rollout of such interventions.

Overall, this study demonstrates that carefully designed web-based tools can effectively support persuasive writing instruction for extending teacher-led lessons and in support of formative assessment to inform instruction. These results show the We Write adds value to the classroom setting and give students and teachers much-needed support for writing instruction.

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